YEAR 10

CambridgeMATHS NSW

STAGE 5.1 / 5.2

SECOND EDITION

STUART PALMER, KAREN McDAID
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INCLUDES INTERACTIVE
TEXTBOOK POWERED BY
CAMBRIDGE HOTMATHS

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About the authors

Stuart Palmer was born and educated in NSW. He is a high school mathematics teacher with more than 25 years' experience teaching students from all walks of life in a variety of schools. He has been a head of department in two schools and is now an educational consultant who conducts professional development workshops for teachers all over NSW and beyond. He also works with pre-service teachers at the University of Sydney.

Karen McDaid has more that 17 years' experience teaching mathematics in several primary and secondary schools, and as a lecturer teaching mathematics to primary preservice teachers at Western Sydney University. Karen was the Professional Teachers Association representative on the NSW Board Curriculum Committee during the development and consultation phases of both the Australian Curriculum and the NSW Mathematics K-10 Syllabus for the Australian Curriculum. She has been active on the executive committee of the Mathematical Association of NSW since 2003 and was the NSW Councillor on the board of the Australian Association of Mathematics Teachers from 2014 to 2018. Karen co-authored the CambridgeMATHS NSW GOLD books Years 7 to 10. Karen is currently Head of Mathematics K to 12 at Cluey Learning.

David Greenwood is the head of Mathematics at Trinity Grammar School in Melbourne and has 20 years' experience teaching mathematics from Years 7 to 12. He has run numerous workshops within Australia and overseas regarding the implementation of the Australian Curriculum and the use of technology for the teaching of mathematics. He has written more than 20 mathematics titles and has a particular interest in the sequencing of curriculum content and working with the Australian Curriculum proficiency strands.

Sara Woolley was born and educated in Tasmania. She completed an Honours degree in Mathematics at the University of Tasmania before completing her education training at the University of Melbourne. She has taught mathematics in Victoria from Years 7 to 12 since 2006, has written more than 10 mathematics titles and specialises in lesson design and differentiation.

Jenny Goodman has worked for 20 years in comprehensive State and selective high schools in NSW and has a keen interest in teaching students of differing ability levels. She was awarded the Jones Medal for Education at Sydney University and the Bourke Prize for Mathematics. She has written for Cambridge NSW and was involved in the *Spectrum* and *Spectrum Gold* series.

Jennifer Vaughan has taught secondary mathematics for more than 30 years in NSW, WA Queensland and New Zealand and has tutored and lectured in mathematics at Queensland University of Technology. She is passionate about providing students of all ability levels with opportunities to understand and to have success in using mathematics. She has taught special needs students and has had extensive experience in developing resources that make mathematical concepts more accessible.

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Introduction and guide to this book

The **second edition** of this popular resource features a new interactive digital platform powered by Cambridge HOTmaths, together with improvements and updates to the textbook, and additional online resources such as video demonstrations of all the worked examples, Desmos-based interactives, carefully chosen HOTmaths resources including widgets and walkthroughs, and worked solutions for all exercises, with access controlled by the teacher. The Interactive Textbook also includes the ability for students to complete textbook work, including full working-out online, where they can self-assess their own work and alert teachers to particularly difficult questions. Teachers can see all student work, the questions that students have 'red-flagged', as well as a range of reports. As with the first edition, the complete resource is structured on detailed teaching programs for teaching the NSW Syllabus, now found in the Online Teaching Suite.

The chapter and section structure has been retained, and remains based on a logical teaching and learning sequence for the syllabus topic concerned, so that chapter sections can be used as ready-prepared lessons. Exercises have questions graded by level of difficulty and are grouped according to the **Working Mathematically components** of the NSW Syllabus, with enrichment questions at the end. Working programs for three ability levels (Building Progressing and Mastering) have been subtly embedded inside the exercises to facilitate the management of differentiated learning and reporting on students' achievement (see page x for more information on the Working Programs). In the second edition, the *Understanding* and *Fluency* components have been combined, as have *Problem-Solving* and *Reasoning*. This has allowed us to better order questions according to difficulty and better reflect the interrelated nature of the Working Mathematically components, as described in the NSW Syllabus.

Topics are aligned exactly to the NSW Syllabus, as indicated at the start of each chapter and in the teaching program, except for topics marked as:

- REVISION — prerequisite knowledge
- EXTENSION — goes beyond the Syllabus
- FRINGE — topics treated in a way that lies at the edge of the Syllabus requirements, but which provide variety and stimulus.

See the Stage 5 books for their additional curriculum linkage.

The parallel ***CambridgeMATHS Gold*** series for Years 7–10 provides resources for students working at Stages 3, 4, and 5.1. The two series have a content structure designed to make the teaching of mixed ability classes smoother.

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Guide to the working programs

It is not expected that any student would do every question in an exercise. The print and online versions contain working programs that are subtly embedded in every exercise. For Stage 5.1 and 5.2, the suggested working programs provide two pathways through each book to allow differentiation for Building and Progressing students.

Each exercise is structured in subsections that match the Working Mathematically components, as well as Enrichment (Challenge).

The questions suggested for each pathway are listed in two columns at the top of each subsection:

- The left column (lighter-shaded colour) is the Building pathway
- The right column (darker-shaded colour) is the Progressing pathway

	Building	Progressing
UNDERSTANDING AND FLUENCY	1–3, 4, 5	3, 4–6
PROBLEM-SOLVING AND REASONING	7, 8, 11	8–12
ENRICHMENT	—	13

Gradients within exercises and question subgroups

The working programs make use of the gradients that have been seamlessly integrated into the exercises. A gradient runs through the overall structure of each exercise, where there is an increasing level of mathematical sophistication required in the Problem-solving and Reasoning group of questions than in the Understanding and Fluency group, and within each group the first few questions are easier than the last.

The right mix of questions

Questions in the working programs are selected to give the most appropriate mix of *types* of questions for each learning pathway. Students going through the Building pathway will likely need more practice at Understanding and Fluency but should also attempt the easier Problem-solving and Reasoning questions.

Choosing a pathway

There are a variety of ways of determining the appropriate pathway for students through the course. Schools and individual teachers should follow the method that works for them if the chapter pre-tests can be used as a diagnostic tool.

For classes grouped according to ability, teachers may wish to set either the Building or Progressing pathway as the default setting for their entire class and then make individual alterations, depending on student need. For mixed-ability classes, teachers may wish to set both pathways within the one class, depending on previous performance and other factors.

The nomenclature used to list questions is as follows:

- 3, 4: complete all parts of questions 3 and 4
- 1–4: complete all parts of questions 1, 2, 3 and 4
- 10(½): complete half of the parts from question 10 (a, c, e … or b, d, f, …)
- 2–4(½): complete half of the parts of questions 2, 3 and 4
- 4(½), 5: complete half of the parts of question 4 and all parts of question 5
- — : do not complete any of the questions in this section.

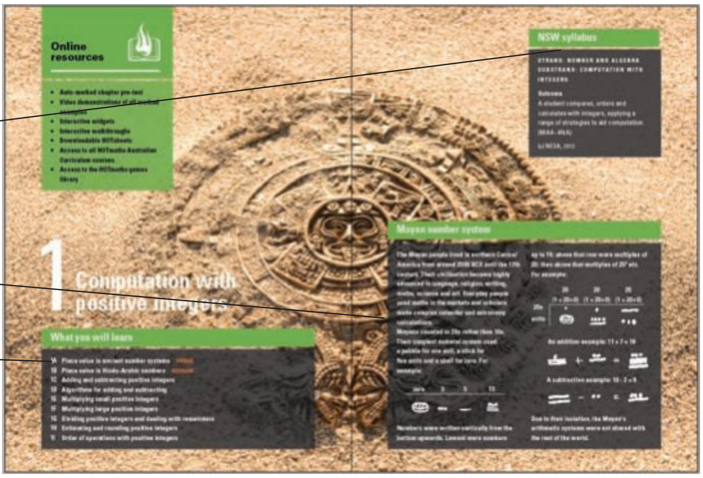
Guide to this book

Features:

NSW Syllabus: strands, substrands and content outcomes for chapter (see teaching program for more detail)

Chapter introduction: use to set a context for students

What you will learn: an overview of chapter contents



Pre-test: establishes prior knowledge (also available as an auto-marked quiz in the Interactive Textbook as well as a printable worksheet)

Pre-test

2 Which of the following is *not* equivalent to one whole?

A $\frac{2}{2}$ B $\frac{6}{6}$ C $\frac{1}{4}$ D $\frac{12}{12}$

3 Which of the following is *not* equivalent to one-half?

Topic introduction: use to relate the topic to mathematics in the wider world

Let's start: an activity (which can often be done in groups) to start the lesson

5A Describing probability

Often, there are times when you may wish to describe how likely it is that an event will occur. For example, you may want to know how likely it is that it will rain tomorrow, or how likely it is that your sporting team will win this year's premiership, or how likely it is that you will win a lottery. Probability is the study of chance.

Let's start: Likely or unlikely?

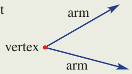
Try to rank these events from least likely to most likely. Compare your answers with other students in the class and discuss any differences.

- It will rain tomorrow.
- Australia will win the soccer World Cup.
- Tails landing uppermost when a 20-cent coin is tossed.

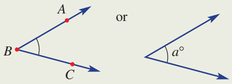
Key ideas: summarises the knowledge and skills for the lesson

Key ideas

- When two rays (or lines) meet, an angle is formed at the intersection point called the **vertex**. The two rays are called **arms** of the angle.



- An **angle** is named using three points, with the vertex as the middle point. A common type of notation is $\angle ABC$ or $\angle CBA$. The measure of the angle is $a°$, where a represents an unknown number.



Examples: solutions with explanations and descriptive titles to aid searches. Video demonstrations of every example are included in the Interactive Textbook.

Example 1 Using measurement systems

a How many feet are there in 1 mile, using the Roman measuring system?

b How many inches are there in 3 yards, using the imperial system?

SOLUTION	EXPLANATION
a $1 \text{ mile} = 1000 \text{ paces}$ $= 5000 \text{ feet}$	There are 1000 paces in a R in a pace.
b $3 \text{ yards} = 9 \text{ feet}$ $= 108 \text{ inches}$	There are 3 feet in an impe in a foot.

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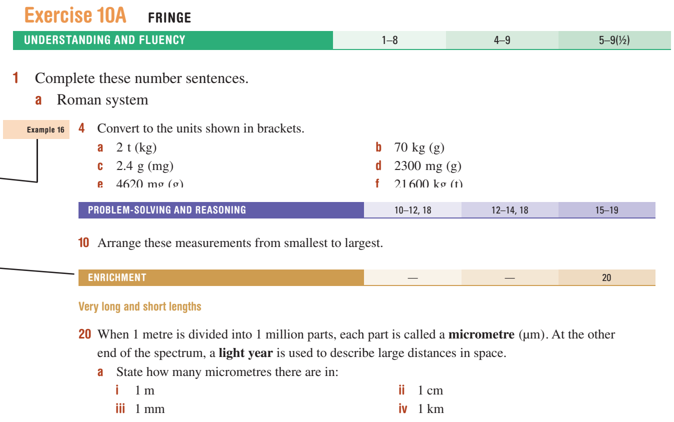
Exercise questions categorised by the **working mathematically components** and **enrichment**

Example references link exercise questions to worked examples.



Exercise 10A FRINGE

UNDERSTANDING AND FLUENCY	1–8	4–9	5–9(½)

1 Complete these number sentences.
  a Roman system

Example 16

4 Convert to the units shown in brackets.
  a 2 t (kg) b 70 kg (g)
  c 2.4 g (mg) d 2300 mg (g)
  e 4620 mg (g) f 21 600 kg (t)

PROBLEM-SOLVING AND REASONING	10–12, 18	12–14, 18	15–19

10 Arrange these measurements from smallest to largest.

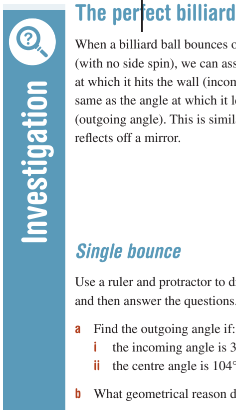
ENRICHMENT	—	—	20

Very long and short lengths

20 When 1 metre is divided into 1 million parts, each part is called a **micrometre** (μm). At the other end of the spectrum, a **light year** is used to describe large distances in space.
  a State how many micrometres there are in:
    i 1 m ii 1 cm
    iii 1 mm iv 1 km

Investigations: inquiry-based activities

Puzzles and **challenges**



Investigation

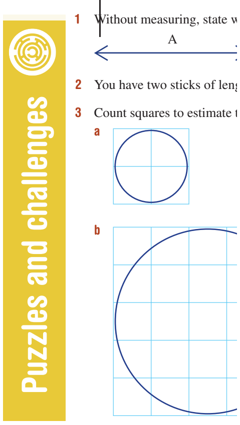
The perfect billiard

When a billiard ball bounces c (with no side spin), we can ass at which it hits the wall (incon same as the angle at which it l (outgoing angle). This is simil reflects off a mirror.

Single bounce

Use a ruler and protractor to d and then answer the questions.

a Find the outgoing angle if:
  i the incoming angle is 3
  ii the centre angle is 104°
b What geometrical reason d



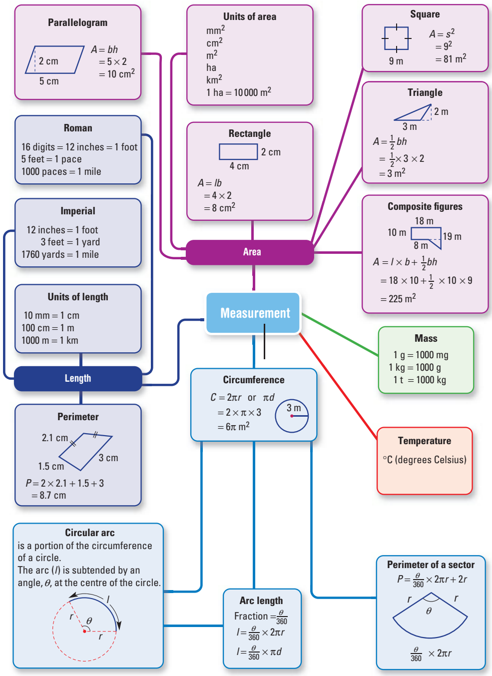
Puzzles and challenges

1 Without measuring, state w

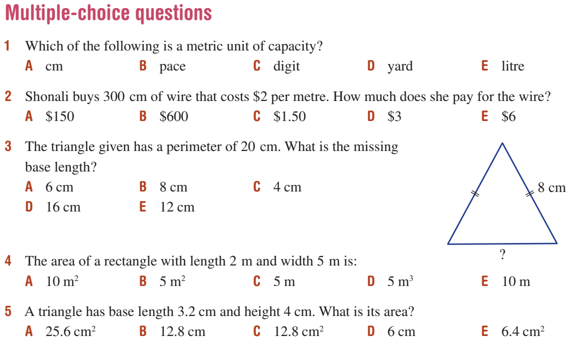
2 You have two sticks of len

3 Count squares to estimate t
  a
  b

Chapter summary: mind map of key concepts & interconnections



Chapter reviews with **multiple-choice, short-answer** and **extended-response questions**



Multiple-choice questions

1 Which of the following is a metric unit of capacity?
  A cm B pace C digit D yard E litre

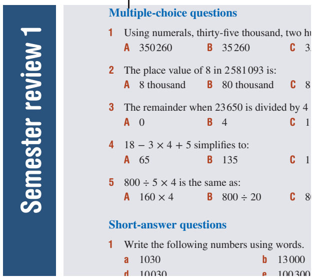
2 Shonali buys 300 cm of wire that costs \$2 per metre. How much does she pay for the wire?
  A \$150 B \$600 C \$1.50 D \$3 E \$6

3 The triangle given has a perimeter of 20 cm. What is the missing base length?
  A 6 cm B 8 cm C 4 cm
  D 16 cm E 12 cm

4 The area of a rectangle with length 2 m and width 5 m is:
  A 10 m² B 5 m² C 5 m D 5 m³ E 10 m

5 A triangle has base length 3.2 cm and height 4 cm. What is its area?
  A 25.6 cm² B 12.8 cm C 12.8 cm² D 6 cm E 6.4 cm²

Two **Semester reviews** per book



Semester review 1

Multiple-choice questions

1 Using numerals, thirty-five thousand, two hu
  A 350 260 B 35 260 C 3

2 The place value of 8 in 2 581 093 is:
  A 8 thousand B 80 thousand C 8

3 The remainder when 23 650 is divided by 4
  A 0 B 4 C 1

4 $18 - 3 \times 4 + 5$ simplifies to:
  A 65 B 135 C 1

5 $800 \div 5 \times 4$ is the same as:
  A 160×4 B $800 \div 20$ C 8

Short-answer questions

1 Write the following numbers using words.
  a 1030 b 13 000
  d 10 030 e 100 300

Textbooks also include:

- Complete **answers**
- **Index**

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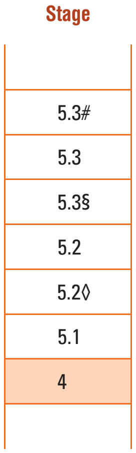
Stage Ladder icons

Shading on the ladder icons at the start of each section indicate the Stage covered by most of that section.

This key explains what each rung on the ladder icon means in practical terms. For more information see the teaching program and teacher resource package:



Stage	Past and present experience in Stages 4 and 5	Future direction for Stage 6 and beyond
5.3#	These are optional topics which contain challenging material for students who will complete all of Stage 5.3 during Years 9 and 10.	These topics are intended for students who are aiming to study Mathematics at the very highest level in Stage 6 and beyond.
5.3	Capable students who rapidly grasp new concepts should go beyond 5.2 and study at a more advanced level with these additional topics.	Students who have completed 5.1, 5.2 and 5.2 and 5.3 are generally well prepared for a calculus-based Stage 6 Mathematics course.
5.3§	These topics are recommended for students who will complete all the 5.1 and 5.2 content and have time to cover some additional material.	These topics are intended for students aiming to complete a calculus-based Mathematics course in Stage 6.
5.2	A typical student should be able to complete all the 5.1 and 5.2 material by the end of Year 10. If possible, students should also cover some 5.3 topics.	Students who have completed 5.1 and 5.2 without any 5.3 material typically find it difficult to complete a calculus-based Stage 6 Mathematics course.
5.2◊	These topics are recommended for students who will complete all the 5.1 content and have time to cover some additional material.	These topics are intended for students aiming to complete a non-calculus course in Stage 6, such as Mathematics Standard.
5.1	Stage 5.1 contains compulsory material for all students in Years 9 and 10. Some students will be able to complete these topics very quickly. Others may need additional time to master the basics.	Students who have completed 5.1 without any 5.2 or 5.3 material have very limited options in Stage 6 Mathematics.
4	Some students require revision and consolidation of Stage 4 material prior to tackling Stage 5 topics.	

Overview of the digital resources

Interactive Textbook: general features

The **Interactive Textbook (ITB)** is an online HTML version of the print textbook powered by the HOTmaths platform, included with the print book or available separately. (A **downloadable PDF textbook** is also included for offline use). These are its features, including those enabled when the students' ITB accounts are linked to the teacher's **Online Teaching Suite (OTS)** account.

The features described below are illustrated in the screenshot below.

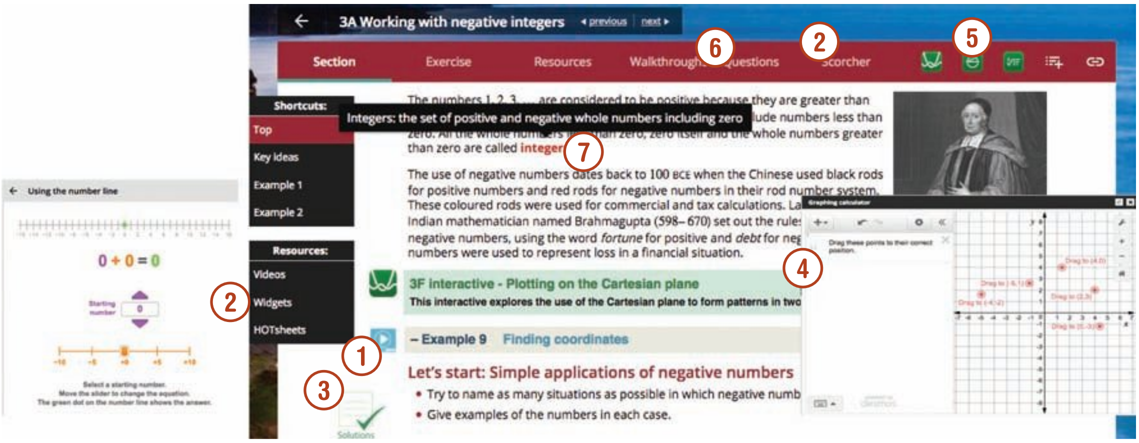
1. Every worked example is linked to a high-quality video demonstration, supporting both in-class learning and the 'flipped classroom'
2. Seamlessly blend with Cambridge HOTmaths, including hundreds of interactive widgets, walkthroughs and games and access to Scorcher
3. **Worked solutions** are included and can be enabled or disabled in the student accounts by the teacher
4. **Desmos interactives** based on embedded graphics calculator and geometry tool windows demonstrate key concepts and enable students to visualise the mathematics
5. The **Desmos scientific calculator** is also available for students to use (as well as the graphics calculator and geometry tools)
6. Auto-marked practice quizzes in each section with saved scores
7. **Definitions** pop up for key terms in the text, and access to the Hotmaths **dictionary**

Not shown but also included:

- Access to alternative HOTmaths lessons is included, including content from previous year levels.
- Auto-marked pre-tests and multiple-choice review questions in each chapter.

INTERACTIVE TEXTBOOK POWERED BY THE HOTmaths PLATFORM

Note: *HOTmaths platform features are updated regularly.*



Select a starting number.
Move the slider to change the equation.
The green dot on the number line shows the answer.

Integers: the set of positive and negative whole numbers including zero

The numbers 1, 2, 3, … are considered to be positive because they are greater than … lude numbers less than zero. … whole numbers greater than zero are called integer

The use of negative numbers dates back to 100 BCE when the Chinese used black rods for positive numbers and red rods for negative numbers in their rod number system. These coloured rods were used for commercial and tax calculations. La… Indian mathematician named Brahmagupta (598–670) set out the rule… negative numbers, using the word *fortune* for positive and *debt* for neg… numbers were used to represent loss in a financial situation.

3F interactive - Plotting on the Cartesian plane

This interactive explores the use of the Cartesian plane to form patterns in two

– Example 9 Finding coordinates

Let's start: Simple applications of negative numbers

- Try to name as many situations as possible in which negative numb
- Give examples of the numbers in each case.

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Interactive Textbook: Workspaces and self-assessment tools

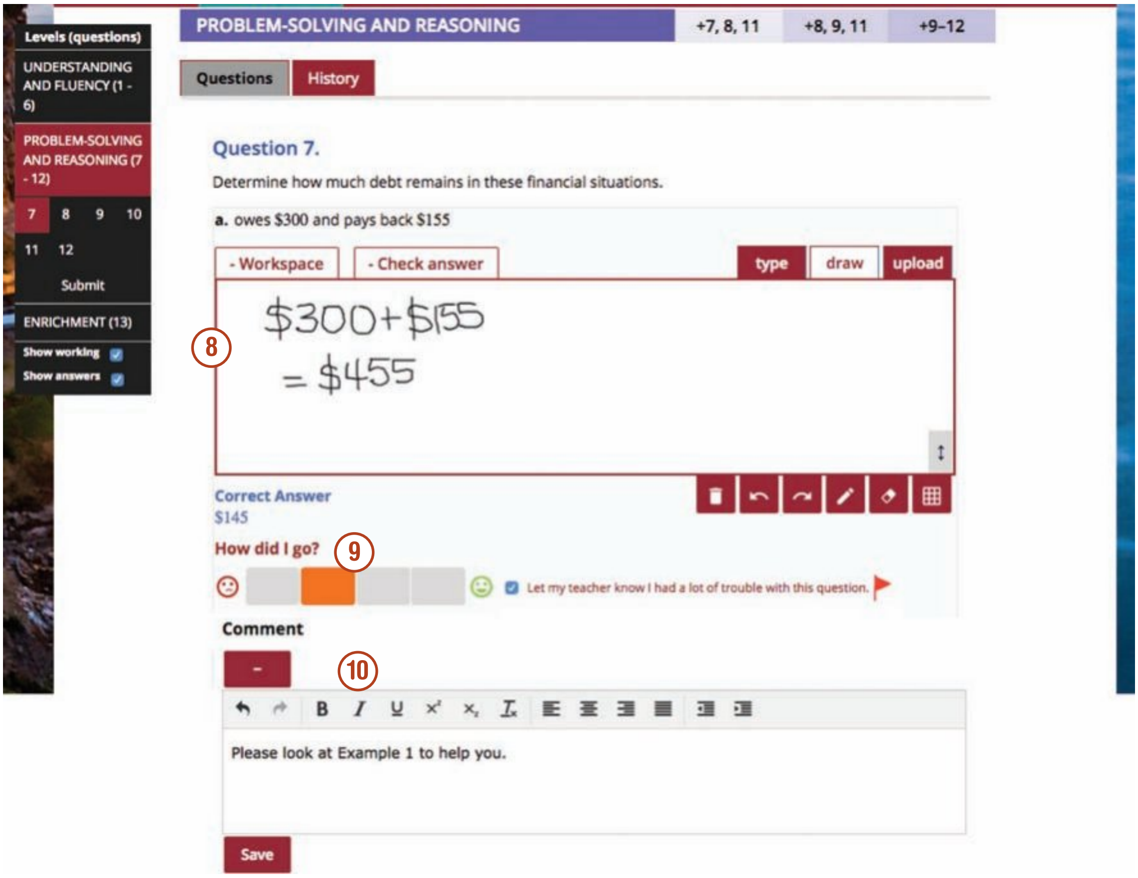
Almost every question in ***CambridgeMATHS NSW Second Edition*** can be completed and saved by students, including showing full working-out and students critically assessing their own work. This is done via the workspaces and self-assessment tools that are found below every question in the Interactive Textbook.

8 The new **workspaces** enable students to enter working and answers online and to save them. Input is by typing, with the help of a symbol palette, handwriting and drawing on tablets, or by uploding images of writing or drawing.

9 The new **self-assessment tools** enable students to check answers including questions that have been red-flagged, and can rate their confidence level in their work, and alert teachers to questions the student has had particular trouble with. This self-assessment helps develop responsibility for learning and communicates progress and performance to the teacher.

10 Teachers can view the students' self-assessment individually or provide feedback. They can also view results by class.

WORKSPACES AND SELF-ASSESSMENT



Question 7.

Determine how much debt remains in these financial situations.

a. owes $300 and pays back $155

$300+$155
= $455

Correct Answer
$145

☑ Let my teacher know I had a lot of trouble with this question.

Please look at Example 1 to help you.

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Downloadable PDF Textbook

The convenience of a downloadable PDF textbook has been retained for times when users cannot go online.

The features include:

11 PDF note-taking
12 PDF search features are enabled
13 highlighting functionality.

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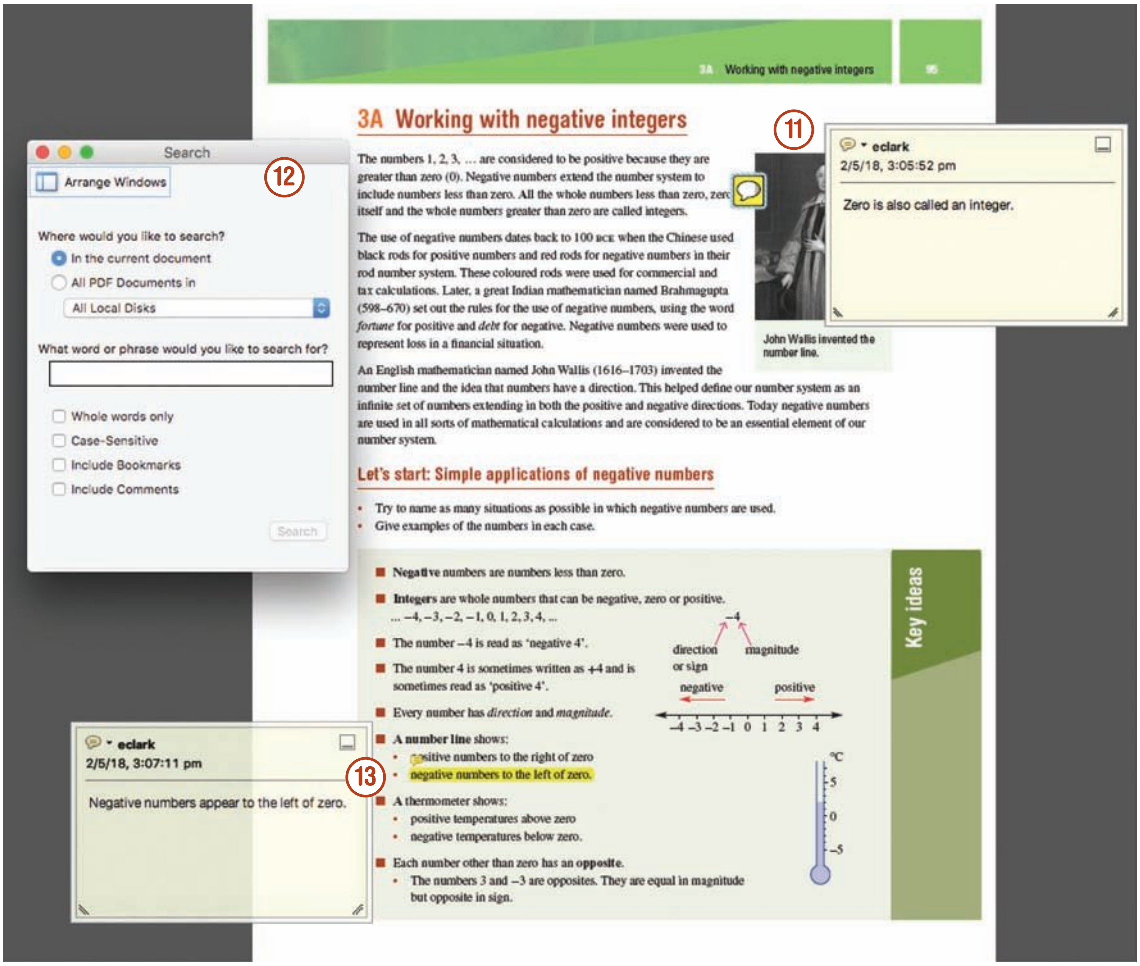

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Zero is also called an integer.

eclark
2/5/18, 3:07:11 pm

Negative numbers appear to the left of zero.

3A Working with negative integers

The numbers 1, 2, 3, … are considered to be positive because they are greater than zero (0). Negative numbers extend the number system to include numbers less than zero. All the whole numbers less than zero, zero itself and the whole numbers greater than zero are called integers.

The use of negative numbers dates back to 100 BCE when the Chinese used black rods for positive numbers and red rods for negative numbers in their rod number system. These coloured rods were used for commercial and tax calculations. Later, a great Indian mathematician named Brahmagupta (598–670) set out the rules for the use of negative numbers, using the word *fortune* for positive and *debt* for negative. Negative numbers were used to represent loss in a financial situation.

An English mathematician named John Wallis (1616–1703) invented the number line and the idea that numbers have a direction. This helped define our number system as an infinite set of numbers extending in both the positive and negative directions. Today negative numbers are used in all sorts of mathematical calculations and are considered to be an essential element of our number system.

Let's start: Simple applications of negative numbers

- Try to name as many situations as possible in which negative numbers are used.
- Give examples of the numbers in each case.

- **Negative** numbers are numbers less than zero.
- **Integers** are whole numbers that can be negative, zero or positive.
  … −4, −3, −2, −1, 0, 1, 2, 3, 4, …
- The number −4 is read as 'negative 4'.
- The number 4 is sometimes written as +4 and is sometimes read as 'positive 4'.
- Every number has *direction* and *magnitude*.
- **A number line** shows:
  - positive numbers to the right of zero
  - negative numbers to the left of zero.
- A thermometer shows:
  - positive temperatures above zero
  - negative temperatures below zero.
- Each number other than zero has an **opposite**.
  - The numbers 3 and −3 are opposites. They are equal in magnitude but opposite in sign.

Online Teaching Suite

The Online Teaching Suite is automatically enabled with a teacher account and is integrated with the teacher's copy of the Interactive Textbook. All the assets and resources are in one place for easy access. The features include:

14 The HOTmaths learning management system with class and student analytics and reports, and communication tools

15 Teacher's view of a student's working and self-assessment, including multiple progress and completion reports viewable at both student and class level, as well as seeing the questions that a class has flagged as being difficult

16 A HOTmaths-style test generator

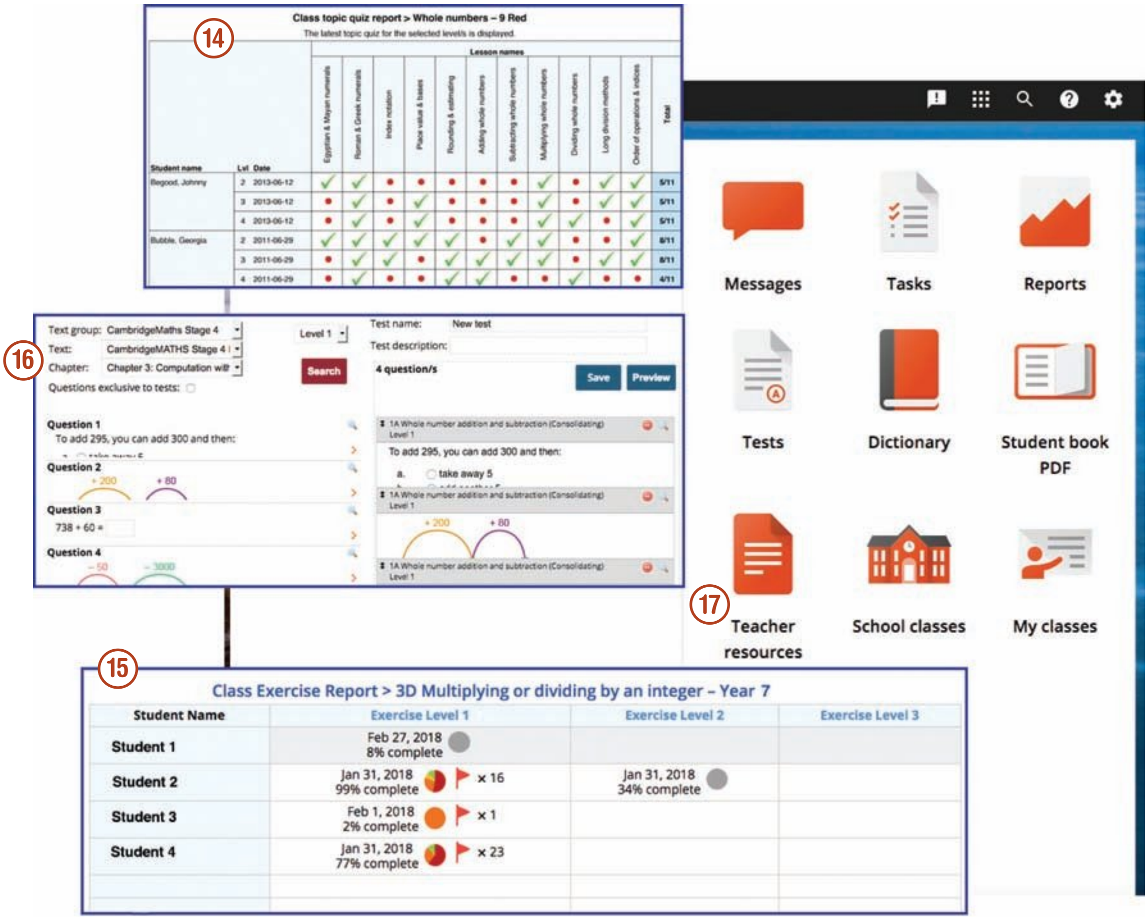
17 Chapter tests and worksheets

Not shown but also available:

- Editable teaching programs and curriculum grids.

ONLINE TEACHING SUITE POWERED BY THE HOTmaths PLATFORM

Note: *HOTmaths platform features are updated regularly.*



Class topic quiz report > Whole numbers – 9 Red

The latest topic quiz for the selected level/s is displayed.

Student name	Lvl	Date	Egyptian & Mayan numerals	Roman & Greek numerals	Index notation	Place value & bases	Rounding & estimating	Adding whole numbers	Subtracting whole numbers	Multiplying whole numbers	Dividing whole numbers	Long division methods	Order of operations & indices	Total
Begood, Johnny	2	2013-06-12	✓	✓	●	●	●	●	●	✓	●	✓	✓	5/11
	3	2013-06-12	●	✓	●	✓	●	●	●	✓	●	✓	✓	5/11
	4	2013-06-12	●	✓	●	✓	●	●	●	✓	✓	●	✓	5/11
Bubble, Georgia	2	2011-06-29	✓	✓	✓	✓	✓	●	✓	✓	●	●	✓	8/11
	3	2011-06-29	●	✓	✓	●	✓	✓	✓	✓	●	✓	✓	8/11
	4	2011-06-29	●	✓	●	●	✓	✓	●	●	✓	●	●	4/11

Text group: CambridgeMaths Stage 4
Text: CambridgeMATHS Stage 4
Chapter: Chapter 3: Computation wit
Questions exclusive to tests: ☐
Level 1

Test name: New test
Test description:

4 question/s

Question 1
To add 295, you can add 300 and then:

Question 2
+ 200 + 80

Question 3
738 + 60 =

Question 4
− 50 − 3000

1A Whole number addition and subtraction (Consolidating) Level 1
To add 295, you can add 300 and then:
a. ○ take away 5

1A Whole number addition and subtraction (Consolidating) Level 1
+ 200 + 80

1A Whole number addition and subtraction (Consolidating) Level 1

Class Exercise Report > 3D Multiplying or dividing by an integer – Year 7

Student Name	Exercise Level 1	Exercise Level 2	Exercise Level 3
Student 1	Feb 27, 2018 8% complete		
Student 2	Jan 31, 2018 99% complete × 16	Jan 31, 2018 34% complete	
Student 3	Feb 1, 2018 2% complete × 1		
Student 4	Jan 31, 2018 77% complete × 23		

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Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

1 Financial mathematics

What you will learn

NSW syllabus

STRAND: NUMBER AND ALGEBRA

SUBSTRAND: FINANCIAL MATHEMATICS

Outcomes

A student solves financial problems involving earning, spending and investing money.
(MA5.1–4NA)
A student solves financial problems involving compound interest.
(MA5.2–4NA)

What is the real cost of a loan?

No-one would walk up to a shop counter and offer to pay $1000 for a $600 TV! But the temptation to buy before saving enough money means that many consumers end up overpaying for purchases. To avoid unmanageable debts or repossession, it is important to calculate the full cost of repaying a loan and budget for it.

A loan with 12% p.a. simple interest repaid over 5 years means you will pay 160% of the original cost, e.g. a $12 500 car will actually cost $20 000.

Payday Loan companies can charge fees of 20% plus 4% per month. If renewed monthly, it is equivalent to a shocking rate of 288% p.a. making a $1000 loan over one year cost almost $4000!

1 Find the following totals.

a $15.92 + $27.50 + $56.20 **b** $134 + $457 + $1021 **c** $457 × 6

d $\$56.34 \times 1\frac{1}{2}$ **e** $87 560 ÷ 52 (to the nearest cent)

2 Write each of the following fractions as decimals.

a $\frac{1}{2}$ **b** $\frac{1}{4}$ **c** $\frac{1}{5}$ **d** $\frac{7}{25}$ **e** $\frac{1}{3}$

3 Express the following fractions with denominators of 100.

a $\frac{1}{2}$ **b** $\frac{3}{4}$ **c** $\frac{1}{5}$ **d** $\frac{17}{25}$ **e** $\frac{9}{20}$

4 Round the following decimals to 2 decimal places.

a 16.7893 **b** 7.347 **c** 45.3444 **d** 6.8389 **e** 102.8999

5 Copy and complete the following table.

Gross income ($)	Deductions ($)	Net income ($)
4976	456.72	**a**
72 156	21 646.80	**b**
92 411	**c**	62 839
156 794	**d**	101 916
e	18 472.10	79 431.36

Net income = gross income − deductions

6 Calculate the following annual incomes for each of these people.

a Tom: $1256 per week

b Viviana: $15 600 per month

c Anthony: $1911 per fortnight

d Crystal: $17.90 per hour, for 40 hours per week, for 50 weeks per year

7 Without a calculator, find:

a 10% of $400 **b** 5% of $5000 **c** 2% of $100

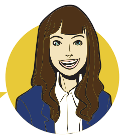
d 25% of $844 **e** 20% of $12.80 **f** 75% of $1000

8 Find the simple interest earned on the following amounts.

a $400 at 5% p.a. for 1 year **b** $5000 at 6% p.a. for 1 year

c $800 at 4% p.a. for 2 years

Simple interest $I = PRN$



9 Complete the following table.

Cost price	Deduction	Sale price
$34	$16	**a**
$460	$137	**b**
$500	**c**	$236
d	$45	$67
e	$12.65	$45.27

10 The following amounts include the 10% GST. By dividing each one by 1.1, find the original costs before the GST was added.

a $55 **b** $61.60 **c** $605

1A Review of percentages REVISION

Interactive
Widgets
HOTsheets
Walkthrough

It is important that we are able to work with percentages in our everyday lives. Banks, retailers and governments use percentages every day to work out fees, prices and interest.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Which option should Jamie choose?

Jamie currently earns \$38 460 p.a. (per year) and is given a choice of two different pay rises. Which should she choose and why?

Choice A	**Choice B**
Increase of \$20 a week	Increase of 2% p.a. on salary

Key ideas

- A **percentage** means 'out of 100'. It can be written using the symbol %, or as a fraction or a decimal.

  For example: 75 per cent $= 75\% = \frac{75}{100}$ or $\frac{3}{4} = 0.75$
- To convert a fraction or a decimal to a percentage, multiply by 100, or $\frac{100}{1}$.
- To convert a percentage to a fraction, write it with a **denominator** of 100 and simplify.

  For example: $15\% = \frac{15}{100} = \frac{3}{20}$
- To convert a percentage to a decimal, divide by 100.

  For example: $15\% = 15 \div 100 = 0.15$
- To find a percentage of a quantity, write the percentage as a fraction or a decimal, then multiply by the quantity.

  For example: 35% of \$600 $= \frac{35}{100} \times \$600$

Percentage A convenient way of writing fractions with denominators of 100

Denominator The part of a fraction that sits below the dividing line

$$\begin{tikzcd}\text{Fraction} \arrow[r, bend left, "\times 100"] & \% \arrow[l, bend left, "\div 100"]\end{tikzcd}$$

$$\begin{tikzcd}\text{Decimal} \arrow[r, bend left, "\times 100"] & \% \arrow[l, bend left, "\div 100"]\end{tikzcd}$$

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Exercise 1A REVISION

UNDERSTANDING AND FLUENCY

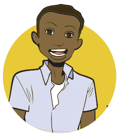
1, 2, 3–8(½) 3–8(½)

1 Write the following with denominators of 100.

a $\frac{2}{5}$ **b** $\frac{17}{20}$ **c** $\frac{49}{50}$

d $\frac{7}{25}$ **e** $\frac{9}{10}$

Make sure you have an equivalent fraction: $\frac{2}{5} = \frac{\square}{100}$.



2 Complete the following.

a $7\% = \frac{7}{\square}$ **b** $0.9 = \square\,\%$ **c** $\frac{3}{5} = \square\,\%$

3 Use mental strategies to find:

a 10% of \$7.50 **b** 20% of \$400 **c** 50% of \$98

d 75% of \$668 **e** 25% of \$412 **f** 2% of \$60

g 5% of \$750 **h** $33\frac{1}{3}\%$ of \$1200 **i** 30% of \$15

$10\% = \frac{10}{100}$

'of' means times

Example 1 Converting to a percentage

Write each of the following as a percentage.

a $\frac{19}{20}$ **b** $\frac{3}{8}$ **c** 0.07

SOLUTION	EXPLANATION
a $\frac{19}{20} = \frac{19 \times 5}{20 \times 5}$ $= \frac{95}{100}$ $= 95\%$	Write using a denominator of 100. Alternatively, multiply the fraction by 100. $\frac{19}{{}^{1}\cancel{20}} \times \frac{\cancel{100}^{5}}{1} = 19 \times 5 = 95$
b $\frac{3}{\cancel{8}_{2}} \times \frac{\cancel{100}^{25}}{1} = \frac{75}{2}$ $= 37.5\%$ So $\frac{3}{8} = 37.5\%$	Multiply the fraction by 100. Cancel common factors, then simplify.
c $0.07 \times 100 = 7$ So $0.07 = 7\%$	Multiply the decimal by 100. Move the decimal point two places to the right.

4 Convert each fraction to a percentage.

a $\frac{1}{2}$ **b** $\frac{1}{5}$ **c** $\frac{1}{4}$ **d** $\frac{1}{10}$

e $\frac{1}{100}$ **f** $\frac{7}{25}$ **g** $\frac{15}{50}$ **h** $\frac{3}{4}$

i $\frac{5}{8}$ **j** $\frac{19}{25}$ **k** $\frac{99}{100}$ **l** $\frac{47}{50}$

First, write using a denominator of 100 or alternatively multiply by 100.

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5 Write these decimals as percentages.

a 0.17 **b** 0.73 **c** 0.48 **d** 0.09
e 0.06 **f** 0.13 **g** 1.13 **h** 1.01
i 0.8 **j** 0.9 **k** 0.99 **l** 0.175

To multiply by 100, move the decimal point two places to the right.

Example 2 Writing a percentage as a simple fraction

Write each of the following percentages as a simple fraction.

a 37% **b** 58% **c** $6\frac{1}{2}\%$

SOLUTION

a $37\% = \frac{37}{100}$

b $58\% = \frac{58}{100}$
$= \frac{29}{50}$

c $6\frac{1}{2}\% = \frac{6\frac{1}{2}}{100}$
$= \frac{13}{200}$

EXPLANATION

Write the percentage with a denominator of 100.

Write the percentage with a denominator of 100.

Simplify $\frac{58}{100}$ by cancelling, using the HCF of 58 and 100, which is 2.

$$\frac{\cancel{58}^{29}}{\cancel{100}_{50}} = \frac{29}{50}$$

Write the percentage with a denominator of 100.

Double the numerator $\left(6\frac{1}{2}\right)$ and the denominator (100) so that the numerator is a whole number.

6 Write each percentage as a simple fraction.

a 71% **b** 80% **c** 25% **d** 55%
e 40% **f** 88% **g** 15% **h** $16\frac{1}{2}\%$
i $17\frac{1}{2}\%$ **j** $2\frac{1}{4}\%$ **k** $5\frac{1}{4}\%$ **l** $52\frac{1}{2}\%$

Write with a denominator of 100, then simplify if possible.

Example 3 Writing a percentage as a decimal

Convert these percentages to decimals.

a 93% **b** 7% **c** 30%

SOLUTION

a $93\% = 93 \div 100$
$= 0.93$

b $7\% = 7 \div 100$
$= 0.07$

c $30\% = 30 \div 100$
$= 0.3$

EXPLANATION

Divide the percentage by 100. This is the same as moving the decimal point two places to the left.
$93 \div 100 = 0.93$

Divide the percentage by 100.
$7 \div 100 = 0.07$

Divide the percentage by 100.
$30 \div 100 = 0.30$
Write 0.30 as 0.3.

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7 Convert to decimals.

a 61%	**b** 83%	**c** 75%	**d** 45%
e 9%	**f** 90%	**g** 50%	**h** 16.5%
i 7.3%	**j** 200%	**k** 430%	**l** 0.5%

Example 4 Finding a percentage of a quantity

Find 42% of \$1800.

SOLUTION

$$\begin{aligned} 42\% \text{ of } \$1800 &= 0.42 \times 1800 \\ &= \$756 \end{aligned}$$

EXPLANATION

Remember that 'of' means multiply.

Write 42% as a decimal or a fraction: $42\% = \frac{42}{100} = 0.42$

Then multiply by the amount.
If using a calculator, type 0.42 × 1800.

Without a calculator: $\frac{42}{1\cancel{00}} \times 18\cancel{00} = 42 \times 18$

8 Use a calculator to find:

a 10% of \$250	**b** 50% of \$300	**c** 75% of \$80
d 12% of \$750	**e** 9% of \$240	**f** 43% of 800 grams
g 90% of \$56	**h** 110% of \$98	**i** $17\frac{1}{2}\%$ of 2000 m

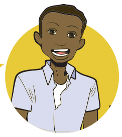
PROBLEM-SOLVING AND REASONING

9–11 11–14

9 A 300 g pie contains 15 g of saturated fat.

a What fraction of the pie is saturated fat?

b What percentage of the pie is saturated fat?



15 g out of 300 g.

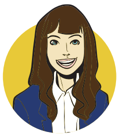
10 About 80% of the mass of a human body is water. If Hugo is 85 kg, how many kilograms of water are in his body?

11 Rema spends 12% of the 6.6 hour school day in Maths. How many minutes are spent in the Maths classroom?

12 In a cricket match, Brett spent 35 minutes bowling.

His team's total fielding time was $3\frac{1}{2}$ hours.

What percentage of the fielding time, correct to 2 decimal places, did Brett spend bowling?



First convert hours to minutes, and then write a fraction comparing times.

13 Malcolm lost 8 kg, and now weighs 64 kg. What percentage of his original weight did he lose?

14 47.9% of a local council's budget is spent on garbage collection. If a rate payer pays \$107.50 per quarter in total rate charges, how much do they contribute in a year to garbage collection?

ENRICHMENT – 15

Australia's population statistics

15 Below is the preliminary data on Australia's population growth, as gathered by the Australian Bureau of Statistics for December 2017.

	Population at end December quarter 2017 ('000)	Change over previous year ('000)	Change over previous year (%, 1 decimal place)
New South Wales	7915.1	116.8	
Victoria	6385.8	143.4	
Queensland	4965.0	81.5	
South Australia	1728.1	10.7	
Western Australia	2584.8	21.4	
Tasmania	524.7	4.9	
Northern Territory	246.7	0.6	
Australian Capital Territory	415.9	8.8	
Australia	**24 770.7**	**388.0**	

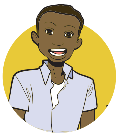
a Calculate the percentage change for each State and Territory shown using the previous year's population, and complete the table.

b What percentage of Australia's overall population, correct to 1 decimal place, is living in:
  - **i** NSW?
  - **ii** Victoria?
  - **iii** WA?

Use a spreadsheet to draw a pie chart (sector graph) showing the populations of the eight States and Territories in the table.

c In your pie chart in part **b**, what is the angle size of the sector representing Victoria?

You will need to calculate the previous year's population; e.g. for NSW, 7915.1 − 116.8.



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1B Applying percentages REVISION

Interactive
Widgets
HOTsheets
Walkthrough

There are many applications of percentages. Prices are often increased by a percentage to create a profit, or decreased by a percentage when on sale.

When goods are purchased by a store, the cost to the owner is called the cost price. The price of the goods sold to the customer is called the selling price. This price will vary according to whether the store is having a sale or decides to make a certain percentage profit.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

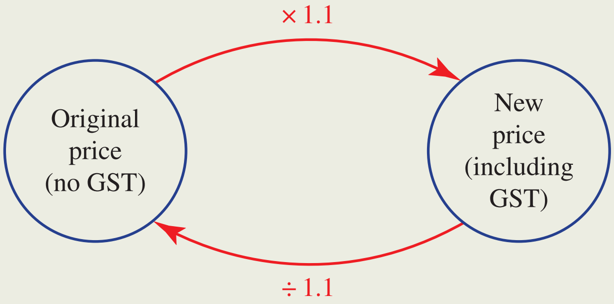
Let's start: Discounts

Discuss as a class:

- Which is better: 20% off or a \$20 discount?
- If a discount of \$20 or 20% off resulted in the same price, what would be the original price?
- Why are percentages used to show discounts, rather than a fixed amount?

Key ideas

- To increase by a given percentage, multiply by the sum of 100% and the given percentage. For example: To increase by 12%, multiply by 112% or 1.12.
- When the Goods and Services Tax (GST) was introduced in Australia in the year 2000, prices of most goods increased by 10% of the original price.



- To decrease by a given percentage, multiply by 100% minus the given percentage. For example: To decrease by 20%, multiply by 80% or 0.8.
- Profits and discounts
  - The normal price of the goods recommended by the manufacturer is called the retail price.
  - If there is a sale and the goods are less than the retail price, they are said to be **discounted**.
  - **Profit** = selling price − cost price
  - Percentage profit $= \dfrac{\text{profit}}{\text{cost price}} \times 100\%$
  - Percentage discount $= \dfrac{\text{discount}}{\text{cost price}} \times 100\%$

Discount An amount subtracted from a price

Profit The amount of money made by selling an item or service for more than its cost

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Exercise 1B REVISION

UNDERSTANDING AND FLUENCY 1–3, 4–5(½), 6–8, 10 4–5(½), 6, 8, 9, 11, 12

1 By what percentage do you multiply to increase an amount by:

a 10%? **b** 20%? **c** 50%?
d 2%? **e** 18%?

2 By what percentage do you multiply to decrease an amount by:

a 5%? **b** 30%? **c** 15%?
d 50%? **e** 17%?

Increase
100% + percentage
Decrease
100% − percentage

3 Decide how much profit or loss is made in each of the following situations.

a cost price = $15 selling price = $20
b cost price = $17.50 selling price = $20
c cost price = $250 selling price = $234
d cost price = $147 selling price = $158
e cost price = $3.40 selling price = $1.20

Example 5 Increasing by a given percentage

Increase $370 by 8%.

SOLUTION	EXPLANATION
$370 × 1.08 = $399.60	100% + 8% = 108% Write 108% as a decimal (or fraction) and multiply by the amount. Remember that money has 2 decimal places.

4 **a** Increase $90 by 5%. **b** Increase $400 by 10%.
c Increase $55 by 20%. **d** Increase $490 by 8%.
e Increase $50 by 12%. **f** Increase $7000 by 3%.
g Increase $49.50 by 14%. **h** Increase $1.50 by 140%.

To increase by 5%, multiply by 100% + 5% = 1.05.

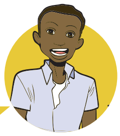
Example 6 Decreasing by a given percentage

Decrease $8900 by 7%.

SOLUTION	EXPLANATION
$8900 × 0.93 = $8277.00	100% − 7% = 93% Write 93% as a decimal (or fraction) and multiply by the amount. Remember to put the units in your answer.

5 **a** Decrease $1500 by 5%. **b** Decrease $400 by 10%.
c Decrease $470 by 20%. **d** Decrease $80 by 15%.
e Decrease $550 by 25%. **f** Decrease $49.50 by 5%.
g Decrease $119.50 by 15%. **h** Decrease $47.10 by 24%.

To decrease by 5%, multiply by 100% − 5% = 0.95.



Example 7 Calculating profits and percentage profit

The cost price for a new car is \$24 780 and it is sold for \$27 600.

a Calculate the profit.

b Calculate the percentage profit to 2 decimal places.

SOLUTION

a Profit = selling price − cost price
= \$27 600 − \$24 780
= \$2820

b $$\text{Percentage profit} = \frac{\text{profit}}{\text{cost price}} \times 100$$
$$= \frac{2820}{24\,780} \times 100$$
$$= 11.38\%$$

EXPLANATION

Write the rule.
Substitute the values and evaluate.

Write the rule.

Substitute the values and evaluate.

Round your answer as instructed.

6 Copy and complete the table on profits and percentage profit.

	Cost price	Selling price	Profit	Percentage profit
a	\$10	\$16		
b	\$240	\$300		
c	\$15	\$18		
d	\$250	\$257.50		
e	\$3100	\$5425		
f	\$5.50	\$6.49		

$$\text{Percentage profit} = \frac{\text{profit}}{\text{cost price}} \times 100$$

Example 8 Finding the selling price

A retailer buys some calico material for \$43.60 a roll. He wishes to make a 35% profit.

a What will be the selling price per roll?

b If he sells 13 rolls, what profit will he make?

SOLUTION

a Selling price = 135% of \$43.60
= 1.35 × \$43.60
= \$58.86 per roll

b Profit per roll = \$58.86 − \$43.60 = \$15.26
Total profit = \$15.26 × 13
= \$198.38

EXPLANATION

For a 35% profit the unit price is 135%.
Write 135% as a decimal (1.35) and evaluate.

Profit = selling price − cost price
There are 13 rolls at \$15.26 profit per roll.

7 A retailer buys some snow globes for \$41.80 each. He wishes to make a 25% profit.

a What will be the selling price per snow globe?

b If he sells a box of 25 snow globes, what profit will he make?

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8 Ski jackets are delivered to a shop in packs of 50 for $3500. If the shop owner wishes to make a 35% profit:

a what will be the total profit made on a pack?

b what is the profit on each jacket?

9 Copy and complete the table.

	Price without GST	GST	Price including GST
a	$120		
b	$50		
c		$8	
d			$99
e			$159.50

Example 9 Finding the discounted price

A shirt worth $25 is discounted by 15%.

a What is the selling price?

b How much is the saving?

SOLUTION	EXPLANATION
a Selling price = 85% of $25 = 0.85 × 25 = $21.25	15% discount means there must be 85% left (100% − 15%). Convert 85% to 0.85 and multiply by the amount.
b Saving = 15% of $25 = 0.15 × 25 = $3.75	You save 15% of the original price. Convert 15% to 0.15 and multiply by the original price.
or Saving = $25 − $21.25 = $3.75	Saving = original price − discounted price

10 Samantha buys a wetsuit from the sports store where she works. Its original price was $79.95. If employees receive a 15% discount:

a what is the selling price?

b how much will Samantha save?

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11 A travel agent offers a 12.5% discount on airfares if you travel during May or June. If the normal fare to London (return trip) is $2446:

a what is the selling price?

b how much is the saving?

12 A store sells second-hand goods at 40% off the recommended retail price. For a lawn mower valued at $369:

a what is the selling price?

b how much do you save?

PROBLEM-SOLVING AND REASONING	13–15	14–17

13 A pair of sports shoes is discounted by 47%. If the recommended price was $179:

a what is the amount of the discount?

b what will be the discounted price?

14 Jeans are priced at a May sale for $89. If this is a saving of 15% off the selling price, what do the jeans normally sell for?

85% of amount = $89
Find 1%, then × 100 to find 100%.

15 Discounted tyres are reduced in price by 35%. They now sell for $69 each. Determine:

a the normal price of one tyre

b the saving if you buy one tyre

16 The local shop purchases a carton of containers for $54. Each container is sold for $4. If the carton has 30 containers, determine:

a the profit per container

b the percentage profit per container, to 2 decimal places

c the overall profit per carton

d the overall percentage profit, to 2 decimal places

17 A retailer buys a book for $50 and wants to sell it for a 26% profit. The 10% GST must then be added to the cost of the book.

a Calculate the profit on the book.

b How much GST is added to the cost of the book?

c What is the advertised price of the book, including the GST?

d Find the overall percentage increase of the final selling price compared to the $50 cost price.

$$\% \text{Increase} = \frac{\text{increase}}{\text{cost price}} \times 100$$

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ENRICHMENT – 18

Building a gazebo

18 Christopher designs a gazebo for a new house. He buys the timber from a retailer, who sources it at the wholesale price and then adds a mark-up before selling to Christopher at the retail price.
The table below shows the wholesale prices as well as the mark-up for each type of timber.

Quantity	Description	Cost/unit	Mark-up
6	treated pine posts	\$23	20%
11	300 × 50 oregon beams	\$75	10%
5	sheet lattice work	\$86	15%
2	300 × 25 oregon fascias	\$46	12%
8	laserlite sheets	\$32	10%

a Determine Christopher's overall cost for the material, including the mark-up.
b Determine the profit the retailer made.
c Determine the retailer's overall percentage profit, to 2 decimal places.
d If the retailer pays 27% of his profits in tax, how much tax does he pay on this sale?

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1C Income

Interactive
Widgets
HOTsheets
Walkthrough

You may have earned money for babysitting or delivering newspapers, or have a part-time job. As you move more into the workforce, it is important that you understand how you are paid.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Who earns what?

As a class, discuss the different types of jobs held by different members of each person's family, and discuss how they are paid.

- What are the different ways that people can be paid?
- What does it mean if you work fewer than full-time hours?
- What does it mean if you work longer than full-time hours?

What other types of income can people in the class think of?

Key ideas

Methods of payment

- Hourly **wages**: You are paid a certain amount per hour worked.
- **Commission**: You are paid a percentage of the total amount of sales.
- **Salary**: You are paid a set amount per year, regardless of how many hours you work.
- **Fees**: You are paid according to the charges you set; e.g. doctors, lawyers, contractors.
- Some terms you should be familiar with include:
  - **Gross income**: The total amount of money you earn before taxes and other deductions
  - **Deductions**: Money taken from your income before you are paid; e.g. taxation, union fees, superannuation
  - **Net income**: The amount of money you actually receive after the deductions are taken from your gross income

$$\text{Net income} = \text{gross income} - \text{deductions}$$

Wages Earnings paid to an employee based on an hourly rate

Commission Earnings of a salesperson based on a percentage of the value of goods or services sold

Salary An employee's fixed agreed yearly income

Gross income Total income before any deductions (e.g. income tax) are made

Deductions Amounts of money taken from gross income

Net income Income remaining after deductions have been made from gross income

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Key ideas

Payments by hourly rate

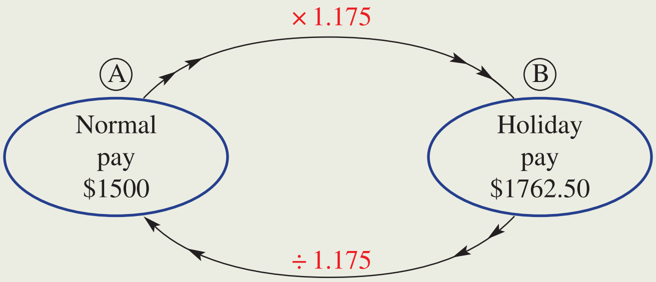
- If you are paid by the hour, you will be paid an amount per hour for your normal working time. Usually, normal working time is 38 hours per week. If you work overtime, the rates may be different.
  Normal: 1.0 × normal rate
  Time and a half: 1.5 × normal rate
  Double time: 2.0 × normal rate
- If you work shift work, the hourly rates may differ from shift to shift.
  For example:

6 a.m.–2 p.m.	\$12.00/hour	(regular rate)
2 p.m.–10 p.m.	\$14.30/hour	(afternoon shift rate)
10 p.m.–6 a.m.	\$16.80/hour	(night shift rate)

Leave loading

- Some wage and salary earners are paid leave loading. When they are on holidays, they earn their normal pay plus a bonus called leave loading. This is usually 17.5% of their normal pay.

$$\boxed{\begin{aligned} 100\% + 17.5\% &= 117.5\% \\ &= 1.175 \end{aligned}}$$



Leave loading = 17.5% of Ⓐ = \$262.50

Exercise 1C

UNDERSTANDING AND FLUENCY | 1–7, 9 | 4–10

1 If Tao earns \$570 for 38 hours' work, calculate his:
  a hourly rate of pay
  b time and a half rate
  c double time rate
  d annual income, given that he works 52 weeks a year, 38 hours a week

2 Which is better: \$5600 a month or \$67 000 a year?

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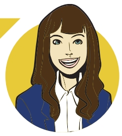
3 Callum earns \$1090 a week and has annual deductions of \$19 838. What is Callum's net income for the year?

Net = total − deductions
1 year = 52 weeks



Example 10 Finding gross and net income (including overtime)

Pauline is paid \$13.20 per hour at the local stockyard to muck out the stalls. Her normal hours of work are 38 hours per week. She receives time and a half for the next 4 hours worked and double time after that.

a What will be Pauline's gross income if she works 50 hours?

b If Pauline pays \$220 per week in taxation and \$4.75 in union fees, what will be her weekly net income?

SOLUTION

a Gross income $= 38 \times \$13.20 + 4 \times 1.5 \times \$13.20 + 8 \times 2 \times \$13.20 = \$792$

b Net income $= \$792 - (\$220 + \$4.75) = \$567.25$

EXPLANATION

First 38 hours is paid at normal rate.
Overtime rate for next 4 hours: time and a half $= 1.5 \times$ normal rate
Overtime rate for next 8 hours: double time $= 2 \times$ normal rate

Net income = gross income − deductions

4 Copy and complete this table.

	Hourly rate	Normal hours worked	Time and a half hours	Double time hours	Gross income	Deductions	Net income
a	\$15	38	0	0		\$155	
b	\$24	38	2	0		\$220	
c	\$13.15	38	4	1		\$300	
d	\$70	40	2	3		\$510	
e	\$17.55	35	4	6		\$184	

Example 11 Calculating shift work

Michael is a shift worker and is paid \$31.80 per hour for the morning shift, \$37.02 per hour for the afternoon shift and \$50.34 per hour for the night shift. Each shift is 8 hours. In a given fortnight he works four morning, two afternoon and three night shifts. Calculate his gross income.

SOLUTION

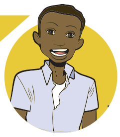
Gross income $= 4 \times \$31.80 \times 8 + 2 \times \$37.02 \times 8 + 3 \times \$50.34 \times 8 = \$2818.08$

EXPLANATION

4 morning shifts at \$31.80 per hour for 8 hours
2 afternoon shifts at \$37.02 per hour
3 night shifts at \$50.34 per hour
Gross income as tax has not been paid.

5 Greg works shifts at a processing plant. In a given rostered fortnight he works:
- three day shifts ($10.60 per hour)
- four afternoon shifts ($12.34 per hour)
- four night shifts ($16.78 per hour).

a If each shift is 8 hours long, determine his gross income for the fortnight.
b If the answer to part **a** was his average fortnightly income, what would be his gross income for a year (52 weeks)?
c If he is to be paid monthly, what would be his gross income for a month?



A fortnight = 2 weeks

Example 12 Calculating income involving commission

Jeff sells memberships to a gym and receives $225 per week plus 5.5% commission on his sales. Calculate his gross income after a 5-day week.

Day	1	2	3	4	5
Sales ($)	680	450	925	1200	1375

SOLUTION	**EXPLANATION**
Total sales = $4630	Determine the total sales by adding the daily sales.
Commission = 5.5% of $4630 = 0.055 × 4630 = $254.65	Determine the commission on the total sales at 5.5% by multiplying 0.055 by the total sales.
Gross income = $225 + $254.65 = $479.65	Gross income is $225 plus commission.

6 A real estate agent receives 2.75% commission on the sale of a house valued at $125 000. Find the commission earned.

Divide by 100 to convert 2.75% to a decimal.

7 A car salesman earns $500 a month plus 3.5% commission on all sales. In the month of January his sales total $56 000. Calculate:
a his commission for January
b his gross income for January

8 Portia earns an annual salary of $27 000 plus 2% commission on all sales. Find:
a her weekly base salary before sales
b her commission for a week where her sales totalled $7500
c her gross weekly income for the week mentioned in part **b**.
d her annual gross income if over the year her sales totalled $571 250

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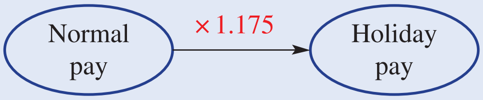
Example 13 Calculating holiday pay

Rachel is normally paid $1200 per week. When she is on holidays she is paid 17.5% p.a. leave loading.

a How much is her holiday pay for 1 week?

b How much is her leave loading for 1 week?

SOLUTION	EXPLANATION
a Holiday pay = $1200 × 1.175 = $1410	
b Leave loading = $1200 × 0.175 = $210	17.5% = 0.175 Loading is 17.5% of normal pay.

9 Ashton is normally paid $900 per week. When he is on holidays he is paid leave loading.

  a Calculate Ashton's holiday pay for 1 week.

  b Calculate Ashton's leave loading for 1 week.

Leave loading is an extra 17.5% of normal pay.

10 Mary earns $800 per week. Calculate her holiday pay for 4 weeks, including leave loading.

PROBLEM-SOLVING AND REASONING 11, 12 12–14

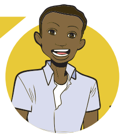
11 If Simone received $2874 on the sale of a property worth $95 800, calculate her rate of commission.

What percentage of $95 800 is $2874?

12 Jonah earns a commission on his sales of fashion items. For goods to the value of $2000 he receives 6% and for sales over $2000 he receives 9% on the amount in excess of $2000. In a given week he sold $4730 worth of goods. Find the commission earned.

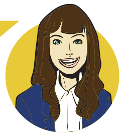
13 Mel is taking her holidays. She received $2937.50. This includes her normal pay and her leave loading. How much was the leave loading?

$2937.50 is 117.5% of Mel's normal pay.



14 Toby earns 1.75% commission on all sales at the electrical goods store where he works. If Toby earns $35 in commission on the sale of one television, how much did the TV sell for?

1.75% is $35. Find 1% then 100%.



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ENRICHMENT		–	15

Elmo's payslip

15 Refer to the payslip below to answer the following questions. During 2013, Elmo received 26 of these payslips.

Kuger Incorporated

Employee ID: 75403A
Name: Elmo Clowner

Page: 1
Pay period: 21/05/2013

Pay method: EFT
Bank account name: E. Clowner
Bank: Mathsville Credit Union
BSB: 102-196 Account No: 00754031

Tax status: Gen Exempt

Payment details this pay:

Amount	Days	Payment description	Rate/Frequency
2777.16	14.00	Normal time	$72 454/annum

Before tax deductions:

This pay	Description
170	Salary sacrifice: car pre-tax deduction

Miscellaneous deductions:

This pay	Description
52.90	Health fund
23.10	Union fees
76.00	

Reconciliation details:

This pay	YTD	Description
2607.15	62 571.60	Taxable gross pay
616.00	14 784.00	Less income tax
76.00	1 824.00	Less miscellaneous deductions
1915.15	45 693.60	

a For what company does Elmo work?
b What is the name of Elmo's bank and what is his account number?
c How much gross pay does Elmo earn in 1 year?
d How often does Elmo get paid?
e How much, per year, does Elmo salary sacrifice?
f How much each week is Elmo's health fund contributions?
g Calculate the union fees for 1 year.
h Using the information on this payslip, calculate Elmo's annual tax and also his annual net income.

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1D The PAYG income tax system

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

It has been said that there are only two sure things in life: death and taxes! The Australian Taxation Office (ATO) collects taxes on behalf of the government to pay for education, hospitals, roads, railways, airports and services, such as the police and fire brigades.

In Australia, the financial year runs from July 1 to June 30 the following year. People engaged in paid employment are normally paid weekly or fortnightly. Most of them pay some income tax every time they are paid for their work. This is known as the Pay-As-You-Go system (PAYG).

At the end of the financial year (June 30), people who earned an income complete an income tax return to determine if they have paid the correct amount of income tax during the year. If they paid too much, they will receive a refund. If they did not pay enough, they will be required to pay more.

The Australian tax system is very complex and the laws change frequently. This section covers the main aspects only.

Let's start: The ATO website

The Australian Taxation Office website has some income tax calculators. Use one to find out how much income tax you would need to pay if your taxable income is:
- $5200 per annum (i.e. $100 per week)
- $10 400 per annum (i.e. $200 per week)
- $15 600 per annum (i.e. $300 per week)
- $20 800 per annum (i.e. $400 per week)
- $26 000 per annum (i.e. $500 per week).

Does a person earning $1000 per week pay twice as much tax as a person earning $500 per week?
Does a person earning $2000 per week pay twice as much tax as a person earning $1000 per week?

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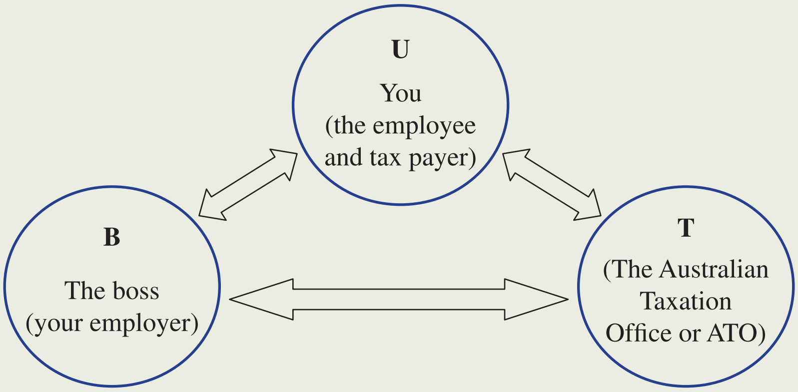
Key ideas



- The PAYG tax system works in the following way.
  - U works for and gets paid by B every week, fortnight or month.
  - B calculates the tax that U should pay for the amount earned by U.
  - B sends that tax to T every time U gets paid.
  - T passes the income tax to the federal government.
  - On June 30, B gives U a **payment summary** to confirm the amount of tax that has been paid to T on behalf of U.
  - Between July 1 and October 31, U completes a **tax return** and sends it to T. Some people pay a registered tax agent to do this return for them.
  - On this tax return, U lists the following.
    - *All* forms of income, including interest from investments.
    - Legitimate deductions shown on receipts and invoices, such as work-related expenses and donations.
  - **Taxable income** is calculated using the formula:
    Taxable income = gross income − deductions
  - There are tables and calculators on the ATO website, such as the following.

Taxable income	Tax on this income
0 – $18 200	Nil
$18 201 – $37 000	19c for each $1 over $18 200
$37 001 – $87 000	$3572 plus 32.5c for each $1 over $37 000
$87 001 – $180 000	$19 822 plus 37c for each $1 over $87 000
$180 001 and over	$54 232 plus 45c for each $1 over $180 000

    This table can be used to calculate the amount of tax U *should have* paid (i.e. the **tax payable**), as opposed to the tax U *did* pay during the year (i.e. the tax withheld). Each row in the table is called a tax bracket.

  - U may also need to pay the Medicare levy. This is a scheme in which all Australian taxpayers share in the cost of running the medical system. For many people this is currently 2% of their taxable income.
  - It is possible that U may have paid too much tax during the year and will receive a **tax refund**.
  - It is also possible that U may have paid too little tax and will receive a letter from T asking for the **tax liability** to be paid.

Exercise 1D

UNDERSTANDING AND FLUENCY	1–8	4–8

Note: The questions in this exercise relate to the tax table given in Key ideas, unless stated otherwise.

1 Complete this statement: Taxable income = ________ income minus ________.

2 Is the following statement true or false?

The highest income earners in Australia pay 45 cents tax for every dollar they earn.

3 Greg paid no income tax. What could his taxable income have been?

4 Ann's taxable income was \$87 000, which puts her at the very top of the middle tax bracket in the tax table. Ben's taxable income was \$87 001, which puts him in a higher tax bracket. Ignoring the Medicare levy, how much extra tax did Ben pay compared to Ann?

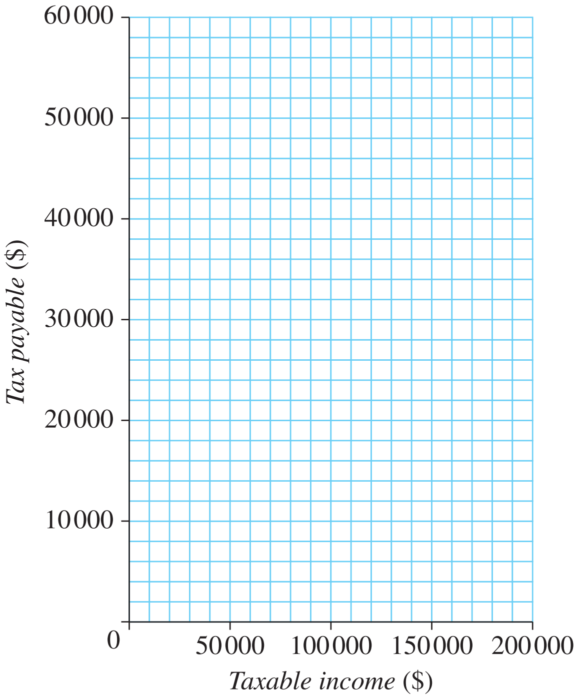
5 Use the tax table to calculate the income tax payable on these taxable incomes.

- **a** \$30 000
- **b** \$60 000
- **c** \$150 000
- **d** \$200 000

6 Consider the amount of tax payable for these six people.

Taxable income	\$0	\$18 200	\$37 000	\$87 000	\$180 000	\$200 000
Tax payable	\$0	\$0	\$3572	\$19 822	\$54 232	\$63 232

Make a copy of this set of axes, plot the points, then join the dots with straight-line segments.



7 Jim worked for three different employers. They each paid him \$15 000. Based on your graph in the previous question, how much income tax should Jim have paid?

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Example 14 Calculating income tax payable

During the financial year, Richard earned \$1050 per week (\$54 600 dollars per annum) from his employer and other sources, such as interest on investments. He has receipts for \$375 for work-related expenses and donations.

a Calculate Richard's taxable income.

b Use this tax table to calculate Richard's tax payable amount.

Taxable income	Tax on this income
0 – \$18 200	Nil
\$18 201 – \$37 000	19c for each \$1 over \$18 200
\$37 001 – \$87 000	\$3572 plus 32.5c for each \$1 over \$37 000
\$87 001 – \$180 000	\$19 822 plus 37c for each \$1 over \$87 000
\$180 001 and over	\$54 232 plus 45c for each \$1 over \$180 000

c Richard must also pay the Medicare levy of 2% of his taxable income. How much is the Medicare levy?

d Add the tax payable and the Medicare levy amounts.

e Express the total tax in part **d** as a percentage of Richard's taxable income, to 1 decimal place.

f During the financial year, Richard's employer sent a total of \$7797 in tax to the ATO. Has Richard paid too much tax or not enough? Calculate his refund or liability.

SOLUTION

a Gross income = \$54 600
Deductions = \$375
Taxable income = \$54 225

b Tax payable:
\$3572 + 0.325 × (\$54 225 – \$37 000)
= \$9170.13

c $\frac{2}{100} \times 54\,225 = \$1084.50$

d \$9170.13 + \$1084.50 = \$10 254.63

e $\frac{10\,254.63}{54\,225} \times 100 = 18.9\%$ (to 1 d.p.)

f Richard paid \$7797 in tax during the year.
He should have paid \$10 254.63.
Richard has not paid enough tax.
He must pay another \$2457.63 in tax.

EXPLANATION

a Taxable income = gross income – deductions

b Richard is in the middle tax bracket in the table, in which it says:
\$3572 plus 32.5c for each \$1 over \$37 000
Note: 32.5 cents is \$0.325.

c Medicare levy is 2% of the taxable income.
Round your answer to the nearest cent.

d This is the total amount of tax that Richard should have paid.

e This implies that Richard paid approximately 18.9% tax on every dollar. This is sometimes read as '18.9 cents in the dollar'.

f This is known as a shortfall or a liability. He will receive a letter from the ATO requesting payment of the difference.
\$10 254.63 – \$7797 = \$2457.63

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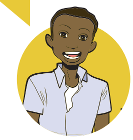
8 Lee has come to the end of her first financial year employed as a website developer. On June 30 she made the following notes about the financial year.

Gross income from employer	$58 725
Gross income from casual job	$7500
Interest on investments	$75
Donations	$250
Work-related expenses	$425
Tax paid during the financial year	$13 070

Taxable income = all incomes − deductions



- **a** Calculate Lee's taxable income.
- **b** Use the tax table shown in **Example 14** to calculate Lee's tax payable amount.
- **c** Lee must also pay the Medicare levy of 2% of her taxable income. How much is the Medicare levy?
- **d** Add the tax payable and the Medicare levy.
- **e** Express the total tax in part **d** as a percentage of Lee's taxable income, to 1 decimal place.
- **f** Has Lee paid too much tax or not enough? Calculate her refund or liability.

PROBLEM-SOLVING AND REASONING

9–13 | 9, 11–16

9 Alec's Medicare levy is $1750. This is 2% of his taxable income. What is his taxable income?

10 Tara is saving for an overseas trip. Her taxable income is usually about $20 000. She estimates that she will need $5000 for the trip, so she is going to do some extra work to raise the money. How much extra will Tara need to earn in order to save the extra $5000 after tax?

11 When Saled used the tax table to calculate his income tax payable, it turned out to be $22 782. What is his taxable income?

Use the tax table given in Example 14 to determine in which tax bracket Saled falls.

12 Explain the difference between gross income and taxable income.

13 Explain the difference between a tax refund and a tax liability.

14 Gordana looked at the last row of the tax table and said, "It is so unfair that people in that tax bracket must pay 45 cents in every dollar in tax." Explain why Gordana is incorrect.

15 Consider the tax tables for the two consecutive financial years. Note that the amounts listed first in each table is often called the tax-free threshold (i.e. the amount that a person can earn before they must pay tax).

2011/2012	
Taxable income	**Tax on this income**
0 – \$6000	Nil
\$6001 – \$37 000	15c for each \$1 over \$6000
\$37 001 – \$80 000	\$4650 plus 30c for each \$1 over \$37 000
\$80 001 – \$180 000	\$17 550 plus 37c for each \$1 over \$80 000
\$180 001 and over	\$54 550 plus 45c for each \$1 over \$180 000
2012/2013	
Taxable income	**Tax on this income**
0 – \$18 200	Nil
\$18 201 – \$37 000	19c for each \$1 over \$18 200
\$37001 – \$80 000	\$3572 plus 32.5c for each \$1 over \$37 000
\$80 001 – \$180 000	\$17 547 plus 37c for each \$1 over \$80 000
\$180 001 and over	\$54 547 plus 45c for each \$1 over \$180 000

a There are some significant changes between the financial years 2011/2012 and 2012/2013. Describe three of them.

b The following people had the same taxable income during both financial years. Find the difference and state whether they were advantaged or disadvantaged by the changes, or not affected at all?

i Ali: Taxable income = \$5000

ii Xi: Taxable income = \$15 000

iii Charlotte: Taxable income = \$30 000

iv Diego: Taxable income = \$50 000

16 Below is the 2012/2103 tax table for people who are not residents of Australia but are working in Australia.

Taxable income	Tax on this income
0 – \$80 000	32.5c for each \$1
\$80 001 – \$180 000	\$26 000 plus 37c for each \$1 over \$80 000
\$180 001 and over	\$63 000 plus 45c for each \$1 over \$180 000

Compare this table to the one in the example for Australian residents.

What difference would it make to the tax paid by these people in 2012/2013 if they were non-residents rather than residents?

a Ali: Taxable income = \$5000

b Xi: Taxable income = \$15 000

c Charlotte: Taxable income = \$30 000

d Diego: Taxable income = \$50 000

ENRICHMENT – 17

What are legitimate tax deductions?

17 a Choose an occupation or career in which you are interested. Imagine that you are working in that job. During the year you will need to keep receipts for items you have bought that are legitimate work-related expenses. Do some research on the internet and write down some of the things that you will be able to claim as work-related expenses in your chosen occupation.

b i Imagine your taxable income is \$80 000. What is your tax payable amount?

ii You just found a receipt for a \$100 donation to a registered charity. This decreases your taxable income by \$100. By how much does it decrease your tax payable amount?

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1E Using a budget to manage income and expenditure FRINGE

Once people have been paid their income for the week, fortnight or month, they must plan how to spend it. Most people work on a budget, allocating money for fixed expenses such as the mortgage or rent and the variable (i.e changing) expenses of petrol, food and clothing.

Let's start: Expenses for the month

Write down everything that you think your family would spend money on for **a** the week and **b** the month, and estimate how much those things might cost for the entire year. Where do you think savings could be made?

Key ideas

- Managing money for an individual is similar to operating a small business. Expenses can be divided into two areas:
  - **Fixed expenses**: Payment of loans, mortgages, regular bills etc.
  - **Variable expenses**: Clothing, entertainment, food etc. (These are estimates.)
- When your budget is completed, you should always check that your figures are reasonable estimates.
- By looking at these figures, you should be able to see how much money is remaining; this can be used as savings or to buy non-essential items.
- We often use percentages in budgets, so remember to change percentages to decimals by dividing by 100. For example: 12% = 0.12.

Fixed expenses Expenses that are set and do not change during a particular time period

Variable expenses Expenses that may change during a particular period of time, or over time

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Exercise 1E FRINGE

UNDERSTANDING AND FLUENCY		1–7	4–8

1 Binh has an income of $956 a week. His expenses, both fixed and variable, total $831.72 of his income. How much money can Binh save each week?

2 Roslyn has the following monthly expenses. Mortgage = $1458, mobile phone = $49, internet = $60, council rates = $350, water = $55, electricity = $190. What is the total of Roslyn's monthly expenses?

3 Last year, a households' four electricity bills were:
1st quarter = $550, 2nd quarter = $729, 3rd quarter = $497, 4th quarter = $661

Using these values as a guide, what should be the family budget, each week, for electricity for the following year? Round your answer to the nearest dollar.

Example 15 Budgeting using percentages

Fiona has a net annual income of $36 000 after deductions. She allocates her budget on a percentage basis.

	Mortgage	Car loan	Food	Education	Sundries	Savings
Expenses (%)	20	15	25	20	10	10

a Determine the amount of fixed expenses, including the mortgage, car loan and education.
b How much should Fiona save?
c Is the amount allocated for food reasonable?

SOLUTION	EXPLANATION
a Fixed expenses $= 55\%$ of $\$36\,000$ $= 0.55 \times 36\,000$ $= \$19\,800$	The mortgage, car and education loan are 55% in total. Change 55% to a decimal and multiply by the net income.
b Savings $= 10\%$ of $\$36\,000$ $= 0.1 \times 36\,000$ $= \$3600$	Savings are 10% of the budget. Change 10% to a decimal and multiply by the net income.
c Food $= 25\%$ of $\$36\,000$ $= 0.25 \times 36\,000$ $= \$9000$ per year, or $173 per week This seems reasonable.	Food is 25% of the budget. Change 25% to a decimal and calculate. Divide the yearly expenditure by 52 to make a decision on the reasonableness of your answer.

4 Paul has an annual income of $25 000 after deductions. He allocates his budget on a percentage basis.

	Mortgage	Car loan	Personal loan	Clothing	Food	Other
Expenses (%)	20	10	25	5	10	30

a Determine the amount of fixed expenses, including the mortgage and loans.
b How much should Paul have left over after the fixed expenses listed in his budget?
c Is the amount allocated for food reasonable?

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5 Lachlan has an income of \$468.30 per month. If he budgets 13% for clothes, how much will he actually have to spend on clothes?

Example 16 Budgeting using fixed values

Running a certain type of car involves yearly, monthly and weekly expenditure. Consider the following vehicle's costs.

• lease	\$210 per month
• registration	\$475 per year
• insurance	\$145 per quarter
• servicing	\$1800 per year
• petrol	\$37 per week

a Determine the overall cost to run this car for a year.

b What percentage of a \$70 000 budget would this be, correct to 1 decimal place?

SOLUTION	EXPLANATION
a Overall cost $= 210 \times 12$	Leasing cost: 12 months in a year
$+ \quad 475$	Registration cost
$+ \quad 145 \times 4$	Insurance cost: 4 quarters in a year
$+ \quad 1800$	Servicing cost
$+ \quad 37 \times 52$	Petrol cost: 52 weeks in a year
$= \$7299$	The overall cost is found by adding the individual totals.
The overall cost to run the car is \$7299.	
b $\% \text{ of budget} = \dfrac{7299}{70\,000} \times 100$	$\text{Percentage} = \dfrac{\text{car cost}}{\text{total budget}} \times 100$
$= 10.4\%$	Round your answer to 1 decimal place.

6 Lemona has the following expenses in her household budget.

- rent \$270 per week
- electricity \$550 per quarter
- phone and internet \$109 per month
- car \$90 per week
- food \$170 per week
- insurance \$2000 a year

a Determine the overall cost for running the household for a year.

b What percentage of Lemona's net annual salary of \$45 000 would this be, correct to 1 decimal place?

Use 52 weeks in a year, 12 months in a year and 4 quarters in a year.

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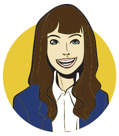
7 The costs of sending a student to Modkin Private College are as follows.

- fees per term (4 terms) \$1270
- subject levies per year \$489
- building fund per week \$35
- uniforms and books per year \$367

a Determine the overall cost per year.

b If the school bills twice a year, covering all the items above, what would be the amount of each payment?

c How much should be saved per week to make the bi-annual payments?



'Bi-annual' means twice yearly.

8 The owner of a small business has the following expenses to budget for.

- rent \$1400 a month
- phone line \$59 a month
- wages \$1200 a week
- electricity \$430 a quarter
- water \$120 a quarter
- insurance \$50 a month

a What is the annual budget for the small business?

b How much does the business owner need to make each week just to break even?

c If the business earns \$5000 a week, what percentage of this needs to be spent on wages?

PROBLEM-SOLVING AND REASONING

9–12 11–15

9 Francine's petrol budget is \$47 from her weekly income of \$350.

a What percentage of her budget is this? Give your answer to 2 decimal places.

b If petrol costs \$1.59 a litre, how many litres of petrol, correct to 2 decimal places, is Francine budgeting for in a week?

10 Grant works a 34-hour week at \$15.50 per hour. His net income is 65% of his gross income.

a Determine his net weekly income.

b If Grant spends 12% of his net income on entertainment, determine the amount he actually spends per year.

c Grant saves \$40 per week. What percentage of his net income is this (to 2 decimal places)?

11 Dario earns \$432 per fortnight at a take-away pizza shop. He budgets 20% for food, 10% for recreation, 13% for transport, 20% for savings, 25% for taxation and 12% for clothing.

a Determine the actual amount budgeted for each category every fortnight.

Dario's wage increases by 30%.

b Determine how much he would now save each week.

c What percentage increase is this on the original amount saved?

d Determine the extra amount of money Dario saves per year after his wage increase.

e If transport is a fixed expense, its percentage of Dario's budget will change. Determine the new percentage.

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Example 17 Calculating best buys

Soft drink is sold in three convenient packs at the local store:

- carton of 36 (375 mL) cans at $22.50
- a six-pack of (375 mL) cans at $5.00
- 2-litre bottles at $2.80

Determine the cheapest way to buy the soft drink.

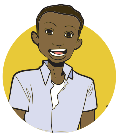
SOLUTION	EXPLANATION
Buying by the carton: Cost = $22.50 ÷ (36 × 375) = $0.0017 per mL	Total mL = 36 × 375 Divide to work out the cost per mL.
Buying by the six-pack: Cost = $5 ÷ (6 × 375) = $0.0022 per mL	Total mL = 6 × 375
Buying by the bottle: Cost = $2.80 ÷ 2000 = $0.0014 per mL	Total mL = 2 × 1000, since 1 L = 1000 mL.
∴ The cheapest way to buy the soft drink is to buy the 2-litre bottle.	Compare the three costs per mL.

12 Tea bags can be purchased from the supermarket in three forms:

- 25 tea bags at $2.36
- 50 tea bags at $4.80
- 200 tea bags at $15.00

What is the cheapest way to buy tea bags?

Find the cost per tea bag for each.



13 A weekly train ticket costs $16. A daily ticket costs $3.60. If you are going to work only 4 days next week, is it cheaper to buy one ticket per day or a weekly ticket?

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14 A holiday resort offers its rooms at the following rates.

$87 per night	(Monday–Thursday)
$187 for a weekend	(Friday and Saturday)
$500 per week	

a Determine the nightly rate in each case.
b Which price is the best value?

15 Tomato sauce is priced at:

- 200 mL bottle $2.35
- 500 mL bottle $5.24

a Find the cost per mL of the tomato sauce in each case.
b Which is the cheapest way to buy tomato sauce?
c What would be the cost of 200 mL at the 500 mL rate?
d How much would be saved by buying the 200 mL bottle at this rate?
e Suggest why the 200 mL bottle is not sold at this price.

ENRICHMENT

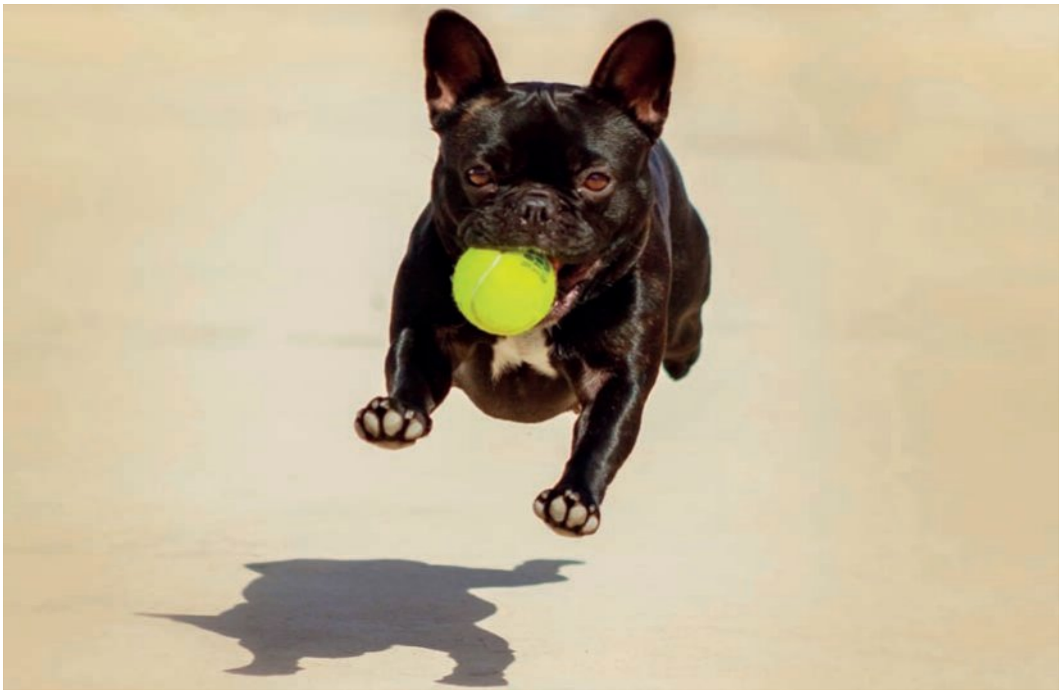
–	16

Tennis ball savings

16 Safeserve has a sale on tennis balls for 1 month. If you buy:

- 1 container, it costs $5
- 6 containers, it costs $28
- 12 containers, it costs $40
- 24 containers, it costs $60

If you need 90 containers for your club to have enough for a season, determine:
a the minimum cost if you buy exactly 90 containers
b the overall minimum cost, and the number of extra containers you will have in this situation



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1F Simple interest

Interactive

Widgets

HOTsheets

Walkthrough

Borrowed or invested money usually has an associated interest rate. The consumer needs to establish the type of interest they are paying and the effects it has on the amount borrowed or invested over time. Some loans or investments deliver the full amount of interest using only the initial loan or investment amount in the interest calculations. These types are said to use simple interest.

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let’s start: How long to invest?

Tom and Brittney each have $200 in their bank accounts. Tom earns $10 a year in interest. Brittney earns 10% p.a., simple interest.

For how long must each of them invest their money for it to double in value?

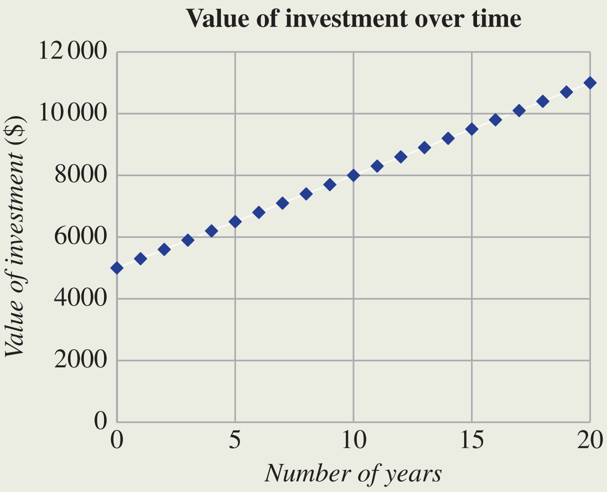
Key ideas

- The terms needed to understand **simple interest** are:
  - **principal (*P*)**: The amount of money borrowed or invested
  - **rate of interest (*R*)**: The annual (yearly) percentage rate of interest (e.g. 3% p.a.)
  - time periods (N): This is usually the number of years
  - interest (I): The amount of interest accrued over a given time.
- The formula for calculating simple interest is:

  $I = PRN$

  I = amount of interest
  P = principal (the initial amount borrowed or invested)
  R = interest rate per period, expressed as a decimal
  N = number of periods
- The graph on the right shows an investment of $5000 growing with 6% p.a. simple interest, which is a linear relationship.
- In the graph, the interest earned is $300 per year. The points in the graph can be generated on a calculator:

  Enter the number 5000, then press $\boxed{=}$.
  Add 300.
  Press $\boxed{=}$ $\boxed{=}$ $\boxed{=}$ $\boxed{=}$ etc.



Simple interest A type of interest that is paid on a loan or earned on an investment, which is always calculated on the principal amount loaned or invested

Principal (*P*) An amount of money invested in a financial institution or loaned to a person/business

Rate of interest (*R*) The annual percentage rate of interest paid or earned on a loan or investment

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Exercise 1F

UNDERSTANDING AND FLUENCY

1–5	4–7

1 Copy and complete:

- **a** 12 months = ________ year
- **b** $\frac{1}{2}$ year = ________ months
- **c** ______ weeks = 1 year
- **d** _____ quarters = 1 year
- **e** 1 quarter = ______ months
- **f** $2\frac{1}{2}$ years = _______ months

2 Interest on a loan is fixed at \$60 a year. How much interest is due in:

- **a** 2 years?
- **b** 7 years?
- **c** 6 months?

3 Simple interest on \$7000 is 6% p.a. How much interest is earned in:

- **a** 1 year?
- **b** 2 years?
- **c** 1 month?

Example 18 Using the simple interest formula

Use the simple interest formula, $I = PRN$, to find:

- **a** the interest (I) when \$600 is invested at 8% p.a. for 18 months
- **b** the annual interest rate (R) when \$5000 earns \$150 interest in 2 years

SOLUTION	EXPLANATION
a $P = 600$ $R = 8 \div 100 = 0.08$	Write out the information that you know and the formula.
$N = 18 \text{ months} = \frac{18}{12} = 1.5 \text{ years}$	Express the rate as a decimal (or fraction).
$I = PRN$ $= 600 \times 0.08 \times 1.5$ $= 72$	Substitute into the formula using years for N.
The interest is \$72 in 18 months.	
b $P = 5000$ $I = 150$ $N = 2$ years $I = PRN$	Write the formula and the information known.
$150 = 5000 \times R \times 2$ $150 = 10\,000R$ $R = 150 \div 10\,000 = 0.015$	Substitute the values into the formula and solve the equation to find R.
The simple interest rate is 1.5% per year.	Write the rate as a percentage (i.e. × 100).

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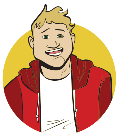
4 Copy and complete this table of values for I, P, R and N.

	P	R	N	I
a	\$700	5% p.a.	4 years	
b	\$2000	7% p.a.	3 years	
c	\$3500	3% p.a.	22 months	
d	\$750	$2\frac{1}{2}$% p.a.	30 months	
e	\$22 500		3 years	\$2025
f	\$1770		5 years	\$354

Recall:
$I = PRN$
N must be years if rate is p.a.



Example 19 Calculating repayments with simple interest

\$3000 is borrowed at 12% p.a. simple interest for 2 years.

a What is the total amount owed over the 2 years?

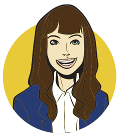
b If repayments of the loan are made monthly, how much would each payment need to be?

SOLUTION	EXPLANATION
a $P = \$3000, R = 12 \div 100 = 0.12, N = 2$	List the information you know.
$I = PRN$	Write the formula.
$= 3000 \times 0.12 \times 2$ $= \$720$	Substitute the values and evaluate.
Total amount $= \$3000 + \$720$ $= \$3720$	Total amount is the original amount *plus* the interest.
b Amount of each payment $= 3720 \div 24$ $= \$155$ per month	2 years = 24 months, so there are 24 payments to be made. Divide the total by 24.

5 \$5000 is borrowed at 11% p.a. simple interest for 3 years.

- **a** What is the total amount owed over the 3 years?
- **b** If repayments of the loan are made monthly, how much would each payment need to be?

Calculate the interest first.



6 Under hire purchase, John bought a new car for \$11 500. He paid no deposit and decided to pay the loan off in 7 years. If the simple interest was at 6.45%, determine:

- **a** the total interest paid
- **b** the total amount of the repayment
- **c** the payments per month

7 \$10 000 is borrowed to buy a second-hand BMW. The interest is calculated at a simple interest rate of 19% p.a. over 4 years.

- **a** What is the total interest on the loan?
- **b** How much is to be repaid?
- **c** What is the monthly repayment on this loan?

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PROBLEM-SOLVING AND REASONING

8–10 10–13

8 Rebecca invests $4000 for 3 years at 5.7% p.a. simple interest paid yearly.

a How much interest will she receive in the first year?

b What is the total amount of interest Rebecca will receive over the 3 years?

c How much money will Rebecca have after the 3-year investment?

9 How much interest will Giorgio receive if he invests $7000 in stocks at 3.6% p.a. simple interest for 4 years?

10 An investment of $15 000 receives an interest payment over 3 years of $7200. What was the rate of simple interest per annum?

11 Jonathon wishes to invest $3000 at 8% per annum. How long will he need to invest for his total investment to double?

Substitute into the formula $I - PRN$ and solve the remaining equation.

12 Jakob wishes to invest some money for 5 years at 4.5% p.a. paid yearly. If he wishes to receive $3000 in interest payments per year, how much should he invest? Round to the nearest dollar.

13 Gretta's interest payment on her loan totalled $1875. If the interest rate was 5% p.a. and the loan had a life of 5 years, what amount did she borrow?

ENRICHMENT

– 14

Which way is best?

14 A shed manufacturer offers finance with a rate of 3.5% p.a. paid at the end of 5 years with a deposit of 10%, or a rate of 6.4% p.a. repaid over 3 years with a deposit of 20%.

Christine and Donald decide to purchase a fully erected 4 m^2 shed for $12 500.

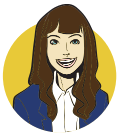
a How much deposit will they need to pay in each case?

b What is the total interest they will incur in each case?

c If they decided to pay per month, what would be their monthly repayment?

d Discuss the benefits of the different types of purchasing methods.

In part **b**, don't forget to take off the deposit before calculating the interest.



1G Compound interest and depreciation

Interactive
Widgets
HOTsheets
Walkthrough

Simple interest is always calculated using the amount invested or borrowed, so the amount of interest earned or charged is the same every year.

In this section, you will see that compound interest on an investment is calculated so that you earn interest on your interest.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: I want to double my money faster!

As noted in Section 1E, Sophie has $100 invested but she would like to have $200.
In this scenario, her investment increases every year by 10% of the **value at the end of the previous year**.

- By how much will her investment increase in the first year?
- How much will her investment be worth at the end of the first year?
- By how much will her investment increase in the second year?
- By how much will her investment increase in the third year?
- Copy and complete the following table.

Year	0	1	2	3	4	5	6	7	8	9	10
Amount	$100	$110									

- How long will it take Sophie to reach her goal?
- How long will it take if her investment increases by 5% every year?
- How long will it take if her investment increases by 7.5% every year?
- How long will it take if her investment increases by 5% every year for the first 5 years, then 6% every year thereafter?

Key ideas

- **Compound interest** is calculated on the current value of an investment (i.e. not the original value).
- The amount of simple interest stays the same for each period. In contrast, the amount of compound interest grows because you earn interest on your interest.

Compound interest A type of interest that is paid on a loan or earned on an investment, which is calculated not only on the initial principal, but also on the interest accumulated during the loan/ investment period

- The table below compares simple interest and compound interest on the same investment.

Simple Interest 6% p.a.			
Year	Opening Balance	Interest	Closing Balance
2012	$5000.00	$300.00	$5300.00
2013	$5300.00	$300.00	$5600.00
2014	$5600.00	$300.00	$5900.00
2015	$5900.00	$300.00	$6200.00
2016	$6200.00	$300.00	$6500.00

Compound Interest 6% p.a.			
Year	Opening Balance	Interest	Closing Balance
2012	$5000.00	$300.00	$5300.00
2013	$5300.00	$318.00	$5618.00
2014	$5618.00	$337.08	$5955.08
2015	$5955.08	$357.30	$6312.38
2016	$6312.38	$378.74	$6691.13

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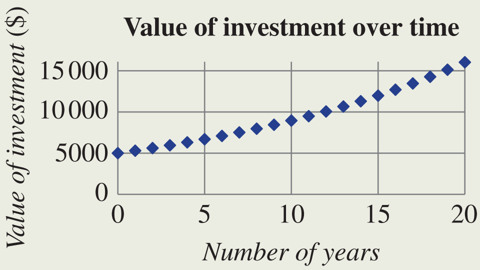
Key ideas

- For compound interest: the numbers in the right-hand table above can be generated on a calculator:
  Enter the number 5000, then press $\boxed{=}$.
  100% plus 6% = 106% = 1.06, so multiply by 1.06.
  Press $\boxed{=}\boxed{=}\boxed{=}\boxed{=}$ etc.
- The final value also can be calculated as 5000×1.06^5.
- To calculate the amount of compound interest earned, subtract the original value from the final value. In the example above:
  Amount of compound interest = \$6691.13 − \$5000 = \$1691.13
- The graph below shows an investment of \$5000 growing as it earns interest of 6% per annum, compounding annually. This is a non-linear relationship. The value of the investment grows exponentially.



- The final value of a compound interest investment can be calculated using the formula

$$A = P(1 + R)^n$$

where A = the final value of the investment
P = the principal (i.e. the amount invested)
R = the interest rate per period, expressed as a decimal
n = the number of compounding periods

- Amount of compound interest = $A - P$
- **Depreciation** is the reverse situation, in which the value of an object decreases by a percentage year after year.
  For example: A \$1000 computer loses 30% in value every year.
  Year 1: \$1000 − (30% of \$1000) = \$700
  Year 2: \$700 − (30% of \$700) = \$490

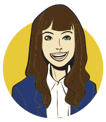
Depreciation A process through which an item loses value every year

Exercise 1G

UNDERSTANDING AND FLUENCY	1–4, 6, 8	5, 6, 7(½), 8

1 Consider \$500 invested at 10% p.a. compounded annually.
  a How much interest is earned in the first year?
  b What is the balance of the account once the first year's interest is added?
  c How much interest is earned in the second year?
  d What is the balance of the account at the end of the second year?
  e Use your calculator to work out $500(1.1)^2$.

For the second year, you need to use \$500 plus the interest from the first year.



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2 Find the value of the following, correct to 2 decimal places.

a $\$1000 \times 1.05 \times 1.05$ **b** $\$1000 \times 1.05^2$

c $\$1000 \times 1.05 \times 1.05 \times 1.05$ **d** $\$1000 \times 1.05^3$

3 Fill in the missing numbers.

a \$700 invested at 8% p.a. compounded annually for 2 years.

$A = \square(1.08)^{\square}$

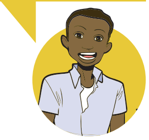
b \$1000 invested at 15% p.a. compounded annually for 6 years.

$A = 1000(\square)^6$

c \$850 invested at 6% p.a. compounded annually for 4 years.

$A = 850(\square)^{\square}$

For compound interest, $A = P(1 + R)^n$



15% as a decimal is 0.15.

Example 20 Converting rates and time periods

Calculate the number of periods and the rates of interest offered per period for the following.

a 6% p.a. over 4 years paid monthly **b** 18% p.a. over 3 years paid quarterly

SOLUTION	EXPLANATION
a $n = 4 \times 12$	4 years is the same as 48 months, as 12 months $= 1$ year.
$= 48$	6% p.a. $=$ 6% in 1 year.
$R = 6 \div 12 \div 100$	Divide by 12 to find the monthly rate.
$= 0.005$	Divide by 100 to convert the percentage to a decimal.
c $n = 3 \times 4$ $= 12$	There are 4 quarters in 1 year; hence, there are 12 quarters in 3 years.
$R = 18 \div 4 \div 100$ $= 0.045$	Divide by 100 to convert the percentage to a decimal.

4 Calculate the number of periods (n) and the rates of interest (R) offered per period for the following. (Round the interest rate to 5 decimal places where necessary.)

a 6% p.a. over 3 years paid bi-annually

b 12% p.a. over 5 years paid monthly

c 4.5% p.a. over 2 years paid fortnightly

d 10.5% p.a. over 3.5 years paid quarterly

e 15% p.a. over 8 years paid quarterly

f 9.6% p.a. over 10 years paid monthly

'Bi-annually' means twice a year.
26 fortnights $= 1$ year

5 **a** By considering an investment of \$4000 at 5% p.a. compounded annually, copy and complete the table shown.

b Repeat question **5a** for a \$4000 car which loses 5% p.a.

Year	Amount ($)	Interest ($)	New amount ($)
1	4000	200	4200
2	4200		
3			
4			
5			

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Example 21 Using the compound interest formula

Determine the amount after 5 years if \$4000 is compounded annually at 8%.

SOLUTION	EXPLANATION
$P = 4000,\ n = 5,\ R = 0.08$	List the values for the terms you know.
$A = P(1 + R)^n$	Write the formula.
$= 4000(1 + 0.08)^5$	Substitute the values.
$= 4000(1.08)^5$	Simplify and evaluate using a calculator.
$= \$5877.31$	Write your answer to the nearest cent.

6 Determine the amount after 5 years if:

- **a** \$4000 is compounded annually at 5%
- **b** \$8000 is compounded annually at 8.35%
- **c** \$6500 is compounded annually at 16%
- **d** \$6500 is compounded annually at 8%

$A = P(1 + R)^n$

7 Determine the amount if \$100 000 is compounded annually at 6% for:

- **a** 1 year
- **b** 2 years
- **c** 3 years
- **d** 5 years
- **e** 10 years
- **f** 15 years

Example 22 Finding compounded amounts using months

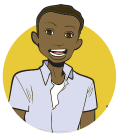
Tony's investment of \$4000 is compounded at 8.4% p.a. over 5 years. Determine the amount he will have after 5 years if the interest is paid monthly.

SOLUTION	EXPLANATION
$P = 4000$	List the values of the terms you know.
$n = 5 \times 12$ $= 60$	Convert the time in years to the number of periods (in this question, months). 60 months = 5 years.
$R = 8.4 \div 12 \div 100$ $= 0.007$	Convert the rate per year to the rate per period (months) by dividing by 12. Then divide by 100 to make a decimal.
$A = P(1 + R)^n$	Write the formula.
$= 4000(1 + 0.007)^{60}$	Substitute the values.
$= 4000(1.007)^{60}$ $= \$6078.95$	Simplify and evaluate.

8 Calculate the value of the following investments if interest is compounded monthly.

- **a** \$2000 at 6% p.a. for 2 years
- **b** \$34 000 at 24% p.a. for 4 years
- **c** \$350 at 18% p.a. for 8 years
- **d** \$670 at 6.6% p.a. for $2\frac{1}{2}$ years
- **e** \$250 at 7.2% p.a. for 12 years

Convert years to months and the annual rate to the monthly rate.



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PROBLEM-SOLVING AND REASONING 9–11 10–13

9 A car worth $20000 loses 15% in value every year. How much will it be worth at the end of 5 years?

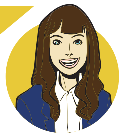
10 Explain why the car discussed in Question **9** will never have a value of $0.

Use $A = P(1 - R)^n$, where $R = 0.15$.

11 **a** Calculate the amount of compound interest paid on $8000 at the end of 3 years for each rate below.

- **i** 12% compounded annually
- **ii** 12% compounded bi-annually (twice a year)
- **iii** 12% compounded monthly
- **iv** 12% compounded weekly
- **v** 12% compounded daily

b What is the interest difference between annual and daily compounding in this case?



Remember: 1 year = 365 days

12 Sophie does the following calculation for a 5-year investment that she is considering: $3000(1.04)^{10}$.

a How much is she considering investing?

b How many times per year will the interest be compounded?

c What is the annual interest rate, as a percentage?

d At the end of the 5-year term, how much interest will she earn?

13 Paula needs to decide whether to invest her $13500 for 6 years at 4.2% p.a. compounded monthly or 5.3% compounded bi-annually. Decide which investment would be the best for Paula.

ENRICHMENT – 14

Double your money

14 You have $100000 to invest and wish to double that amount. Use trial and error in the following.

a Determine, to the nearest whole number of years, the length of time it will take to do this using the compound interest formula at rates of:

- **i** 12% p.a.
- **ii** 6% p.a.
- **iii** 8% p.a.
- **iv** 16% p.a.
- **v** 10% p.a.
- **vi** 20% p.a.

b If the amount of investment is $200000 and you wish to double it, determine the time it will take using the same interest rates as above.

c Are the lengths of time to double your investment the same in part **a** and part **b**?

1H Investments and loans

Interactive
Widgets
HOTsheets
Walkthrough

When you borrow money, interest is charged, and when you invest money, interest is earned. When you invest money, the institution in which you invest (e.g. bank or credit union) pays you interest. However, when you borrow money, the institution from which you borrow charges you interest, so that you must pay back the money you initially borrowed, plus the interest.

Credit cards charge high rates of interest if the full amount owing is not paid off every month.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Credit card statements

Refer to Allan's credit card statement below.

a How many days were there between the closing balance and the due date?

b What is the minimum payment due?

c If Allan pays only the minimum, on what balance is the interest charged?

d How much interest is charged if Allan pays $475.23 on 25/5?

Statement Issue Date: 2/5/18		
Date of purchase	**Details**	**Amount**
3/4/18	Opening balance	314.79
5/4/18	Dean's Jeans	59.95
16/4/18	Tyre Warehouse	138.50
22/4/18	Payment made—thank you	−100.00
27/4/18	Cottonworth's Grocery Store	58.64
30/4/18	Interest charges	3.35
2/5/18	Closing balance	475.23
Percentage rate 18.95%	**Due date** 25/5/18	**Min. payment** 23.75

Key ideas

- Interest rates are associated with many loan and savings accounts.
- Bank accounts:
  - accrue interest each month on the minimum monthly balance
  - incur account-keeping fees each month
- **Loans** (money borrowed) have interest charged to them on the amount left owing (balance).
- **Repayments** are amounts paid to the bank, usually each month, to repay a loan plus interest within an agreed time period.

Loan Money borrowed and then repaid, usually with interest

Repayment An amount paid to a financial institution at regular intervals to repay a loan, with interest included

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Exercise 1H

UNDERSTANDING AND FLUENCY	1–4, 6–8	4–9

1 Donna can afford to repay \$220 a month. How much does she repay over:
- **a** 1 year?
- **b** 18 months?
- **c** 5 years?

2 Sarah buys a new bed on an ‘interest-free’ offer. No interest is charged if she pays for the bed in 2 years. Sarah’s bed costs \$2490 and she pays it back in 20 months in 20 equal instalments. How much is each instalment?

3 A bank pays 0.3% interest on the minimum monthly balance in an account. Determine the interest due on accounts with the following minimum monthly balances.
- **a** \$400
- **b** \$570
- **c** \$1000
- **d** \$29.55

Example 23 Repaying a loan

Wendy takes out a personal loan of \$7000 to fund her trip to South Africa. Repayments are made monthly for 3 years at \$275 a month. Find:
- **a** the total cost of Wendy’s trip
- **b** the interest charged on the loan

SOLUTION	EXPLANATION
a Total cost $= \$275 \times 36$	3 years $= 3 \times 12 = 36$ months
$= \$9900$	Cost = 36 lots of \$275
b Interest $= \$9900 - \$7000$	Interest = total paid − amount borrowed
$= \$2900$	

4 Jason has a personal loan of \$10 000. He is repaying the loan over 5 years. The monthly repayment is \$310.
- **a** Calculate the total amount Jason repays over the 5-year loan.
- **b** How much interest is he charged?

5 Robert borrows \$5500 to buy a second-hand car. He repays the loan in 36 equal monthly instalments of \$155.
- **a** Calculate the total cost of the loan.
- **b** How much interest does Robert pay?

6 Alma borrows \$250 000 to buy a house. The repayments are \$1736 a month for 30 years.
- **a** How many repayments does Alma make?
- **b** What is the total amount Alma pays for the house?
- **c** How much interest is paid over the 30 years?

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Example 24 Paying off a purchase

Harry buys a new \$2100 computer on the following terms.

- 20% deposit
- monthly repayments of \$90 for 2 years

Find:

a the deposit paid

b the total amount paid for the computer

c the interest charged

SOLUTION	EXPLANATION
a Deposit $= 0.2 \times 2100$ $= \$420$	Find 20% of 2100.
b Repayments $= \$90 \times 24$ $= \$2160$ Total paid $= \$2160 + \$420$ $= \$2580$	2 years = 24 months Repay 24 lots of \$90. Repay = repayments + deposit
c Interest $= \$2580 - \$2100$ $= \$480$	Interest = total paid − original price

7 George buys a car marked at \$12 750 on the terms 20% deposit and 36 monthly repayments of \$295.

a Calculate the deposit.

b How much is owed after the deposit is paid?

c Find the total of all the repayments.

d Find the cost of buying the car on those terms.

e Find the interest George pays on these terms.

Example 25 Calculating interest

An account has a minimum monthly balance of \$200 and interest is credited on this amount monthly at 1.5%.

a Determine the amount of interest to be credited at the end of the month.

b If the bank charges a fixed administration fee of \$5 per month and other fees totalling \$1.07, what will be the net amount credited or debited to the account at the end of the month?

SOLUTION	EXPLANATION
a Interest $= 1.5\%$ of \$200 $= 0.015 \times 200$ $= \$3$	Interest is 1.5% per month. Change 1.5% to a decimal and calculate.
b Net amount $= 3 - (5 + 1.07)$ $= -3.07$ \$3.07 will be debited from the account.	Subtract the deductions from the interest. A negative amount is called a debit.

8 A bank account has a minimum monthly balance of \$300 and interest is credited monthly at 1.5%.

a Determine the amount of interest to be credited each month.

b If the bank charges a fixed administration fee of \$3 per month and fees of \$0.24, what will be the net amount credited to the account at the end of the month?

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9 An account has no administration fee. The monthly balances for May–October are in the table below. If the interest payable on the minimum monthly balance is 1%, how much interest will be added:

a for each separate month? **b** over the 6-month period?

May	June	July	August	September	October
$240	$300	$12	$500	$208	$73

PROBLEM-SOLVING AND REASONING 10–12 13–15

10 Supersound offers two deals on a sound system worth $7500.

- Deal A: no deposit, interest free and nothing to pay for 18 months
- Deal B: 15% off for cash

a Thomas chooses deal A. Find:

  i the deposit he must pay

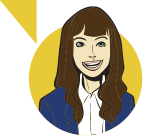
  ii the interest charged

  iii the total cost if Thomas pays the system off within the 18 months

b Phil chooses deal B. What does Phil pay for the same sound system?

c How much does Phil save by paying cash?

15% off is 85% of the original amount.



11 Camden Finance Company charges 35% flat interest on all loans.

a Mei borrows $15 000 from Camden Finance over 6 years.

  i Calculate the interest on the loan.

  ii What is the total amount repaid (loan + interest)?

  iii What is the value of each monthly repayment?

b Lancelle borrows $24 000 from the same company over 10 years.

  i Calculate the interest on her loan.

  ii What is the total amount repaid?

  iii What is the value of each monthly instalment?

12 A list of transactions that Suresh made over a 1-month period is shown below. The bank calculates interest *daily* at 0.01% and adds the total to the account balance at the end of this period. It has an administrative fee of $7 per month and other fees over this time total $0.35.

a Copy the table and complete the balance column.

b Determine the amount of interest added over this month.

c Determine the final balance after all calculations have been made.

d Suggest what the regular deposits might be for.

In part **b**, interest is calculated on the end-of-the-day balance.

Date	Deposit	Withdrawal	Balance
1 May			$3010
3 May	$490		
5 May		$2300	
17 May	$490		
18 May		$150	
20 May		$50	
25 May		$218	
31 May	$490		

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13 The table below shows the interest and monthly repayments on loans when the simple interest rate is 8.5% p.a.

a Use the table to find the monthly repayments for a loan of:

i \$1500 over 2 years **ii** \$2000 over 3 years **iii** \$1200 over 18 months

b Damien and his wife Lisa can afford monthly repayments of \$60. What is the most they can borrow and on what terms?

	18-month term		24-month term		36-month term	
Loan amount (\$)	Interest (\$)	Monthly payments (\$)	Interest (\$)	Monthly payments (\$)	Interest (\$)	Monthly payments (\$)
1000	127.50	62.64	170.00	48.75	255.00	34.86
1100	140.25	68.90	187.00	53.63	280.50	38.35
1200	153.00	75.17	204.00	58.50	306.00	41.83
1300	165.75	81.43	221.00	63.38	331.50	45.32
1400	178.50	87.69	238.00	68.25	357.00	48.81
1500	191.25	93.96	255.00	73.13	382.50	52.29
1600	204.00	100.22	272.00	78.00	408.00	55.78
1700	216.75	106.49	289.00	82.88	433.50	59.26
1800	229.50	112.75	306.00	87.75	459.00	62.75
1900	242.25	119.01	323.00	92.63	484.50	66.24
2000	255.00	125.28	340.00	97.50	510.00	69.72

14 Part of a credit card statement is shown here.

understanding your account

CLOSING BALANCE **\$403.80**	CLOSING BALANCE This is the amount you owe at the end of the statement period.
MINIMUM PAYMENT DUE **\$10.00**	MINIMUM PAYMENT DUE This is the minimum payment that must be made towards this account.
PAYABLE TO MINIMISE FURTHER INTEREST CHARGES **\$403.80**	PAYABLE TO MINIMISE FURTHER INTEREST CHARGES This amount you must pay to minimise interest charges for the next statement period.

a What is the closing balance?

b What is due on the credit card if only the minimum payment is made on the due date?

c This credit card charges 21.9% p.a. interest calculated daily on the unpaid balances. To find the daily interest, the company multiplies this balance by 0.0006. What does it cost in interest per day if only the minimum payment is made?

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15 Loans usually involve an establishment fee to set up the loan and an interest rate calculated monthly on your balance. You make a monthly or fortnightly payment, which reduces the balance. Bank fees also apply.

Consider the period for the loan statement shown below.

a What is the opening balance for this statement?
b What is the administrative fee charged by the bank for each transaction?
c What is the regular fee charged by the bank for servicing the loan?
d If the term of the loan is 25 years, what will be the total servicing fees charged by the bank?
e What is the regular fortnightly payment made?
f What will be the total fortnightly payments made over the term of the 25-year loan?

Complete Home Loan Transactions – Account number 33164000

Date	Transaction description	Debits	Credits	Balance
	Balance brought forward from previous page			98822.90 Dr
15 Oct	Repayment/Payment		378.50	
	Administrative fee	0.23		98444.63 Dr
24 Oct	Interest charged	531.88		98976.51 Dr
24 Oct	Fee for servicing your loan	8.00		98984.51 Dr
29 Oct	Repayment/Payment		378.50	
	Administrative fee	0.23		98606.24 Dr
12 Nov	Repayment/Payment		378.50	
	Administrative fee	0.23		98227.97 Dr
24 Nov	Interest charged	548.07		98776.04 Dr
24 Nov	Fee for servicing your loan	8.00		98784.04 Dr
26 Nov	Repayment/Payment		378.50	
	Administrative fee	0.23		98405.77 Dr
	→ Change in interest rate on 03/12/18 to 06.800% per annum			
10 Dec	Repayment/Payment		378.50	
	Administrative fee	0.23		98027.50 Dr
24 Dec	Interest charged	543.08		98570.58 Dr
24 Dec	Fee for servicing your loan	8.00		98578.58 Dr
24 Dec	Repayment/Payment		378.50	
	Administrative fee	0.23		98200.31 Dr
31 Dec	Closing balance			98200.31 Dr

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ENRICHMENT – 16

Reducing the balance of loans (a spreadsheet approach)

When you take out a loan from a lending institution you will be asked to make regular payments (usually monthly) for a certain period of time to repay the loan completely. The larger the repayment, the shorter the term of the loan.

Loans work mostly on a reducing balance and you can find out how much balance is owing at the end of each month from a statement, which is issued on a regular basis.

Let's look at an example of how the balance is reducing.

If you borrow \$15 000 at 17% p.a. and make repayments of \$260 per month, at the end of the first month your statement would be calculated as shown at the right.

$$\begin{aligned}\text{Interest due} &= \frac{15\,000 \times 0.17}{12}\\ &= \$212.50\\ \text{Repayment} &= \$260\\ \text{Amount owing} &= \$15\,000 + \$212.50 - \$260\\ &= \$14952.50\end{aligned}$$

This process would be repeated for the next month:

$$\begin{aligned}\text{Interest due} &= \frac{14952.50 \times 0.17}{12}\\ &= \$211.83\\ \text{Repayment} &= \$260\\ \text{Amount owing} &= \$14952.50 + \$211.83 - \$260\\ &= \$14904.33\end{aligned}$$

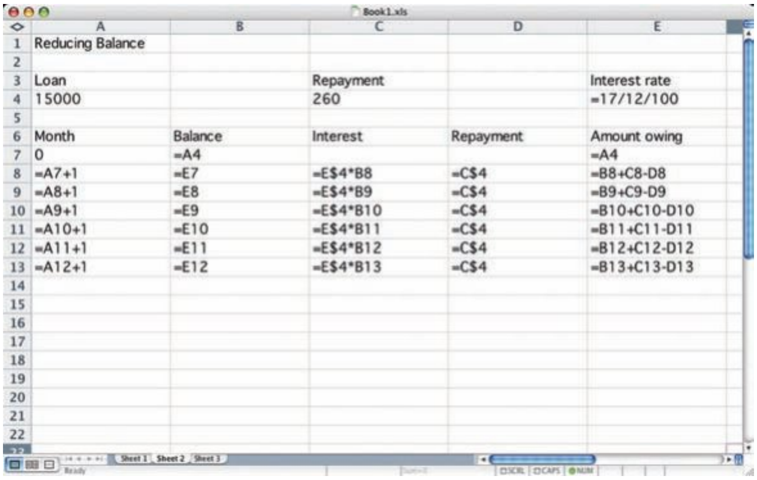
As you can see, the amount owing is decreasing and so is the interest owed each month. Meanwhile, more of your repayment is actually reducing the balance of the loan.

A statement might look like this:

Balance	Interest	Repayment	Amount owing
15 000	212.50	260	14 952.50
14 952.50	211.83	260	14 904.33
14 904.33	211.14	260	14 855.47
14 855.47	210.45	260	14 805.92
14 805.92	209.75	260	14 755.67

16 Check to see that all the calculations are correct on the statement above.

As this process is repetitive, the calculations are best done by means of a spreadsheet. To create a spreadsheet for the process, copy the following, extending your sheet to cover 5 years.



Book1.xls

	A	B	C	D	E
1	Reducing Balance				
2					
3	Loan		Repayment		Interest rate
4	15000		260		=17/12/100
5					
6	Month	Balance	Interest	Repayment	Amount owing
7	0	=A4			=A4
8	=A7+1	=E7	=E$4*B8	=C$4	=B8+C8-D8
9	=A8+1	=E8	=E$4*B9	=C$4	=B9+C9-D9
10	=A9+1	=E9	=E$4*B10	=C$4	=B10+C10-D10
11	=A10+1	=E10	=E$4*B11	=C$4	=B11+C11-D11
12	=A11+1	=E11	=E$4*B12	=C$4	=B12+C12-D12
13	=A12+1	=E12	=E$4*B13	=C$4	=B13+C13-D13
14					
15					
16					
17					
18					
19					
20					
21					
22					

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1I Comparing interest using technology

Interactive

Widgets

HOTsheets

Walkthrough

In the following exercise we compare compound and simple interest and look at their applications in the banking world. You are expected to use technology to its best advantage when solving the problems in this section.

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

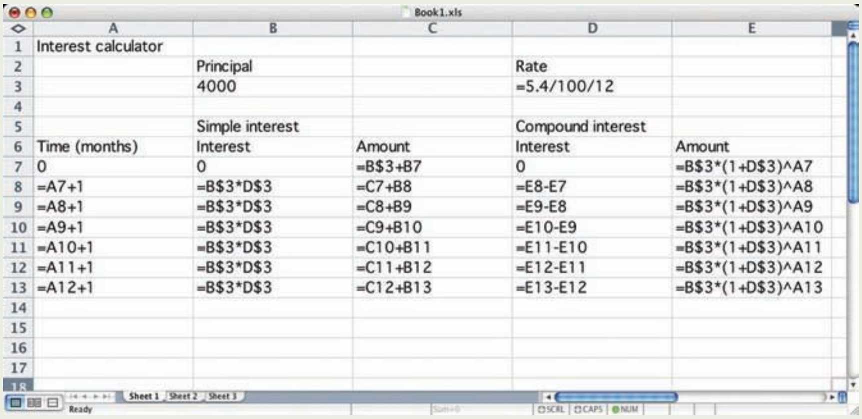
Let's start: Who earns the most?

- Ceanna invests \$500 at 8% p.a. compounded monthly over 3 years.
- Huxley invests \$500 at 10% p.a. compounded annually over 3 years.
- Loreli invests \$500 at 15% p.a. simple interest over 3 years.
  - How much does each person have at the end of the 3 years?
  - Who earned the most?

Key ideas

You can calculate the total amount of your investment for either form of interest using technology.

The following spreadsheet can be used to compile a simple interest and compound interest sheet.



	A	B	C	D	E
1	Interest calculator				
2		Principal		Rate	
3		4000		=5.4/100/12	
4					
5		Simple interest		Compound interest	
6	Time (months)	Interest	Amount	Interest	Amount
7	0	0	=B\$3+B7	0	=B\$3*(1+D\$3)^A7
8	=A7+1	=B\$3*D\$3	=C7+B8	=E8-E7	=B\$3*(1+D\$3)^A8
9	=A8+1	=B\$3*D\$3	=C8+B9	=E9-E8	=B\$3*(1+D\$3)^A9
10	=A9+1	=B\$3*D\$3	=C9+B10	=E10-E9	=B\$3*(1+D\$3)^A10
11	=A10+1	=B\$3*D\$3	=C10+B11	=E11-E10	=B\$3*(1+D\$3)^A11
12	=A11+1	=B\$3*D\$3	=C11+B12	=E12-E11	=B\$3*(1+D\$3)^A12
13	=A12+1	=B\$3*D\$3	=C12+B13	=E13-E12	=B\$3*(1+D\$3)^A13
14					
15					
16					
17					
18					

Fill in the principal in B3 and the rate per period in D3. For example, for \$4000 invested at 5.4% monthly, B3 will be 4000 and D3 will be $\frac{0.054}{12}$.

Exercise 1I

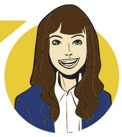
UNDERSTANDING AND FLUENCY 1–4 3–5

1 Which earns more on an investment of \$100 for 2 years?

A simple interest calculated at 20% p.a.

B compound interest calculated at 20% p.a. and paid annually

Recall: For simple interest $I = PRN$; for compound interest $A = P(1 + R)^n$



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2 Write down the values of P, R and n for an investment of \$750 at 7.5% p.a. compounded annually for 5 years.

3 Write down the values of I, P, R and N for an investment of \$300 at 3% p.a. simple interest over 300 months.

4 **a** Find the total amount of the following investments, using technology.
- **i** \$6000 at 6% p.a. compounded annually for 3 years
- **ii** \$6000 at 3% p.a. compounded annually for 5 years
- **iii** \$6000 at 3.4% p.a. compounded annually for 4 years
- **iv** \$6000 at 10% p.a. compounded annually for 2 years
- **v** \$6000 at 5.7% p.a. compounded annually for 5 years

b Which of the above yields the most interest?

Example 26 Using a spreadsheet

Find the total amount of the following investments, using technology.

a \$5000 at 5% p.a. compounded annually for 3 years

b \$5000 at 5% p.a. simple interest for 3 years

SOLUTION	EXPLANATION
a \$5788.13 **b** \$5750	Set up a spreadsheet (refer to Key ideas) to compare the amounts earned from the two types of interest. Alternatively, use $A = P(1 + R)^n$ and $I = PRN$.

5 **a** Find the total amount of the following investments, using technology where possible.
- **i** \$6000 at 6% p.a. simple interest for 3 years
- **ii** \$6000 at 3% p.a. simple interest for 6 years
- **iii** \$6000 at 3.4% p.a. simple interest for 7 years
- **iv** \$6000 at 10% p.a. simple interest for 2 years
- **v** \$6000 at 5.7% p.a. simple interest for 5 years

b Which of the above yields the most interest?

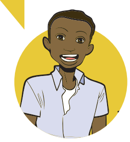
PROBLEM-SOLVING AND REASONING		6, 7	7, 8

6 **a** Determine the total simple and compound interest accumulated on the following.
- **i** \$4000 at 6% p.a. payable annually for:
  - **I** 1 year **II** 2 years **III** 5 years **IV** 10 years
- **ii** \$4000 at 6% p.a. payable bi-annually for:
  - **I** 1 year **II** 2 years **III** 5 years **IV** 10 years
- **iii** \$4000 at 6% p.a. payable monthly for:
  - **I** 1 year **II** 2 years **III** 5 years **IV** 10 years

b Would you prefer the same rate of compound interest or simple interest if you were investing money?

c Would you prefer the same rate of compound interest or simple interest if you were borrowing money?

6% p.a. paid bi-annually is 3% per 6 months.
6% p.a. paid monthly is $\frac{6}{12}\% = 0.5\%$ per month.



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7 **a** Copy and complete the following table if simple interest is applied.

Principal	Rate	Overall time	Interest	Amount
$7000		5 years		$8750
$7000		5 years		$10 500
	10%	3 years	$990	
	10%	3 years	$2400	
$9000	8%	2 years		
$18 000	8%	2 years		

$I = PRN$

$A = P + I$

b Explain the effect on the interest when we double the:

i rate **ii** period **iii** overall time

8 Copy and complete the following table if compound interest is applied. You may need to use a calculator and trial and error to find some of the missing numbers.

Principal	Rate	Period	Overall time	Interest	Amount
$7000		Annually	5 years		$8750
$7000		Annually	5 years		$10 500
$9000	8%	Fortnightly	2 years		
$18 000	8%	Fortnightly	2 years		

ENRICHMENT		–	9, 10

Changing the parameters

9 If you invest $5000, determine the interest rate per annum (to 2 decimal places) if the total amount is approximately $7500 after 5 years and if:

a interest is compounded annually

b interest is compounded quarterly

c interest is compounded weekly

Comment on the effect of changing the period for each payment on the rate needed to achieve the same total amount in a given time.

10 **a** Determine, to 1 decimal place, the equivalent simple interest rate for the following investments over 3 years.

i $8000 at 4% compounded annually

ii $8000 at 8% compounded annually

b If you double or triple the compound interest rate, how is the simple interest rate affected?

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1 Find and define the 10 terms related to consumer arithmetic and percentages hidden in this wordfind.

C	O	M	M	I	S	S	I	O	N	Q	R	W
P	G	S	L	E	R	S	T	B	L	D	U	J
H	L	A	A	P	I	E	C	E	W	O	R	K
U	F	N	U	L	N	Q	B	D	Z	T	J	L
V	K	N	S	T	A	M	O	N	T	H	L	Y
B	H	U	A	I	G	R	O	S	S	U	B	S
N	E	A	C	Y	K	S	Y	E	T	Y	M	D
M	A	L	O	V	E	R	T	I	M	E	Q	T
S	F	O	R	T	N	I	G	H	T	L	Y	S

2 How do you stop a bull charging you? Answer the following problems and match the letters to the answers below to find out.

\$19.47 − \$8.53 **E**	5% of \$89 **T**	50% of \$89 **I**
$12\frac{1}{2}$% of \$100 **A**	If 5% = \$8.90 then 100% is? **S**	\$4.48 to the nearest 5 cents **R**
6% of \$89 **W**	Increase \$89 by 5% **H**	10% of \$76 **O**
\$15 monthly for 2 years **D**	$12\frac{1}{2}$% as a decimal **K**	\$50 − \$49.73 **U**
Decrease \$89 by 5% **C**	\$15.96 + \$12.42 **Y**	

☐	☐	☐			
\$28.38	\$7.60	27c			
☐	☐	☐	☐		
\$4.45	\$12.50	0.125	\$10.94		
☐	☐	☐	☐		
\$12.50	\$5.34	\$12.50	\$28.38		
☐	☐	☐			
\$93.45	\$44.50	\$178			
☐	☐	☐	☐	☐	☐
\$84.55	\$4.50	\$10.94	\$360	\$44.50	\$4.45
☐	☐	☐	☐		
\$84.55	\$12.50	\$4.50	\$360		

3 How many years does it take \$1000 to double if it is invested at 10% p.a. compounded annually?

4 The chance of Jayden winning a game of cards is said to be 5%. How many consecutive games should Jayden play to be 95% certain he has won at least one of the games played?

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Chapter summary

Financial mathematics

Conversions

$$\begin{tikzcd} \text{Fraction} \arrow[r, bend left, "\times 100"] & \text{Percentage} \arrow[l, bend left, "\div 100"] \end{tikzcd}$$

$$\begin{tikzcd} \text{Decimal} \arrow[r, bend left, "\times 100"] & \text{Percentage} \arrow[l, bend left, "\div 100"] \end{tikzcd}$$

Percentage work

15% of 459

$= \frac{15}{100} \times 459$

Increase 20 by 8%

$= 20 \times 108\%$

$= 20 \times 1.08$

Decrease 20 by 8%

$= 20 \times 92\%$

$= 20 \times 0.92$

Profit = selling price − cost price

$\%\text{ profit} = \frac{\text{profit}}{\text{cost price}} \times 100$

$\%\text{ discount} = \frac{\text{discount}}{\text{cost price}} \times 100$

Percentages

'Out of 100'

79 per cent = $79\% = \frac{79}{100}$

Income

hourly rate = \$/h

time and a half = $1\frac{1}{2}$ × hrly rate

double time = 2 × hrly rate

commission is x% of total sales

Gross income = total of all money earned

Net income = gross income − deductions

Simple (flat rate) interest

$I = PRN$

I = simple interest

P = principal (\$ invested)

R = rate per year, as a decimal

N = number of years

Compound interest

$A = P(1 + R)^n$

A = final balance

P = principal (\$ invested)

R = rate per time period, as a decimal

n = number of time periods money is invested for

Spreadsheets can be used to manage money or compare loans.

Budgets

Deciding how income is spent on *fixed* and *variable* expenses.

Tax

Taxation = money given from wages (income tax) to the government

(Refer to the income tax table on page 24)

Loans

Balance owing = amount left to repay

Repayment = money given each month to repay the loan amount and the interest

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Multiple-choice questions

1 28% of $89 is closest to:
A $28.00 **B** $64.08 **C** $113.92 **D** $2492 **E** $24.92

2 As a percentage, $\frac{21}{60}$ is:
A 21% **B** 3.5% **C** 60% **D** 35% **E** 12.6%

3 If a budget allows 30% for car costs, how much is allocated from a weekly wage of $560?
A $201 **B** $145 **C** $100 **D** $168 **E** $109

4 The gross income for 30 hours at $5.26 per hour is:
A $35.26 **B** $389.24 **C** $157.80 **D** $249.20 **E** $24.92

5 If Simone received $2874 commission on the sale of a property worth $195 800, her rate of commission, to 1 decimal place, was:
A 21% **B** 1.5% **C** 60% **D** 15% **E** 12.6%

6 In a given rostered fortnight, Bill works the following number of 8-hour shifts:

- three day shifts ($10.60 per hour)
- three afternoon shifts ($12.34 per hour)
- five night shifts ($16.78 per hour)

His total income for the fortnight is:
A $152.72 **B** $1457.34 **C** $1000 **D** $168.84 **E** $1221.76

7 An iPod Shuffle is discounted by 26%. What is the price if it was originally $56?
A $14.56 **B** $41.44 **C** $26.56 **D** $13.24 **E** $35.22

8 A $5000 loan is repaid by monthly instalments of $200 for 5 years. The amount of interest charged is:
A $300 **B** $7000 **C** $12 000 **D** $2400 **E** $6000

9 The simple interest on $600 at 5% for 4 years is:
A $570 **B** $630 **C** $120 **D** $720 **E** $30

10 The compound interest on $4600 at 12% p.a. for 2 years is:
A $1104 **B** $5704 **C** $4600 **D** $5770.24 **E** $1170.24

Short-answer questions

1 Find 15.5% of $9000.

2 Increase $968 by 12%.

3 Decrease $4900 by 7%.

4 The cost price of an item is $7.60. If the mark-up is 50%, determine:
a the retail price
b the profit made

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5 An airfare of $7000 is discounted 40% if you fly off-peak. What would be the discounted price?

6 A couch is discounted to $375. If this is a 35% discount, find the recommended retail price.

7 Pina budgets 20% of her income for entertainment. If her yearly income is $37 000, how much could be spent on entertainment in:

a a year?

b a month?

c a week?

8 Mariah works a 34-hour week at $13.63 per hour. Her net income is 62% of her wage.

a Work out Mariah's net income.

b If 15% of her net income is spent on clothing, determine the amount Mariah can spend each week.

c If Mariah saves $50 each week, what percentage (to 2 decimal places) of her gross weekly income is this?

9 Milan has the following costs to run his car.

• hire purchase payment	$350 per month
• registration	$685 per year
• insurance	$315 per quarter
• servicing	$1700 per year
• petrol	$90 per week

a Find the total cost of running his vehicle for 1 year.

b What percentage (to the nearest per cent) of the overall cost to run the car is the cost of the petrol?

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10 Tranh works 36 hours at \$9.63 per hour. He pays \$47.53 in tax and \$8.50 in superannuation. Determine:

a his gross wage **b** his net pay

11 Lil receives an annual salary of \$47 842. Using the tax table shown, calculate the amount of tax she pays over the year.

Taxable income	Tax on this income
0 – \$18 200	Nil
\$18 201 – \$37 000	19 c for each \$1 over \$18 200
\$37 001 – \$80 000	\$3572 plus 32.5 c for each \$1 over \$37 000
\$80 001 – \$180 000	\$17 547 plus 37 c for each \$1 over \$80 000
\$180 001 and over	\$54 547 plus 45 c for each \$1 over \$180 000

12 Pedro receives 4.5% commission on sales of \$790. Determine the amount of his commission.

13 A vehicle worth \$7000 is purchased on a finance package. The purchaser pays 15% deposit and \$250 per month over 4 years.

a How much deposit is paid?

b What are the total repayments?

c How much interest is paid over the term of the loan?

14 Find the interest paid on a \$5000 loan under the following conditions.

a 8% p.a. simple interest over 4 years

b 7% p.a. simple interest over 3 years and 4 months

c 4% p.a. compounded annually over 3 years

d 9.75% p.a. compounded annually over 2 years

Extended-response questions

1 \$5000 is invested at 4% p.a. compounding annually for 3 years.

a What is the value of the investment after the 3 years?

b How much interest is earned in the 3 years?

c Using $R = \frac{I}{PN}$, what simple rate of interest results in the same amount?

d How much interest is earned on the investment if it is compounded monthly at 4% p.a. for the 3 years?

2 Your bank account has an opening July monthly balance of \$217.63. You have the following transactions over the month.

Date	Withdrawals	Deposits
July 7th	\$64.00	
July 9th		\$140
July 11th	\$117.34	
July 20th		\$20
July 20th	\$12.93	
July 30th		\$140

a Design a statement of your records if \$0.51 is taken out as a fee on 15 July.

b Find the minimum balance.

c If interest is credited monthly on the minimum balance at 0.05%, determine the interest for July, rounded to the nearest cent.

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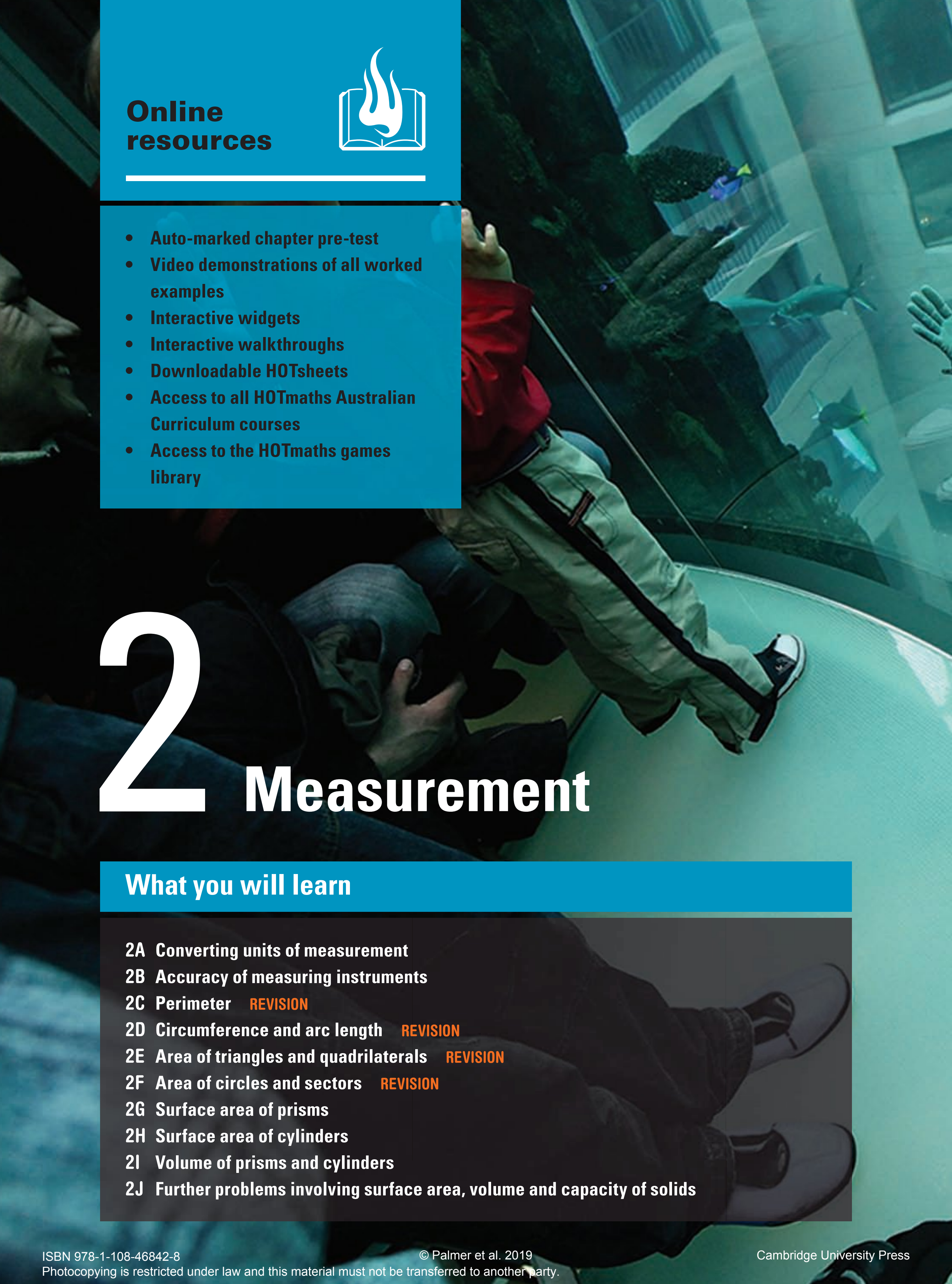

Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

2

Measurement

What you will learn

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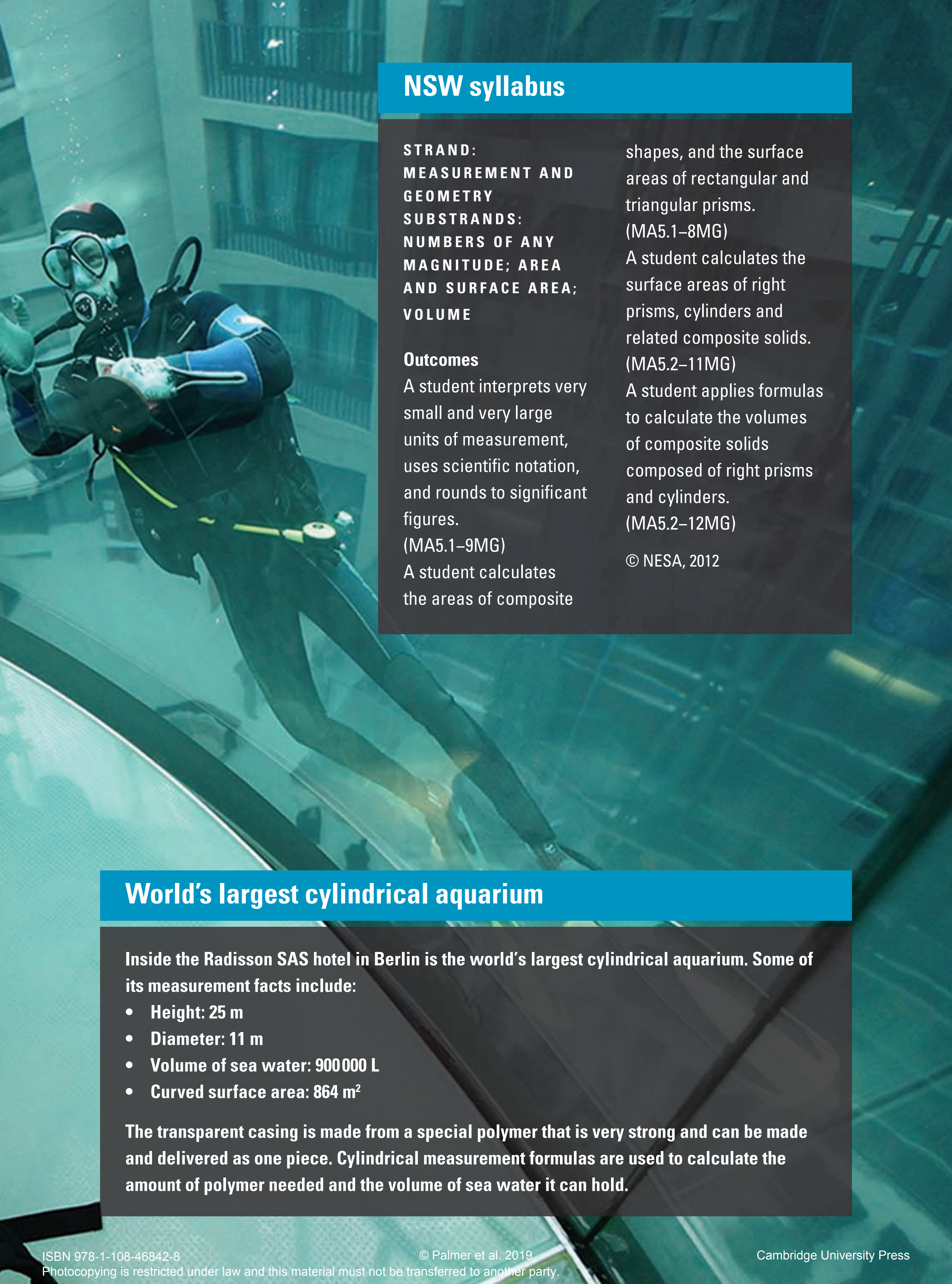


NSW syllabus

STRAND: MEASUREMENT AND GEOMETRY

SUBSTRANDS: NUMBERS OF ANY MAGNITUDE; AREA AND SURFACE AREA; VOLUME

Outcomes

A student interprets very small and very large units of measurement, uses scientific notation, and rounds to significant figures.
(MA5.1–9MG)

A student calculates the areas of composite shapes, and the surface areas of rectangular and triangular prisms.
(MA5.1–8MG)

A student calculates the surface areas of right prisms, cylinders and related composite solids.
(MA5.2–11MG)

A student applies formulas to calculate the volumes of composite solids composed of right prisms and cylinders.
(MA5.2–12MG)

World's largest cylindrical aquarium

Inside the Radisson SAS hotel in Berlin is the world's largest cylindrical aquarium. Some of its measurement facts include:

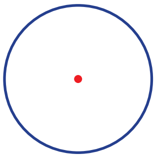
- **Height: 25 m**
- **Diameter: 11 m**
- **Volume of sea water: 900 000 L**
- **Curved surface area: 864 m^2**

The transparent casing is made from a special polymer that is very strong and can be made and delivered as one piece. Cylindrical measurement formulas are used to calculate the amount of polymer needed and the volume of sea water it can hold.

Pre-test

1 Name these shapes.

a



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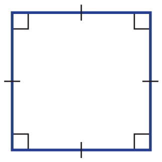

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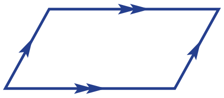

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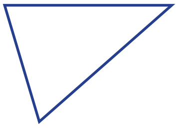

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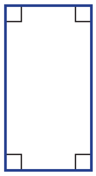

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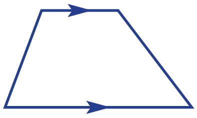

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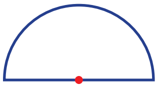

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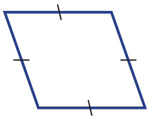


2 Write the missing number.

a 1 km = ☐ m

b 1 m = ☐ cm

c 1 cm = ☐ mm

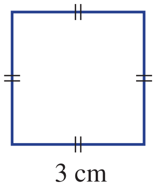
d 1 L = ☐ mL

e 0.5 km = ☐ m

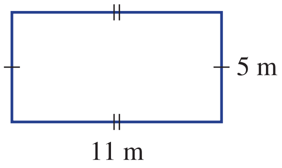
f 2.5 cm = ☐ mm

3 Find the perimeter of these shapes.

a



b



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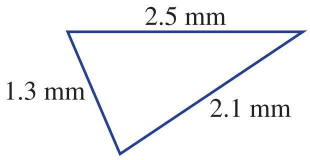
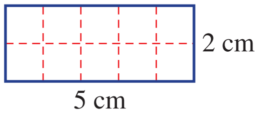


4 Find the area of these shapes.

a



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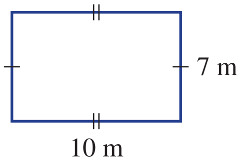

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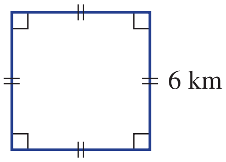
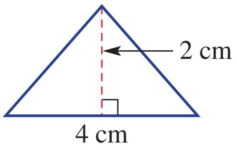


5 Find the area of these triangles using $A = \frac{1}{2}bh$.

a



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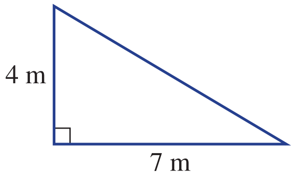

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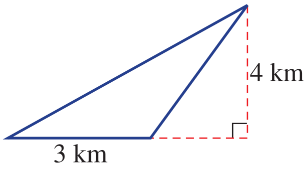
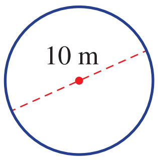


6 Use $C = \pi d$ and $A = \pi r^2$ to find the circumference and area of this circle. Round your answer to 2 decimal places.



$d = 10$ m, $r = 5$ m

2A Converting units of measurement

Interactive
Widgets
HOTsheets
Walkthrough

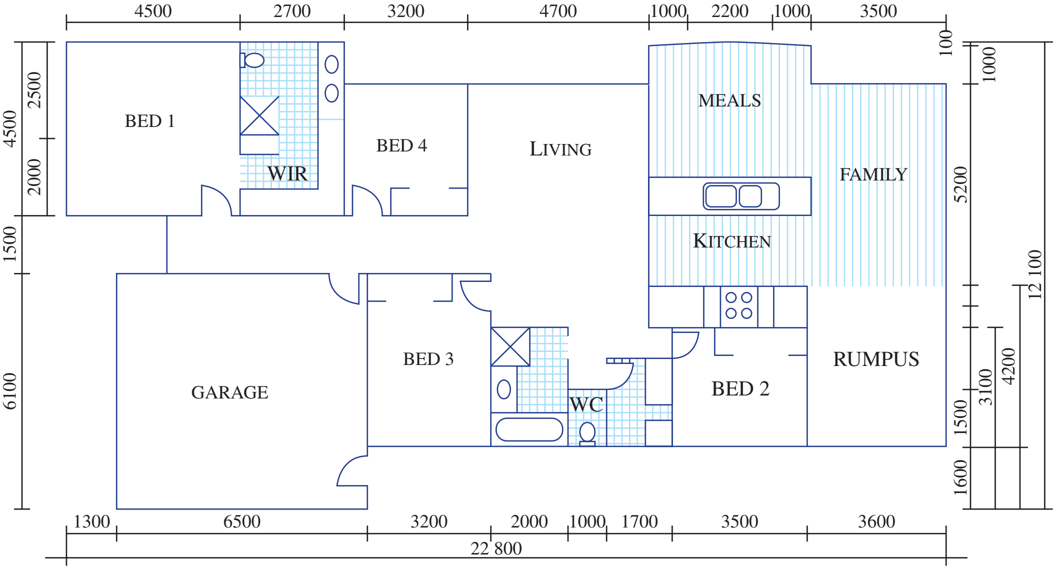
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

To work with length, area or volume measurements, it is important to be able to convert between different units. Timber, for example, is widely used in buildings for frames, roof trusses and windows, to name a few things. It is important to order the correct amount of timber so that the cost of the house is minimised. Although plans give measurements in millimetres and centimetres, timber is ordered in metres (often referred to as lineal metres), so we have to convert all our measurements to metres.

Building a house also involves many area and volume calculations and conversions.

Let's start: House plans

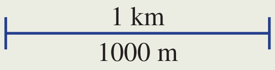
All homes start from a plan, which is usually designed by an architect and shows most of the basic features and measurements that are needed to build the house. Measurements are given in millimetres.

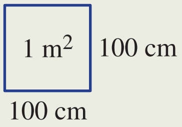


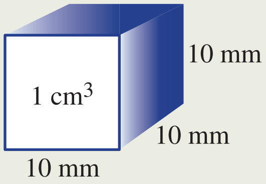
- How many bedrooms are there?
- What are the dimensions of the master bedroom (BED 1)?
- What are the dimensions of the master bedroom, in metres?
- Will the rumpus room fit a pool table that measures 2.5 m × 1.2 m, and still have room to play?
- How many cars do you think will fit in the garage?
- What do you think is going to cover the floor of the kitchen, meals and family rooms?

Key ideas

- To convert units, draw an appropriate diagram and use it to find the conversion factor. For example:







$1 \text{ km} = 1000 \text{ m}$

$$\begin{aligned} 1 \text{ m}^2 &= 100 \times 100 \\ &= 10000 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} 1 \text{ cm}^3 &= 10 \times 10 \times 10 \\ &= 1000 \text{ mm}^3 \end{aligned}$$

- Conversions:

Length

$$\begin{tikzcd} \text{km} \arrow[r, bend left, "\times 1000"] & \text{m} \arrow[l, bend left, "\div 1000"] \arrow[r, bend left, "\times 100"] & \text{cm} \arrow[l, bend left, "\div 100"] \arrow[r, bend left, "\times 10"] & \text{mm} \arrow[l, bend left, "\div 10"] \end{tikzcd}$$

Area

$$\begin{tikzcd} \text{km}^2 \arrow[r, bend left, "\times 1000^2"] & \text{m}^2 \arrow[l, bend left, "\div 1000^2"] \arrow[r, bend left, "\times 100^2"] & \text{cm}^2 \arrow[l, bend left, "\div 100^2"] \arrow[r, bend left, "\times 10^2"] & \text{mm}^2 \arrow[l, bend left, "\div 10^2"] \end{tikzcd}$$

Volume

$$\begin{tikzcd} \text{km}^3 \arrow[r, bend left, "\times 1000^3"] & \text{m}^3 \arrow[l, bend left, "\div 1000^3"] \arrow[r, bend left, "\times 100^3"] & \text{cm}^2 \arrow[l, bend left, "\div 100^3"] \arrow[r, bend left, "\times 10^3"] & \text{mm}^3 \arrow[l, bend left, "\div 10^3"] \end{tikzcd}$$

- To multiply by 10, 100, 1000 etc. move the decimal point one place to the right for each zero; e.g. $3.425 \times 100 = 342.5$
- To divide by 10, 100, 1000 etc. move the decimal point one place to the left for each zero; e.g. $4.10 \div 1000 = 0.0041$

- Metric prefixes in everyday use.

Prefix	Symbol	Factor of 10	Standard form	
tera	T	1 000 000 000 000	10^{12}	1 trillion
giga	G	1 000 000 000	10^{9}	1 billion
mega	M	1 000 000	10^{6}	1 million
kilo	k	1000	10^{3}	1 thousand
hecto	h	100	10^{2}	1 hundred
deca	da	10	10	1 ten
deci	d	0.1	10^{-1}	1 tenth
centi	c	0.01	10^{-2}	1 hundredth
milli	m	0.001	10^{-3}	1 thousandth
micro	μ	0.000001	10^{-6}	1 millionth
nano	n	0.000000001	10^{-9}	1 billionth

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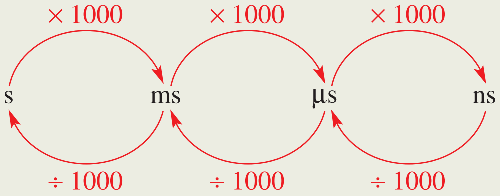
Key ideas

For time conversions, this can be represented on a flow diagram similar to those for length, area and volume.

s – seconds
ms – milliseconds
µs – microseconds
ns – nanoseconds

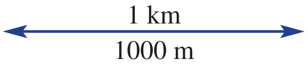


Exercise 2A

UNDERSTANDING AND FLUENCY	1–5, 6–8(1/2)	4, 5, 6–8(1/2)

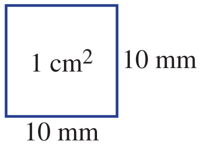
1 Write the missing numbers in these sentences involving length.

- **a** There are ☐ m in 1 km.
- **b** There are ☐ mm in 1 cm.
- **c** There are ☐ cm in 1 m.



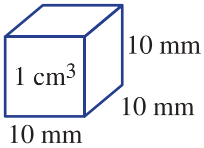
2 Write the missing numbers in these sentences involving area units.

- **a** There are ☐ mm^2 in 1 cm^2.
- **b** There are ☐ cm^2 in 1 m^2.
- **c** There are ☐ m^2 in 1 km^2.



3 Write the missing numbers in these sentences involving volume units.

- **a** There are ☐ mm^3 in 1 cm^3.
- **b** There are ☐ m^3 in 1 km^3.
- **c** There are ☐ cm^3 in 1 m^3.



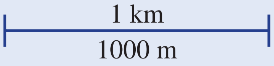
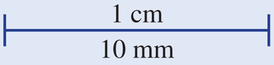
4 Given the basic units of grams (g), litres (L), metres (m) and seconds (s), write down the meaning of the following units.

a mm **b** mg **c** GL **d** ms **e** µs **f** ns

Example 1 Converting length measurements

Convert these length measurements to the units shown in the brackets.

a 8.2 km (m) **b** 45 mm (cm)

SOLUTION	EXPLANATION
a $8.2\text{ km} = 8.2 \times 1000\text{ m}$ $= 8200\text{ m}$	 1 km = 1000 m
b $45\text{ mm} = 45 \div 10\text{ cm}$ $= 4.5\text{ cm}$	 1 cm = 10 mm Divide if converting from a smaller unit to a larger unit.

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5 Convert the following measurements of length to the units given in the brackets.

a 4.32 cm (mm)
b 327 m (km)
c 834 cm (m)
d 0.096 m (mm)
e 297.5 m (km)
f 0.0127 m (cm)

If converting to a smaller unit, multiply. Otherwise, divide.

Example 2 Converting other units

Convert the following.

a 3 minutes to microseconds
b 4 000 000 000 mg to t

SOLUTION	EXPLANATION
a 3 minutes $= 180$ s	1 minute $= 60$ seconds $(3 \times 60 = 180)$
$= 180 \times 10^6\ \mu s$	1 second $= 1\,000\,000$ microseconds $(180 \times 1\,000\,000)$
$= 1.8 \times 10^8\ \mu s$	Express the answer in scientific notation.
b 4 000 000 000 mg $= 4\,000\,000$ g	mg means milligrams 1000 mg $= 1$ gram
$= 4000$ kg	1000 g $= 1$ kg
$= 4$ t	1000 kg $= 1$ tonne (t)
	Dividing by the conversion factor converts a small unit to a larger unit as there are less of them.

6 Convert the following.

a 7 kg to g
b 7000 m to km
c 15 Mt to t
d 4 kW to W (watts)
e 8900 t to Mt
f 5 ns to s
g 0.6 g to µg
h 600 s to min
i 1285 s to ms
j 680 t to Mt
k 40 000 000 µm to cm
l 8 GB to B (bytes)
m 8500 ms to s
n 3 000 000 000 ns to s
o 9000 mg to g

The *Salmonella* bacterium, which is a common cause of food poisoning, is so small that it is measured in micrometres (µm).

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Example 3 Converting area measurements

Convert these area measurements to the units shown in the brackets.

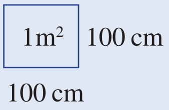
a 930 cm^2 (m^2) **b** 0.4 cm^2 (mm^2)

SOLUTION

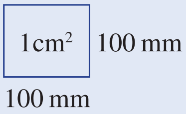
a $930\text{ cm}^2 = 930 \div 10\,000\text{ m}^2$
$= 0.093\text{ m}^2$

b $0.4\text{ cm}^2 = 0.4 \times 100\text{ mm}^2$
$= 40\text{ mm}^2$

EXPLANATION



$1\text{ m}^2 = 100 \times 100\text{ cm}^2$
$= 10\,000\text{ cm}^2$

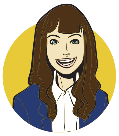


$1\text{ cm}^2 = 10 \times 10\text{ mm}^2$
$= 100\text{ mm}^2$

7 Convert the following area measurements to the units given in the brackets.

a 3000 cm^2 (mm^2)
b 0.5 m^2 (cm^2)
c 5 km^2 (m^2)
d 2 980 000 mm^2 (cm^2)
e 537 cm^2 (mm^2)
f 0.023 m^2 (cm^2)

$$\begin{tikzcd}
\text{km}^2 \arrow[r, bend left, "\times 1000^2"] & \text{m}^2 \arrow[l, bend left, "\div 1000^2"] \arrow[r, bend left, "\times 100^2"] & \text{cm}^2 \arrow[l, bend left, "\div 100^2"] \arrow[r, bend left, "\times 10^2"] & \text{mm}^2 \arrow[l, bend left, "\div 10^2"]
\end{tikzcd}$$



Example 4 Converting volume measurements

Convert these volume measurements to the units shown in the brackets.

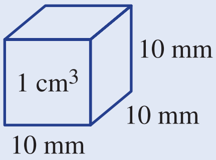
a 3.72 cm^3 (mm^3) **b** 4300 cm^3 (m^3)

SOLUTION

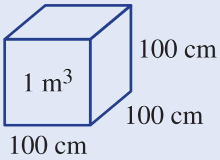
a $3.72\text{ cm}^3 = 3.72 \times 1000\text{ mm}^3$
$= 3720\text{ mm}^3$

b $4300\text{ cm}^3 = 4300 \div 1\,000\,000\text{ m}^3$
$= 0.0043\text{ m}^3$

EXPLANATION



$1\text{ cm}^3 = 10 \times 10 \times 10\text{ mm}^3$
$= 1000\text{ mm}^3$



$1\text{ m}^3 = 100 \times 100 \times 100\text{ cm}^3$
$= 1\,000\,000\text{ cm}^3$

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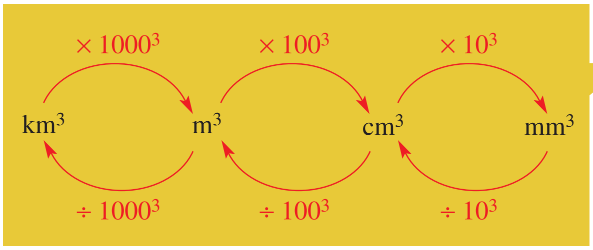
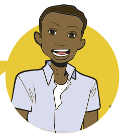
8 Convert these volume measurements to the units given in the brackets.

- **a** 2 cm^3 (mm^3)
- **b** 0.2 m^3 (cm^3)
- **c** 5700 mm^3 (cm^3)
- **d** 0.015 km^3 (m^3)
- **e** 28 300 000 m^3(km^3)
- **f** 762 000 cm^3 (m^3)





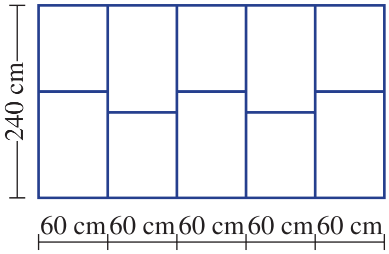
PROBLEM-SOLVING AND REASONING

9, 10, 11(1/2), 12 | 11(1/2), 13–17

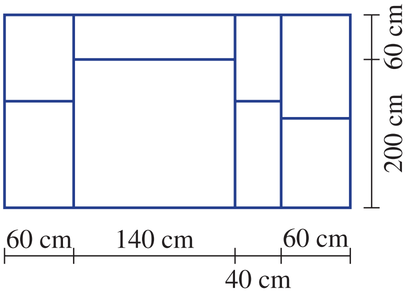
9 An athlete has completed a 5.5 km run. How many metres did the athlete run?

10 Determine the metres of timber needed to construct the following frames.

a



b



11 Find the total sum of the measurements given, expressing your answer in the units given in the brackets.

- **a** 10 cm, 18 mm (mm)
- **b** 1.2 m, 19 cm, 83 mm (cm)
- **c** 453 km, 258 m (km)
- **d** 400 mm^2, 11.5 cm^2 (cm^2)
- **e** 0.3 m^2, 251 cm^2 (cm^2)
- **f** 0.000 03 km^2, 9m^2, 37 000 000 cm^2 (m^2)
- **g** 482 000 mm^3, 2.5 cm^3 (mm^3)
- **h** 0.000 51 km^3, 27 300 m^3 (m^3)

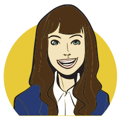
Convert to the units in brackets. Add up to find the sum.

12 A snail is moving at a rate of 43 mm every minute. How many centimetres will the snail move in 5 minutes?

13 Why do you think that builders measure many of their lengths using only millimetres, even their long lengths?

14 How many 4 kB files can fit onto an 8 GB USB stick?

1 GB = 1 000 000 000 bytes



15 An Olympic sprinter places second in the 100 metres, with the time 10.45 seconds. If this athlete is beaten by 2 milliseconds, what is the winning time for the race?

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16 Stored on her computer, Sarah has photos of her recent weekend away. She has filed them according to various events. The files have the following sizes: 1.2 MB, 171 KB, 111 KB, 120 KB, 5.1 MB and 2.3 MB. (Note that some computers use KB instead of kB in their information on each file.)

- **a** What is the total size of the photos of her weekend, in kilobytes?
- **b** What is the total in megabytes?
- **c** Sarah wishes to email these photos to her mum. However, her mum's file server can only receive email attachments no bigger than 8 MB. Is it possible for Sarah to send all of her photos from the weekend in one email?

17 **a** How many times greater than a gigabyte is a terabyte?

- **b** How many 4 GB files can fit into 1 TB?

ENRICHMENT		–	18

Special units

18 Many units of measurement apart from those relating to mm, cm, m and km are used in our society. Some of these are described here.

Length	inches	1 inch ≈ 2.54 cm = 25.4 mm
	feet	1 foot = 12 inches ≈ 30.48 cm
	miles	1 mile ≈ 1.609 km = 1609 m
Area	squares	1 square = 100 square feet
	hectares (ha)	1 hectare = 10000 m^2
Volume	millilitres (mL)	1 millilitre = 1 cm^3
	litres (L)	1 litre = 1000 cm^3

Convert these special measurements to the units given in the brackets. Use the conversion information given earlier to help.

- **a** 5.5 miles (km)
- **b** 54 inches (feet)
- **c** 10.5 inches (cm)
- **d** 2000 m (miles)
- **e** 5.7 ha (m^2)
- **f** 247 cm^3 (L)
- **g** 8.2 L (mL)
- **h** 5.5 m^3 (mL)
- **i** 10 squares (sq. feet)
- **j** 2 m^3 (L)
- **k** 1 km^2 (ha)
- **l** 152 000 mL (m^3)

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2B Accuracy of measuring instruments

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Humans and machines measure many different things, such as the time taken to swim a race, a length of timber needed for a building and the volume of cement needed to lay a concrete path around a swimming pool. The degree or level of accuracy required usually depends on what is being measured and what the information is being used for.

All measurements are approximate. Errors can come from the equipment being used or the person using the measuring device.

Accuracy is the measure of how true to the ‘real’ the measure is, whereas **precision** is the ability to obtain the same result over and over again.

Let’s start: Rounding a decimal

1 A piece of timber is measured to be 86 cm, correct to the nearest centimetre. What is the smallest decimal that it could be rounded from and what is the largest decimal that, when rounded to the nearest whole, is recorded as 86 cm?

2 If a measurement is recorded as 6.0 cm, correct to the nearest millimetre, then:
- **i** what units were used when measuring?
- **ii** what is the smallest decimal that could be rounded to this value?
- **iii** what is the largest decimal that would have resulted in 6.0 cm?

3 Consider a square with sides given as 7.8941 km each.
- **a** What is the perimeter of the square if the side length is:
  - **i** left unchanged with 4 decimal places?
  - **ii** rounded to 1 decimal place?
  - **iii** truncated (i.e. chopped off) at 1 decimal place?
- **b** What is the difference between the perimeters if the decimal is rounded to 2 decimal places or truncated at 2 decimal places or written with 2 significant figures?

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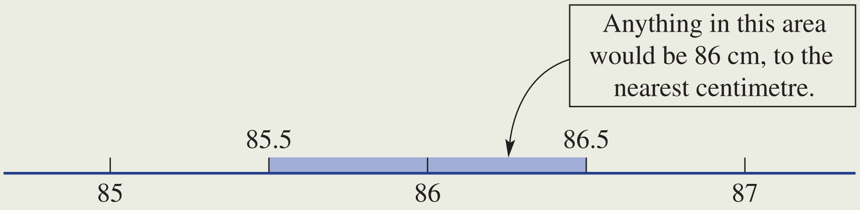
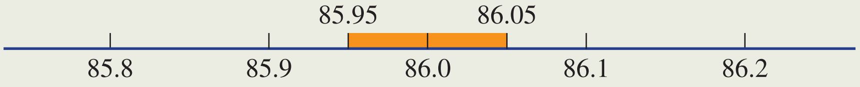
Key ideas

- The limits of accuracy tell you what the upper and lower boundaries are for the true measurement.
  - Usually, it is ±0.5 × the smallest unit of measurement.
  - Note that values are stated to 1 decimal place beyond that of the given measurement. For example, when measuring to the nearest centimetre, 86 cm has limits from 85.5 cm up to 86.5 cm.



- When measuring to the nearest millimetre, the limits of accuracy for 86.0 cm are 85.95 cm to 86.05 cm.



Exercise 2B

UNDERSTANDING AND FLUENCY 1–3, 4–5(1/2) 4–5(1/2)

1 Write down a decimal that, when rounded from 2 decimal places, gives 3.4.

2 Write down a measurement of 3467 mm, correct to the nearest:

a centimetre **b** metre

3 What is the smallest decimal that, when rounded to 1 decimal place, could result in an answer of 6.7?

Example 5 Stating the smallest unit of measurement

For each of the following, write down the smallest unit of measurement.

a 89.8 cm **b** 56.85 m

SOLUTION	EXPLANATION
a 0.1 cm or 1 mm	The measurement is given to 1 decimal place. That means the smallest unit of measurement is tenths.
b 0.01 m or 1 cm	This measurement is given to 2 decimal places. Therefore, the smallest unit of measurement is hundredths or 0.01.

4 For each of the following, state the smallest unit of measurement.

a 45 cm **b** 6.8 mm **c** 12 m **d** 15.6 kg **e** 56.8 g
f 10 m **g** 673 h **h** 9.84 m **i** 12.34 km **j** 0.987 km

Example 6 Finding limits of accuracy

Give the limits of accuracy for these measurements.

a 72 cm

b 86.6 mm

SOLUTION	EXPLANATION
a $72 \pm 0.5 \times 1$ cm $= 72 - 0.5$ cm to $72 + 0.5$ cm $= 71.5$ cm to 72.5 cm	Smallest unit of measurement is one whole cm. Error $= 0.5 \times 1$ cm This error is subtracted and added to the given measurement to find the limits of accuracy.
b $86.6 \pm 0.5 \times 0.1$ mm $= 86.6 \pm 0.05$ mm $= 86.6 - 0.05$ mm to $86.6 + 0.05$ mm $= 86.55$ mm to 86.65 mm	Smallest unit of measurement is 0.1 mm. Error $= 0.5 \times 0.1$ mm This error is subtracted and added to the given measurement to find the limits of accuracy.

5 Give the limits of accuracy for each of these measurements.

- **a** 5 m
- **b** 8 cm
- **c** 78 mm
- **d** 5 ns
- **e** 2 km
- **f** 34.2 cm
- **g** 3.9 kg
- **h** 19.4 kg
- **i** 457.9 t
- **j** 18.65 m
- **k** 7.88 km
- **l** 5.05 s

PROBLEM-SOLVING AND REASONING 6–8 6, 9–11

6 Write the following as a measurement, given that the lower and upper limits of the measurements are as follows.

- **a** 29.5 m to 30.5 m
- **b** 144.5 g to 145.5 g
- **c** 4.55 km to 4.65 km

7 Martha writes down the length of her fabric as 150 cm. As Martha does not give her level of accuracy, give the limits of accuracy of her fabric if it was measured correct to the nearest:

- **a** centimetre
- **b** 10 centimetres
- **c** millimetre

8 A length of copper pipe is given as 25 cm, correct to the nearest centimetre.

- **a** What are the limits of accuracy for this measurement?
- **b** If 10 pieces of pipe each with a given length of 25 cm are joined:
  - **i** what is the minimum length that it could be?
  - **ii** what is the maximum length that it could be?

9 The sides of a square are recorded as 9.2 cm, correct to 2 significant figures.

- **a** What is the minimum length that each side of this square could be?
- **b** What is the maximum length that each side of this square could be?
- **c** Find the upper and lower boundaries for this square’s perimeter.

10 Johan measures the mass of an object to be 6 kg. Amy says the same object is 5.8 kg and Thomas gives his answer as 5.85 kg.

- **a** Explain how all three people could have different answers for the same measurement.
- **b** Write down the level of accuracy being used by each person.
- **c** Are all their answers correct? Discuss.

11 Write down a sentence explaining the need to accurately measure items in our everyday lives and the accuracy that is needed for each of your examples. Give three examples of items that need to be measured correct to the nearest:

a kilometre **b** millimetre **c** millilitre **d** litre

ENRICHMENT – 12

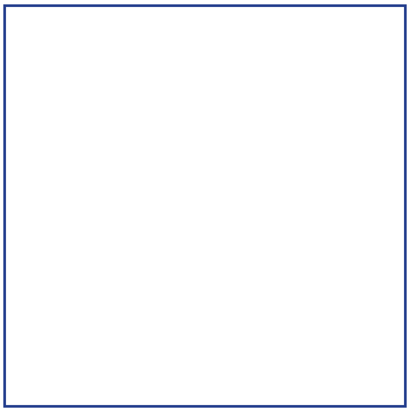
Practical measurement

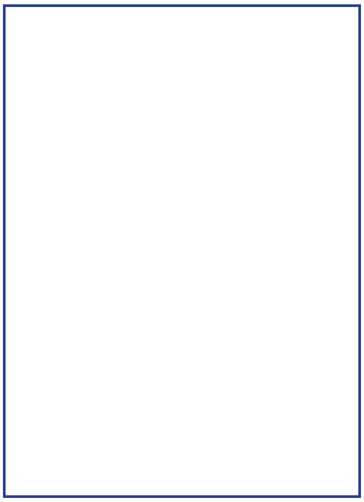
12 **a** Measure each of the shapes below, correct to the nearest:
  i cm **ii** mm

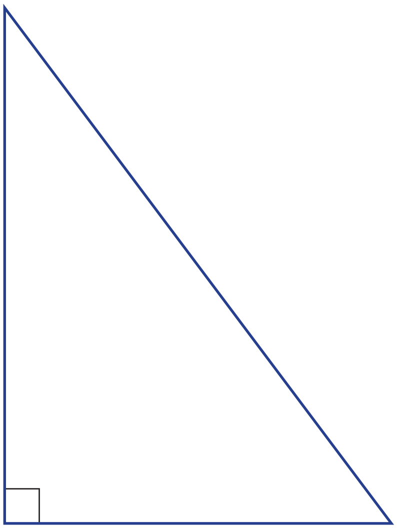
b Use your measurements to find the perimeter and area of each shape.

c After collating your classmates' measurements, find the average perimeter for each shape.

d By how much did the lowest and highest perimeters vary? How can this difference be explained?







2C Perimeter REVISION

Interactive

Widgets

HOTsheets

Walkthrough

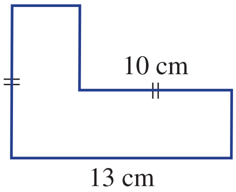
Perimeter is a measure of length around the outside of a shape. We calculate perimeter when ordering ceiling cornices for a room, or materials for fencing a paddock or building a television frame.

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: L-shaped perimeters

This L-shaped figure includes only right (90°) angles. Only two measurements are given.

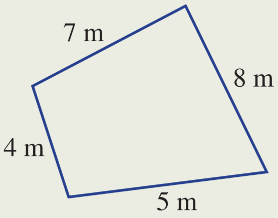


- Can you figure out any other side lengths?
- Is it possible to find its perimeter? Why?

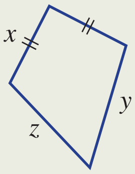
Key ideas

■ **Perimeter** is the distance around the outside of a two-dimensional shape.

- To find the perimeter we add all the lengths of the sides in the same units.
For example: $P = 4 + 5 + 7 + 8 = 24$ m



- If two sides of a shape are the same length, they are labelled with the same markings.
For example: $P = 2x + y + z$



Perimeter The total distane (length) around the outside of a figure

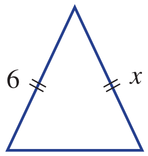
Exercise 2C REVISION

UNDERSTANDING AND FLUENCY 1, 2, 3–4(1/2) 3–4(½)

1 Write the missing word: The distance around the outside of a shape is called the ____________.

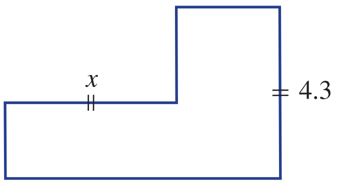
2 Write down the value of x for these shapes.

a



b

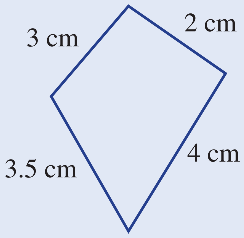
c



Example 7 Finding perimeters of basic shapes

Find the perimeter of these shapes.

a



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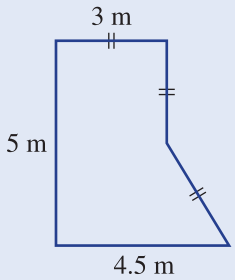
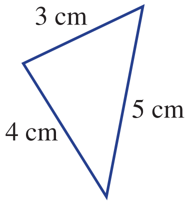


SOLUTION	EXPLANATION
a Perimeter $= 3 + 2 + 4 + 3.5$ $= 12.5$ cm	Add all the lengths of the sides together.
b Perimeter $= 5 + 4.5 + 3 \times 3$ $= 18.5$ m	Three lengths have the same markings and are therefore the same length.

3 Find the perimeter of these shapes.

a



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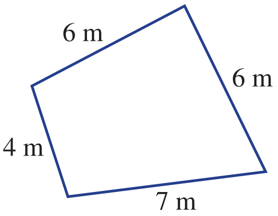

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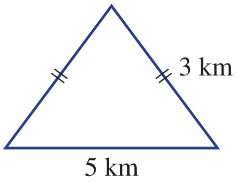
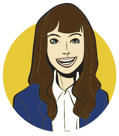


Sides with the same markings are the same length.



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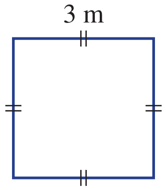

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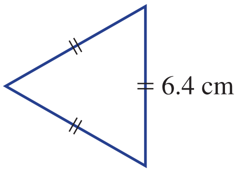

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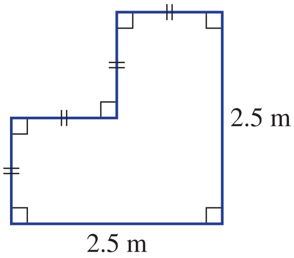

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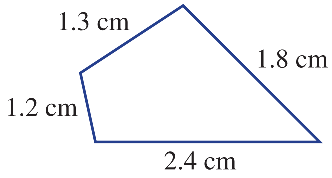
4 Find the perimeter of these shapes.

a



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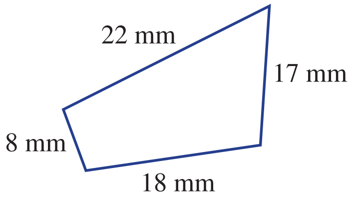

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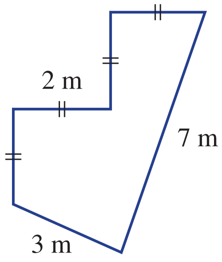

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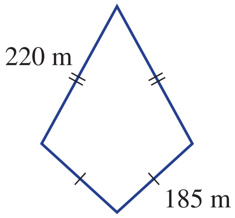

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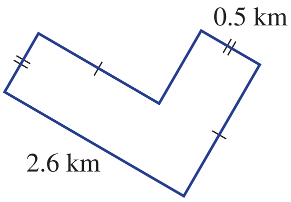

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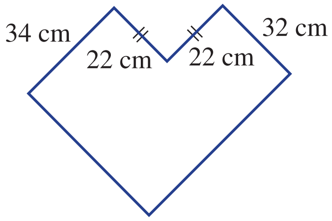
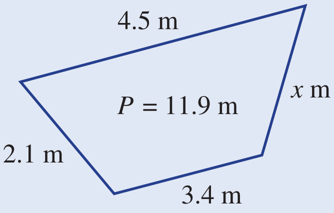


PROBLEM-SOLVING AND REASONING		
	5, 6, 7(1/2)	6, 7(1/2), 8–10

Example 8 Finding a missing side length

Find the value of x for this shape with the given perimeter, P.



SOLUTION	EXPLANATION
$4.5 + 2.1 + 3.4 + x = 11.9$	All the sides add to 11.9 in length.
$10 + x = 11.9$	Simplify.
$x = 1.9$	Subtract 10 from both sides.

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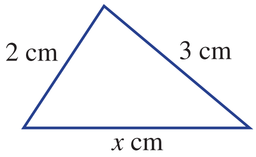
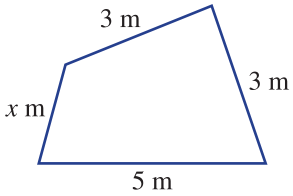
5 Find the value of x for these shapes with the given perimeters.

a



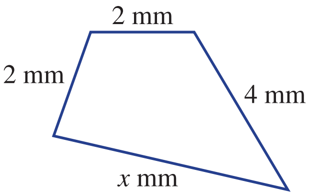
Perimeter $= 9$ cm

b



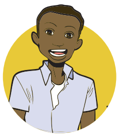
Perimeter $= 13$ mm

c



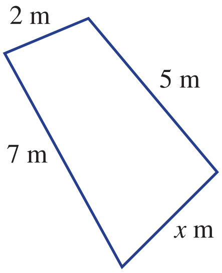
Perimeter $= 14$ m

Add up all the sides then determine the value of x for the given perimeters.



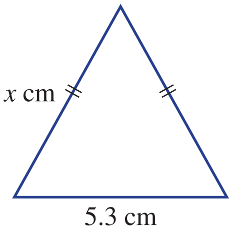
6 Find the value of x for these shapes with the given perimeters.

a



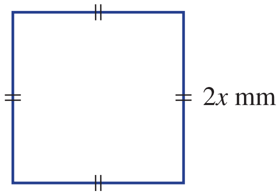
Perimeter $= 17$ m

b



Perimeter $= 22.9$ cm

c



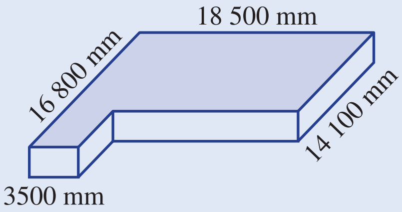
Perimeter $= 0.8$ mm

Example 9 Working with concrete slabs

For the concrete slab shown:

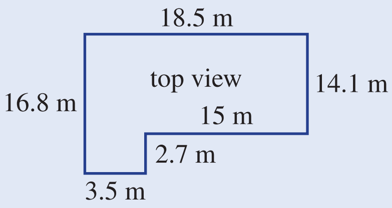
a Draw a new diagram showing all the measurements in metres.

b Determine the lineal metres of timber needed to surround the concrete slab.



SOLUTION

a



b Perimeter $= 18.5 + 16.8 + 3.5 + 2.7 + 15 + 14.1$

$= 70.6$ m

The lineal metres of timber needed is 70.6 m.

EXPLANATION

Convert your measurements and place them all on the diagram.

$1 \text{ m} = 100 \times 10 = 1000 \text{ mm}$

Add or subtract to find the missing measurements.

Add all the measurements.

Write your answer in words.

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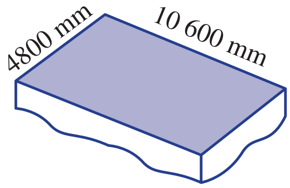
7 Complete the following for the concrete slabs shown.

- **i** Draw a new diagram with the measurements in metres.
- **ii** Determine the lineal metres of timber needed to surround it.

a



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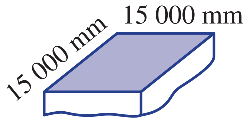

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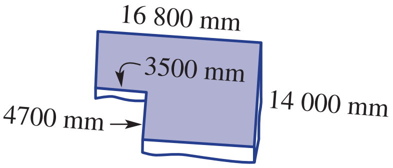

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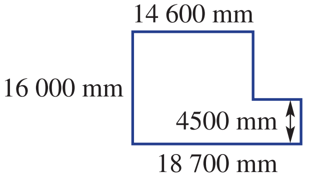

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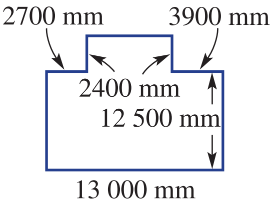

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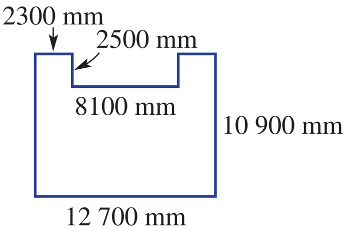
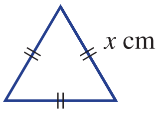


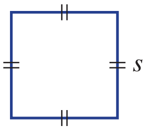
8 A rectangular paddock has perimeter 100 m. Find the breadth of the paddock if its length is 30 m.

9 The equilateral triangle shown has perimeter 45 cm. Find its side lengths.



10 Find formulas for the perimeter of these shapes using the pronumerals given.

a



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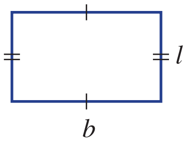

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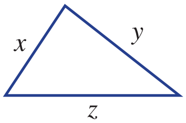

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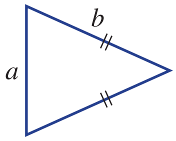

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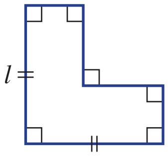

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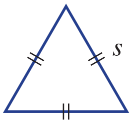

A formula for perimeter could be $P = l + 2b$ or $P = a + b + c$.

ENRICHMENT – 11, 12

How many different tables?

11 How many rectangles (using whole number lengths) have perimeters between 16 m and 20 m, inclusive?

12 A large dining table is advertised with a perimeter of 12 m. The length and breadth are a whole number of metres (e.g. 1 m, 2 m). How many different-sized tables are possible?

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2D Circumference and arc length REVISION

To find the distance around the outside of a circle (i.e. the circumference) we use the special number called pi (π). Pi provides a direct link between the diameter of a circle and the circumference of that circle.

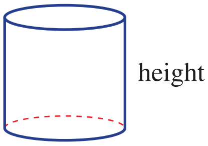
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

The wheel is one of the most useful components in many forms of machinery, and its shape, of course, is a circle. One revolution of a vehicle's wheel moves the vehicle a distance equal to the wheel's circumference.

Let's start: When circumference = height

Here is an example of a cylinder.

- Try drawing your own cylinder so that its height is equal to the circumference of the circular top.
- How would you check that you have drawn a cylinder with the correct dimensions? Discuss.

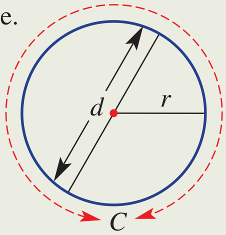


Key ideas

- The **radius** is the distance from the centre of a circle to a point on the circle.
- The **diameter** is the distance across a circle through its centre.
  - Radius $= \frac{1}{2}$ diameter *or* diameter $= 2 \times$ radius
- **Circumference** is the distance around a circle.
  - Circumference $= 2\pi \times$ radius
    $= 2\pi r$

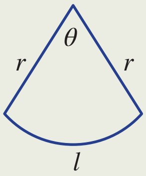
    or

    Circumference $= \pi \times$ diameter
    $= \pi d$



  - π is a special number and can be found on your calculator. It can be approximated by $\pi \approx 3.142$.
- A **sector** is the region inside a circle bounded by two radii and an arc.
  In the diagram:
  r = radius of circle
  θ = number of degrees in angle at centre of circle
  l = length of arc
  Formula for length of arc:

$$l = \frac{\theta}{360} \times 2\pi r$$



Radius The distance from the centre of a circle to its outside edge

Diameter A line passing through the centre of a circle with its end points on the circumference

Circumference The distance around the outside of a circle; the curved boundary

Sector A region bounded by two radii of a circle and the arc between them

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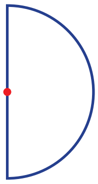
Exercise 2D REVISION

UNDERSTANDING AND FLUENCY	1, 2, 3–5(1/2)	3–5(½)

1 What fraction of a circle is shown here?

a



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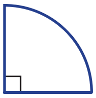

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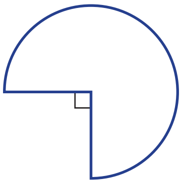


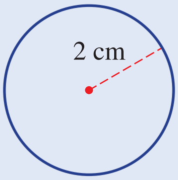
2 **a** What is the diameter of a circle if its radius is 4.3 m?

b What is the radius of a circle if its diameter is 3.6 cm?

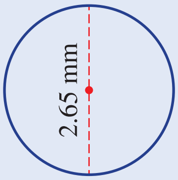
Example 10 Finding the circumference of a circle

Find the circumference of these circles, to 2 decimal places.

a



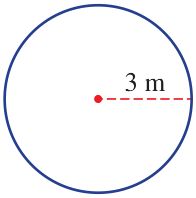
b



SOLUTION	EXPLANATION
a $C = 2\pi r$	Write the formula involving radius.
$= 2\pi(2)$	Substitute $r = 2$.
$= 12.57$ cm (to 2 d.p.)	Write your answer to 2 decimal places.
b $C = \pi d$	Write the formula involving diameter.
$= \pi(2.65)$	Substitute $d = 2.65$.
$= 8.33$ mm (to 2 d.p.)	Write your answer to 2 decimal places.

3 Find the circumference of these circles, to 2 decimal places.

a



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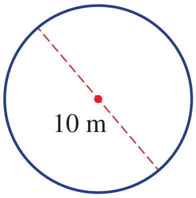
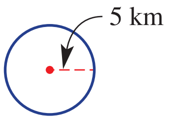


c



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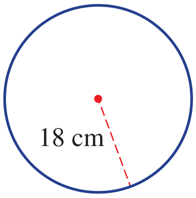

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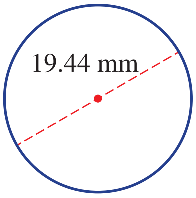

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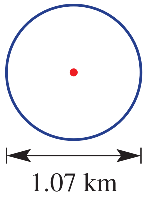

Use $C = 2\pi r$ or $C = \pi d$.

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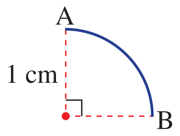
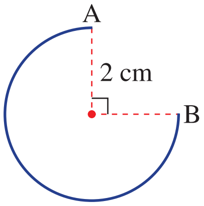
4 Find the length of arc AB (to 1 decimal place).

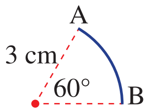
a



b

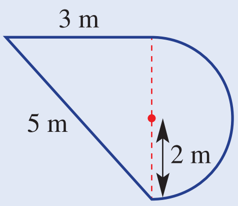


c



Example 11 Finding perimeters of composite shapes

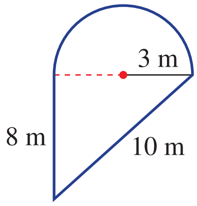
Find the perimeter of this composite shape, to 2 decimal places.



SOLUTION	EXPLANATION
$P = 3 + 5 + \frac{1}{2} \times 2\pi(2)$	Add all the sides, including half a circle.
$= 8 + 2\pi$	Simplify.
$= 14.28$ m (to 2 d.p.)	Round your answer as instructed.

5 Find the perimeter of these composite shapes, to 2 decimal places.

a



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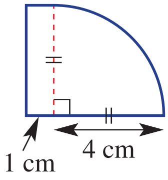
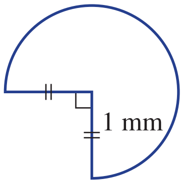
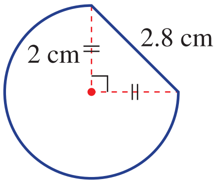


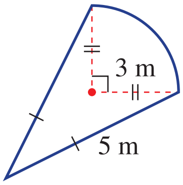
c



d



e



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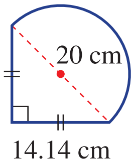

Don't forget to add the straight sides to the fraction $\left(\frac{1}{4}, \frac{1}{2} \text{ or } \frac{3}{4}\right)$ of the circumference.

PROBLEM-SOLVING AND REASONING		6–8	8, 9(1/2), 10

6 David wishes to build a circular fish pond. The diameter of the pond is to be 3 m.

a How many linear metres of bricks are needed to surround it? Round your answer to 2 decimal places.

b What is the cost if the bricks are $45 per metre? (Use your answer from part **a**.)

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7 The wheels of a bike have a diameter of 1 m.

a How many metres will the bike travel (to 2 decimal places) after:

  i one full turn of the wheels?

  ii 15 full turns of the wheels?

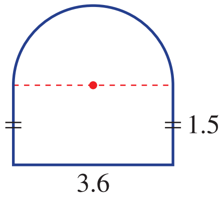
b How many kilometres will the bike travel after 1000 full turns of the wheels? (Give your answer correct to 2 decimal places.)

For one revolution, use $C = \pi d$.

8 What is the minimum number of times a wheel of diameter 1 m needs to spin to cover a distance of 1 km? You will need to find the circumference of the wheel first. Answer as a whole number.

9 Find the perimeter of these composite shapes, correct to 2 decimal places.

a



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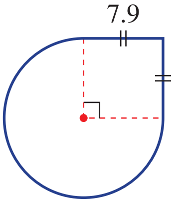
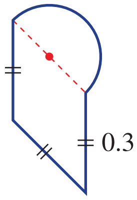
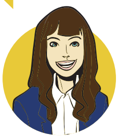


c



Make sure you know the radius or diameter of the circle you are dealing with.



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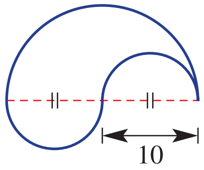

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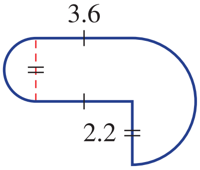

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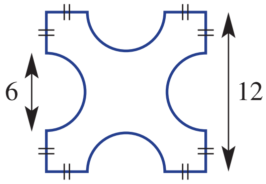


10 **a** Rearrange the formula for the circumference of a circle, $C = 2\pi r$, to write r in terms of C.

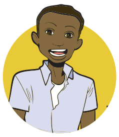
b Find, to 2 decimal places, the radius of a circle with the given circumference.

  i 35 cm

  ii 1.85 m

  iii 0.27 km

To make r the subject, divide both sides by 2π.



ENRICHMENT – 11

Target practice

11 A target is made up of three rings, as shown.

a Find the radius of the smallest ring.

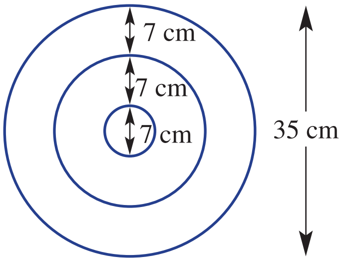
b Find, to 2 decimal places, the circumference of:

  i the smallest ring

  ii the middle ring

  iii the outside ring

c If the circumference of a different ring was 80 cm, what would be its radius, to 2 decimal places?



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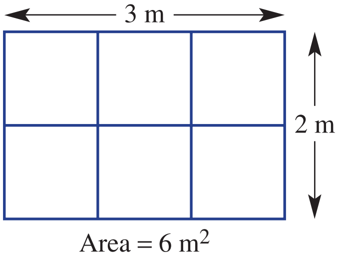
2E Area of triangles and quadrilaterals REVISION

Interactive
Widgets
HOTsheets
Walkthrough

In this simple diagram, a rectangle with side lengths 2 m and 3 m has an area of 6 square metres or 6 m². This is calculated by counting the number of squares (each a square metre) that make up the rectangle.

We use formulas to help us quickly count the number of square units contained within a shape. For this rectangle, for example, the formula $A = lb$ simply tells us to multiply the length by breadth to find the area.

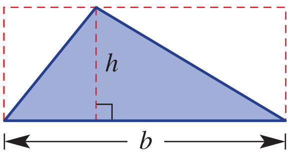


Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: How does $A = \frac{1}{2}bh$ work for a triangle?

Look at this triangle, including its rectangular red dashed lines.

- How does the shape of the triangle relate to the shape of the outside rectangle?
- How can you use the formula for a rectangle to help find the area of the triangle (or parts of the triangle)?
- Why is the rule for the area of a triangle given by $A = \frac{1}{2}bh$?

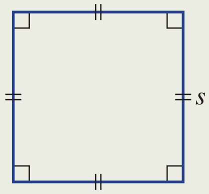


Key ideas

- The **area** of a two-dimensional shape is the number of square units contained within its boundaries.
- Some of the common area formulas are as follows.

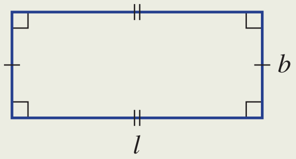
Area The number of square units needed to cover the space inside the boundaries of a 2D shape

Square



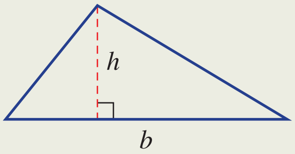
Area $= s^2$

Rectangle

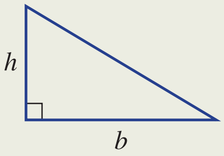


Area $= lb$

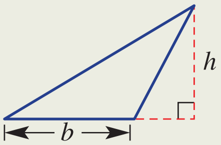
Triangle



Area $= \frac{1}{2}bh$



Area $= \frac{1}{2}bh$



Area $= \frac{1}{2}bh$

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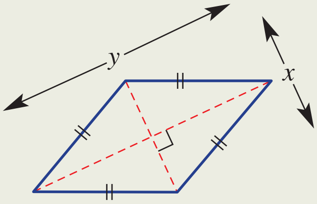
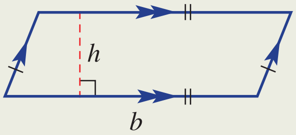
Key ideas

Rhombus



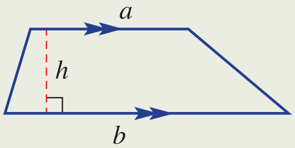
Area = $\frac{1}{2}xy$

Parallelogram



Area = bh

Trapezium



Area = $\frac{1}{2}h(a + b)$

- The 'height' in a triangle, parallelogram or trapezium should be perpendicular (i.e. at 90°) to the base.

Exercise 2E REVISION

UNDERSTANDING AND FLUENCY		
	1–4	3, 4

1 Match each shape (**a**–**f**) with its area formula (**A**–**F**).

a square

b rectangle

c rhombus

d parallelogram

e trapezium

f triangle

A $A = \frac{1}{2}bh$

B $A = lb$

C $A = bh$

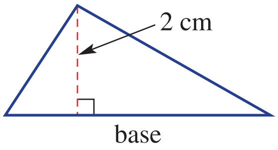
D $A = \frac{1}{2}h(a + b)$

E $A = s^2$

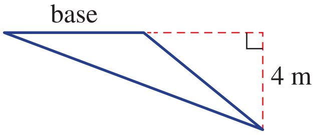
F $A = \frac{1}{2}xy$

2 These shapes show the base and a height length. What is the height of each shape?

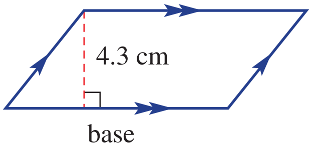
a



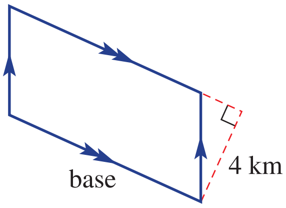
b



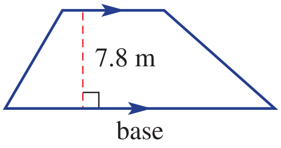
c



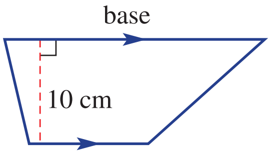
d



e



f



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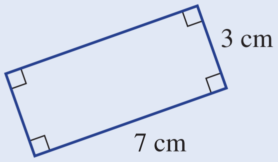
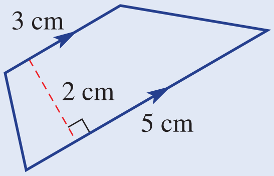
Example 12 Using area formulas

Find the area of these basic shapes.

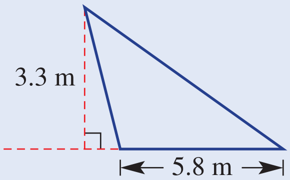
a



b



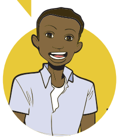
c



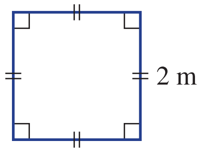
SOLUTION	EXPLANATION
a $\text{Area} = lb$	Write the formula for a rectangle.
$= 7 \times 3$	Substitute the lengths $l = 7$ and $b = 3$.
$= 21\text{ cm}^2$	Simplify and add the units.
b $\text{Area} = \frac{1}{2}h(a + b)$	Write the formula for a trapezium.
$= \frac{1}{2} \times 2 \times (3 + 5)$	Substitute the lengths $a = 3$, $b = 5$ and $h = 2$.
$= 8\text{ cm}^2$	Simplify and add the units.
c $\text{Area} = \frac{1}{2}bh$	Write the formula for a triangle.
$= \frac{1}{2}(5.8)(3.3)$	Substitute the lengths $b = 5.8$ and $h = 3.3$.
$= 9.57\text{ m}^2$	Simplify and add the units.

3 Find the area of these basic shapes.

First choose the correct formula and substitute for each pronumeral (letter).



a



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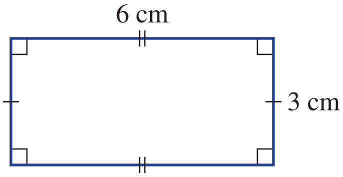

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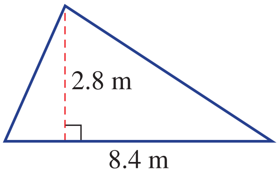
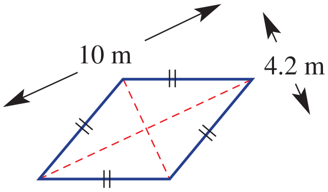


d



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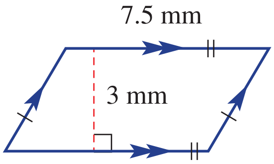

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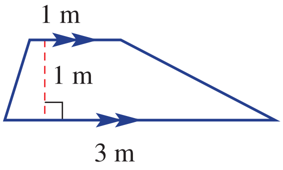
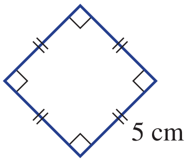


4 Find the area of these basic shapes, rounding to 2 decimal places where necessary.

a



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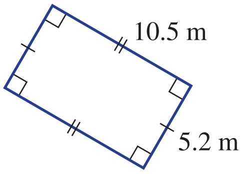

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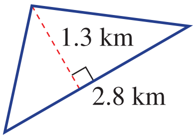
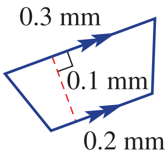


d



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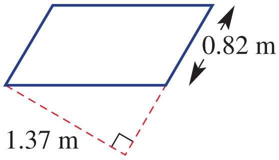

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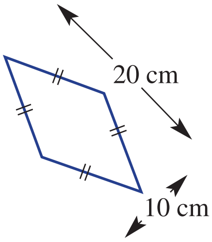


PROBLEM-SOLVING AND REASONING		5–8	8–11

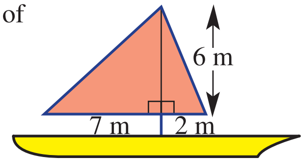
5 A rectangular table top is 1.2 m long and 80 cm wide. Find the area of the table top using:

a square metres (m^2)

b square centimetres (cm^2)

First convert to the units that you wish to work with.

6 Two triangular sails have side lengths as shown. Find the total area of the two sails.

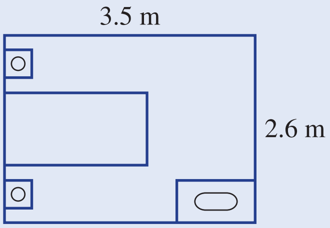


Example 13 Finding areas of floors

Christine decides to use carpet squares to cover the floor of her bedroom, shown at right. Determine:

a the area of floor to be covered

b the total cost if the carpet squares cost \$32 a square metre



SOLUTION

a Area of floor $= l \times b$

$= 3.5 \times 2.6$

$= 9.1\ \text{m}^2$

b Cost of carpet squares $= 9.1 \times 32$

$= \$291.20$

EXPLANATION

The room is a rectangle, so use $A = l \times b$ to calculate the total floor space.

Every square metre of carpet squares costs \$32.

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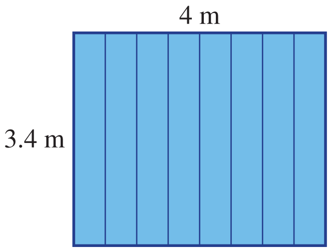
7 Jack's shed is to have a flat roof, which he decides to cover with metal sheets.

a Determine the total area of the roof.

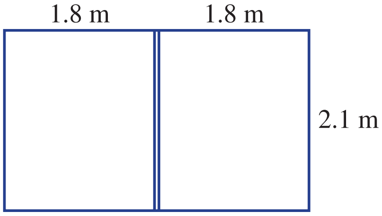
b If the metal roofing costs $11 a square metre, how much will it cost in total?



8 A sliding door has two glass panels. Each of these is 2.1 m high with a breadth of 1.8 m.

a How many square metres of glass are needed?

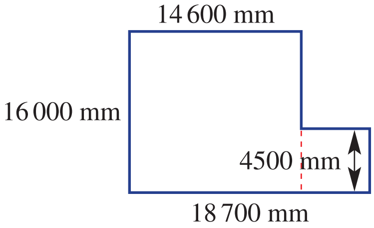
b What is the total cost of the glass if the price is $65 per square metre?



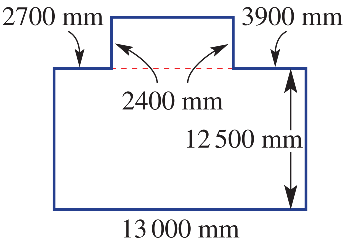
9 A rectangular window has a whole number measurement for its length and breadth and its area is 24 m^2. Write down the possible lengths and breadths for the window.

10 Determine the area of the houses shown, in square metres (correct to 2 decimal places).

a



b



Note that there are 1000 mm in 1 m. Use the red lines to break up shapes into two rectangles.

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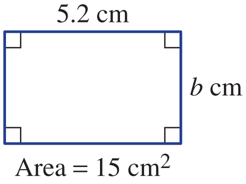
11 Find the value of the pronumeral in these shapes, rounding to 2 decimal places each time.

a



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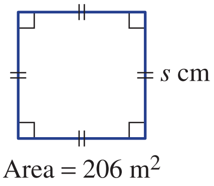
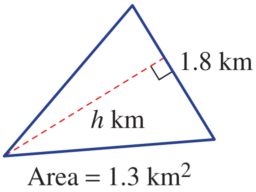
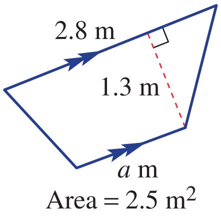


If $x \times 2 = 15$, then $x = \frac{15}{2} = 7.5$.

c

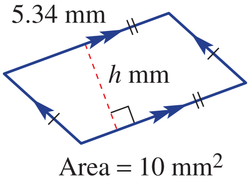


d



Write out the formula, then substitute the known values.

e



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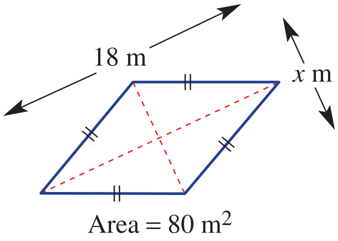
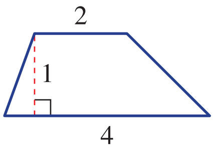


ENRICHMENT – 12

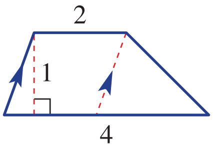
Four ways to find the area of a trapezium

12 Find the area of the trapezium, using each of the suggested methods.

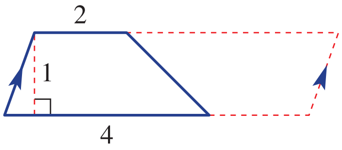
a formula $A = \frac{h}{2}(a + b)$



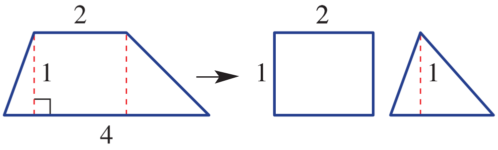
b parallelogram and triangle



c half parallelogram



d rectangle + triangle



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2F Area of circles and sectors REVISION

Interactive

Widgets

HOTsheets

Walkthrough

Like its circumference, a circle's area is linked to the special number pi (π). The area is the product of pi and the square of the radius, so $A = \pi r^2$.

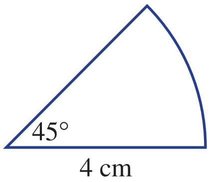
Knowing the formula for the area of a circle helps us to build circular garden beds, plan water sprinkler systems and estimate the damage caused by an oil slick from a ship in calm seas.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: What fraction is that?

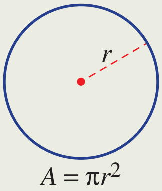
When finding areas of sectors, first we need to decide what fraction of a circle we are dealing with. This sector, for example, has a radius of 4 cm and a 45° angle.

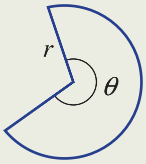
- What fraction of a full circle is shown in this sector?
- How can you use this fraction to help find the area of this sector?
- How would you set out your working?



Key ideas

- The formula for finding the area (A) of a circle of radius r is given by the equation $A = \pi r^2$.
- If the diameter (d) of the circle is given, determine the radius before calculating the area of the circle: $r = d \div 2$.
- The area of a sector is given by $A = \dfrac{\theta}{360} \times \pi r^2$, where $\dfrac{\theta}{360}$ represents the fraction of a full circle.



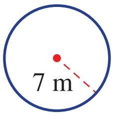


Exercise 2F REVISION

UNDERSTANDING AND FLUENCY	1–3, 4–5(1/2)	3–5(½)

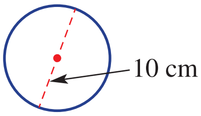
1 Which is the correct working step for the area of this circle?

A $A = \pi(7)$ **B** $A = 2\pi(7)$ **C** $A = \pi(14)^2$ **D** $A = (\pi 7)^2$ **E** $A = \pi(7)^2$



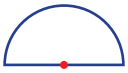
2 Which is the correct working step for the area of this circle?

A $A = \pi(10)^2$ **B** $A = \pi(10)^2$ **C** $A = \pi(5)^2$ **D** $A = 2\pi(5)$ **E** $A = 5\pi$



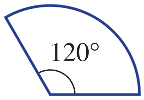
3 What fraction of a circle is shown by these sectors? Simplify your fraction.

a

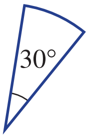


b

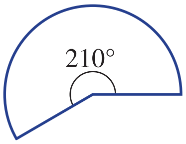
c



d



e



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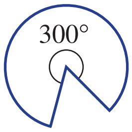
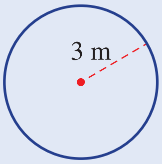


A full circle has 360°.

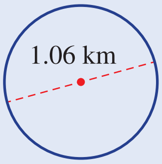
Example 14 Finding areas of circles

Find the area of these circles, correct to 2 decimal places.

a



b

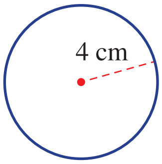


SOLUTION	EXPLANATION
a $A = \pi r^2$	Write the formula.
$= \pi(3)^2$	Substitute $r = 3$. Evaluate $3^2 = 9$, then multiply by π.
$= \pi \times 9$	
$= 28.27\text{ m}^2$ (to 2 d.p.)	Round your answer as required.
b Radius, $r = 1.06 \div 2 = 0.53$ km	Find the radius, given that the diameter is 1.06.
$A = \pi r^2$	Write the formula.
$= \pi(0.53)^2$	Substitute $r = 0.53$.
$= 0.88\text{ km}^2$ (to 2 d.p.)	Write your answer to 2 decimal places, with units.

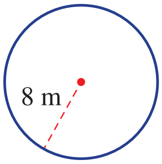
4 Find the area of these circles, correct to 2 decimal places.

Remember: $r = d \div 2$

a



b



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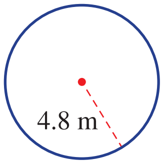
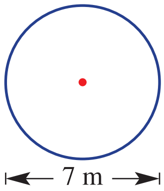
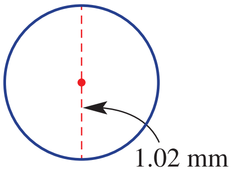


d



e



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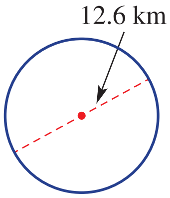

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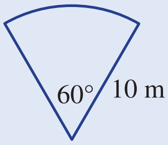
Example 15 Finding areas of sectors

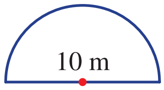
Find the area of this sector, correct to 2 decimal places.



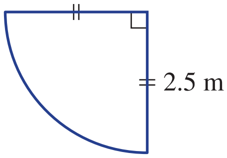
SOLUTION	EXPLANATION
Fraction of circle $= \frac{60}{360} = \frac{1}{6}$	The sector uses 60° out of the 360° in a whole circle.
Area $= \frac{1}{6} \times \pi r^2$	Write the formula, including the fraction part.
$= \frac{1}{6} \times \pi(10)^2$	Substitute $r = 10$.
$= 52.36\ \text{m}^2$ (to 2 d.p.)	Write your answer to 2 decimal places.

5 Find the area of these sectors, correct to 2 decimal places.

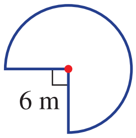
a



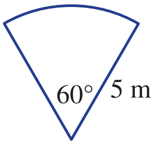
b



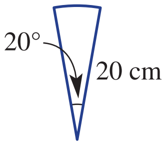
c



d



e



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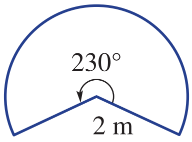
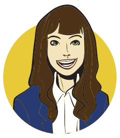


First determine the fraction of a full circle that you are dealing with.



PROBLEM-SOLVING AND REASONING 6–8 7–9

6 A pizza with diameter 40 cm is divided into eight equal parts. Find the area of each portion, correct to 1 decimal place.

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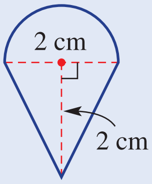
Example 16 Finding areas of composite shapes

Find the area of this composite shape, correct to 2 decimal places.



SOLUTION

$$\begin{aligned} A &= \frac{1}{2}\pi r^2 + \frac{1}{2}bh \\ &= \frac{1}{2}\pi(1)^2 + \frac{1}{2}(2)(2) \\ &= 1.5707\ldots + 2 \\ &= 3.57 \text{ cm}^2 \text{ (to 2 d.p.)} \end{aligned}$$

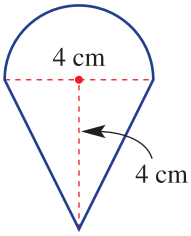
EXPLANATION

The shape is made up of a semicircle and a triangle.
Write the formulas for both.
Substitute $r = 1$, $b = 2$ and $h = 2$.

Write your answer to 2 decimal places, with units.

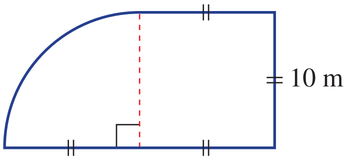
7 Find the area of these composite shapes, correct to 2 decimal places.

a



Find the area of each shape within the larger shape, then add them; e.g. triangle + semicircle.

b



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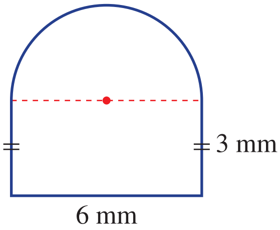
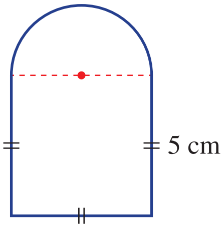


8 The lawn area in a backyard is made up of a semicircular region with diameter 6.5 m and a triangular region of length 8.2 m, as shown. Find the total area of lawn in the backyard, correct to 2 decimal places.

9 Find the area of these composite shapes, correct to 1 decimal place.

a



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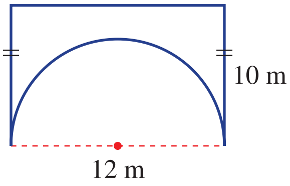

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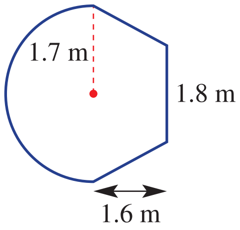

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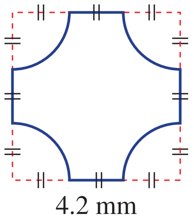

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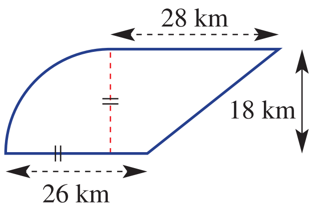

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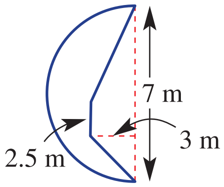
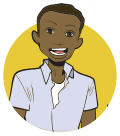


Use addition or subtraction, depending on the shape given.

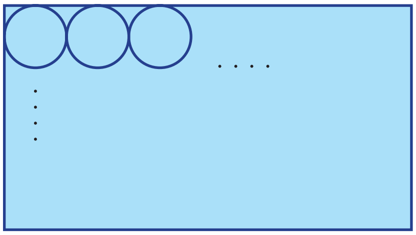


Four equal quarter circles make up the area of *one* full circle.

ENRICHMENT – 10

Circular pastries

10 A rectangular piece of pastry is used to create small circular pastry discs for the base of Christmas tarts. The rectangular piece of pastry is 30 cm long, 24 cm in breadth and each circular piece has a diameter of 6 cm.



- **a** How many circular pieces of pastry can be removed from the rectangle?
- **b** Find the total area removed from the original rectangle, correct to 2 decimal places.
- **c** Find the total area of pastry remaining, correct to 2 decimal places.
- **d** If the remaining pastry was collected and re-rolled to the same thickness, how many circular pieces could be cut? Assume that the pastry can be re-rolled many times.

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2G Surface area of prisms

Interactive

Widgets

HOTsheets

Walkthrough

The surface area of a three-dimensional object can be found by finding the sum of the areas of each of the shapes that make up the surface of the object.

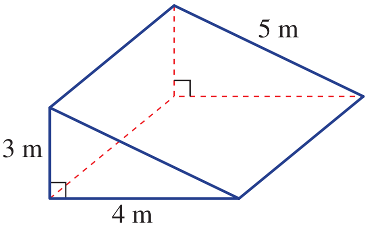
Stage

- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

Let's start: Which net?

The solid below is a triangular prism with a right-angled triangle as its cross-section.

- How many different types of shapes make up its outside surface?
- What is a possible net for the solid? Is there more than one?
- How would you find the surface area of the solid?



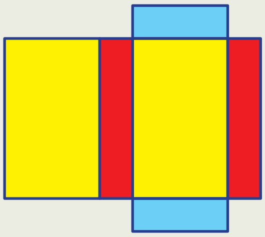
It is very common to use rectangular prisms for food packaging.

Key ideas

- To calculate the **Surface area (*A*)** of a solid:
  - Draw a net (a two-dimensional drawing including all the surfaces).
  - Determine the area of each shape inside the net.
  - Add the areas of each shape together.

Shape

Net



Surface area (*A*) The total number of square units needed to cover the outside of a solid

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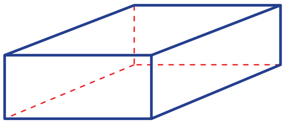
Exercise 2G

UNDERSTANDING AND FLUENCY 1–4 3–5

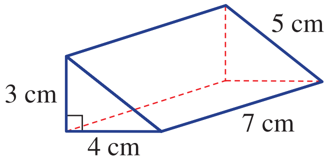
1 For a rectangular prism, answer the following.

- **a** How many faces does the prism have?
- **b** How many *different* rectangles form the surface of the prism?



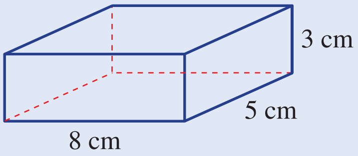
2 For this triangular prism, answer the following.

- **a** What is the area of the largest surface rectangle?
- **b** What is the area of the smallest surface rectangle?
- **c** What is the combined area of the two triangles?
- **d** What is the surface area?

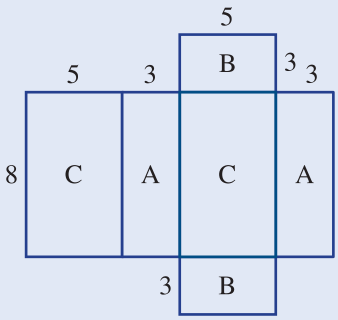


Example 17 Finding the surface area of a rectangular prism

Find the surface area (A) of this rectangular prism by first drawing its net.



SOLUTION



$$A = 2 \times \text{area of A} + 2 \times \text{area of B} + 2 \times \text{area of C}$$
$$= 2 \times (8 \times 3) + 2 \times (5 \times 3) + 2 \times (8 \times 5)$$
$$= 158\text{ cm}^2$$

EXPLANATION

Draw the net of the solid, labelling the lengths and shapes of equal areas.

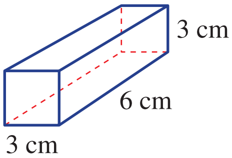
Describe each area.

Substitute the correct lengths.

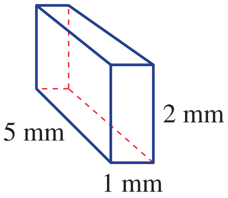
Simplify and add units.

3 Find the surface area (A) of these rectangular prisms by first drawing their nets.

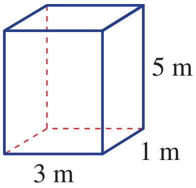
a



b

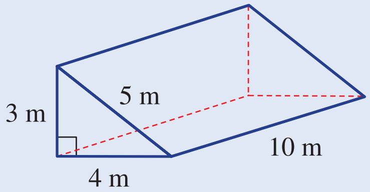


c

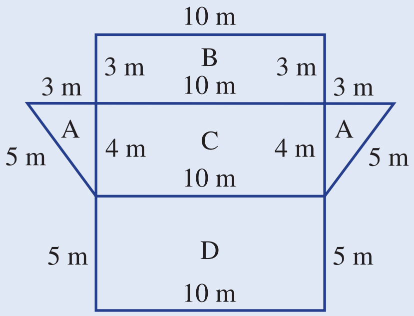


Example 18 Finding the surface area of a triangular prism

Find the surface area of the triangular prism shown.



SOLUTION



$A = 2 \times \text{area A} + \text{area B} + \text{area C} + \text{area D}$

$= 2 \times \left(\frac{1}{2} \times 3 \times 4\right) + (3 \times 10) + (4 \times 10) + (5 \times 10)$

$= 12 + 30 + 40 + 50$

$= 132\ \text{m}^2$

EXPLANATION

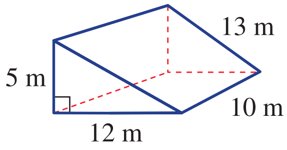
Draw a net of the object with all the measurements and label the sections to be calculated.

There are two triangles with the same area and three different rectangles. Substitute the correct lengths.

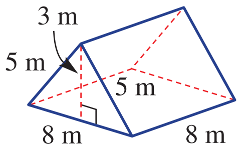
Calculate the area of each shape.
Add the areas together.

4 Find the surface area of the following prisms.

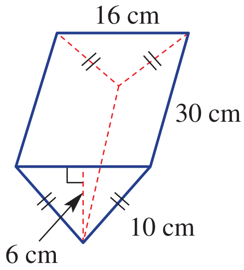
a



b



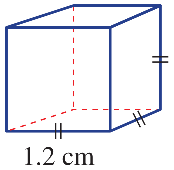
c



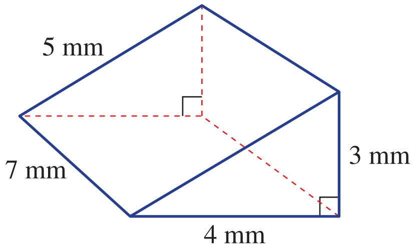
For part **c**, notice that there are three rectangles and two identical triangles.

5 Find the surface area of these prisms by first drawing a net.

a



b



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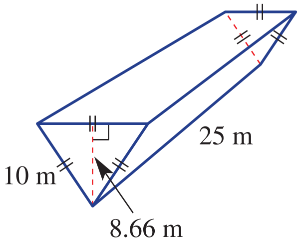
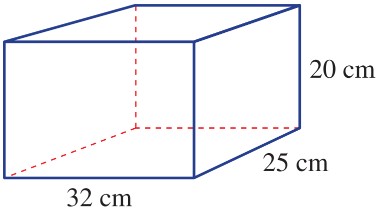


PROBLEM-SOLVING AND REASONING 6–8 8–11

6 A cube with side lengths 8 cm is to be painted all over with bright red paint. What is the surface area that is to be painted?

7 What is the minimum amount of paper required to wrap a box with dimensions of breadth 25 cm, length 32 cm and height 20 cm?



8 An open-topped box is to be covered inside and out with a special material. If the box has length 40 cm, breadth 20 cm and height 8 cm, find the minimum amount of material required to cover the box.

Count both inside and out but do not include the top.

9 David wishes to paint his bedroom. The ceiling and walls are to be the same colour. If the room measures 3.3 m × 4 m and the ceiling is 2.6 m high, find the amount of paint needed:

a if each litre covers 10 square metres

b if each litre covers 5 square metres

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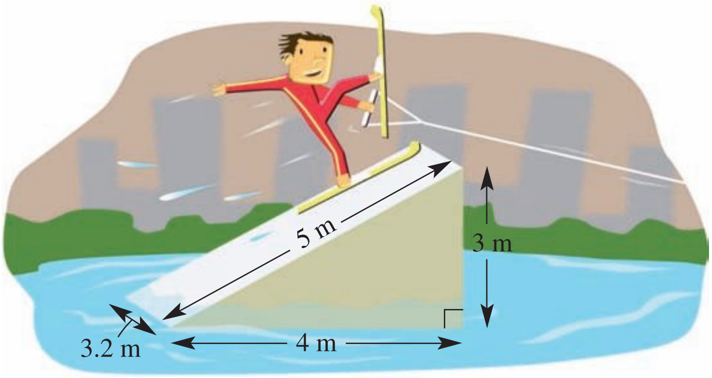
10 A ski ramp in the shape of a triangular prism needs to be painted before the Moomba Classic waterskiing competition in Melbourne. The base and sides of the ramp require a fully waterproof paint, which covers 2.5 square metres per litre. The top needs special smooth paint, which covers only 0.7 square metres per litre.

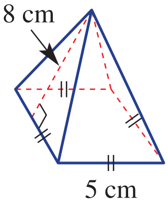


a Determine the amount of each type of paint required. Round your answer to 2 decimal places where necessary.

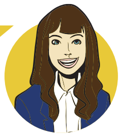
b If the waterproof paint is \$7 per litre and the special smooth paint is \$20 per litre, calculate the total cost of painting the ramp, to the nearest cent. (Use the exact answers from part **a** to help.)

11 Find the surface area (A) of these square-based pyramids.

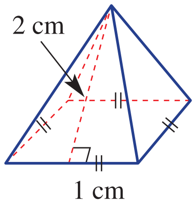
a



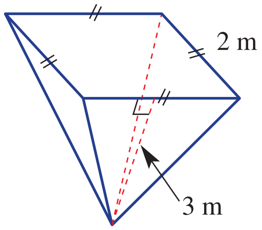
There is one square and four identical triangles.



b



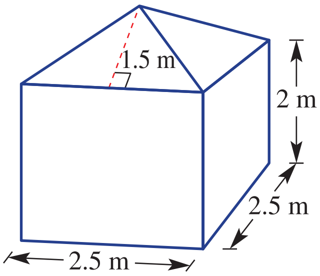
c



ENRICHMENT – 12

Will I have enough paint?

12 I have 6 litres of paint and on the tin it says that the coverage is 5.5 m^2 per litre. I wish to paint the four outside walls of a shed and the roof, which has four triangular sections. Will I have enough paint to complete the job?



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2H Surface area of cylinders

Interactive
Widgets
HOTsheets
Walkthrough

Like a prism, a cylinder has a uniform cross-section with identical discs at both ends. The curved surface of a cylinder can be rolled out to form a rectangle with a length equal to the circumference of the circle.

A can is a good example of a cylinder. We need to know the area of the ends and the curved surface area in order to cut sections from a sheet of aluminium to manufacture the can.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

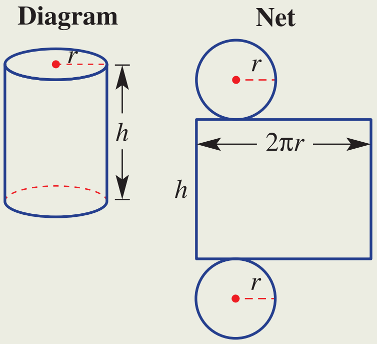
Let's start: Why $2\pi rh$?

We can see from the net of a cylinder (see Key ideas below) that the total area of the two circular ends is $2 \times \pi r^2$ or $2\pi r^2$. For the curved part, though, consider the following.

- Why can it be drawn as a rectangle? Can you explain this using a piece of paper?
- Why are the dimensions of this rectangle h and $2\pi r$?
- Where does $A = 2\pi r^2 + 2\pi rh$ come from?

Key ideas

- A **cylinder** is a solid with a circular cross-section.
  - The net contains two circular ends and a rectangle. The rectangle has one side length equal to the circumference of the circle.
  - $A = 2$ circles $+ 1$ rectangle
    $= 2\pi r^2 + 2\pi rh$
  - Another way of writing $2\pi r^2 + 2\pi rh$ is $2\pi r(r + h)$.



Exercise 2H

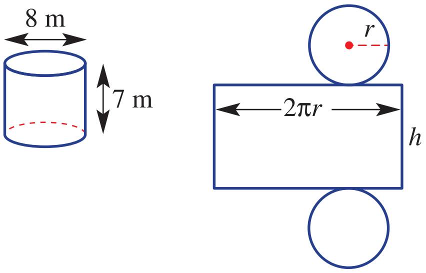
UNDERSTANDING AND FLUENCY	1, 2, 3(1/2), 4, 5	2, 3(1/2), 4, 5

1 Write the missing word/expression.

a The cross-section of a cylinder is a __________.

b The surface area of a cylinder is $A = 2\pi r^2 +$ __________.

2 A cylinder and its net are shown here.



a What is the value of:

i r?

ii h?

b Find the value of $2\pi r$, correct to 2 decimal places.

c Use $A = 2\pi r^2 + 2\pi rh$ to find the surface area, correct to 2 decimal places.

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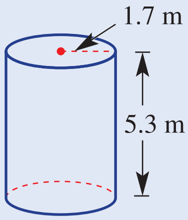
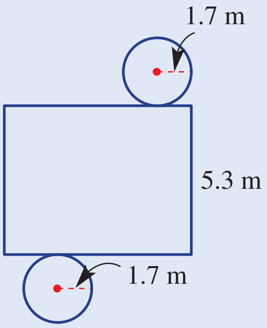
Example 19 Finding the surface area of a cylinder

By first drawing a net, find the surface area of this cylinder, to 2 decimal places.



SOLUTION



$A = 2$ discs $+$ 1 rectangle
$= 2\pi r^2 + 2\pi rh$
$= 2\pi(1.7)^2 + 2\pi(1.7)(5.3)$
$= 74.77\ \text{m}^2$ (to 2 d.p.)

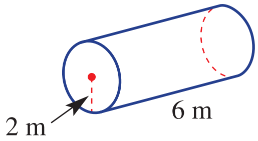
EXPLANATION

Draw the net and label the lengths.

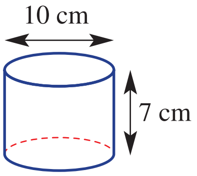
Write what you need to calculate.
Write the formula.
Substitute the correct lengths: $r = 1.7$ and $h = 5.3$.
Round your answer to 2 decimal places.

3 By first drawing a net, find the total surface area of these cylinders, to 2 decimal places.

a

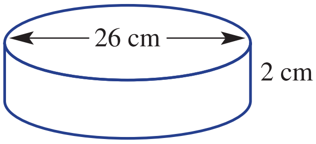


b

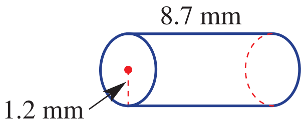


Remember that radius = diameter ÷ 2.

c

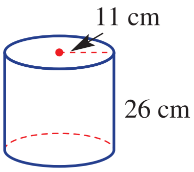


d



4 Use the formula $A = 2\pi r^2 + 2\pi rh$ to find the surface area of these cylinders, to 1 decimal place.

a



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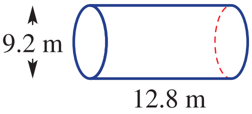

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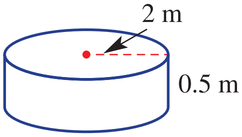
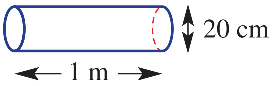
5 Find the area of only the curved surface of these cylinders, to 1 decimal place.

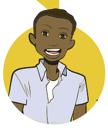
a



b



Find only the rectangular part of the net, so use $A = 2\pi rh$. Watch the units.



PROBLEM-SOLVING AND REASONING

6, 7 | 8, 9

6 Find the outer surface area of a pipe of radius 85 cm and length 4.5 m, to 1 decimal place. Answer in m^2.

7 The base and sides of a circular cake tin are to be lined on the inside with baking paper. The tin has a base diameter of 20 cm and is 5 cm high. What is the minimum amount of baking paper required, to 1 decimal place?

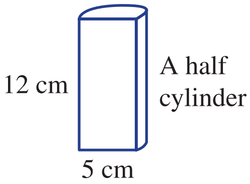
What parts of the formula do you need?

8 The inside and outside of an open-topped cylindrical concrete tank is to be coated with a special waterproofing paint. The tank has diameter 4 m and height 2 m. Find the total area to be coated with the paint. Round your answer to 1 decimal place.

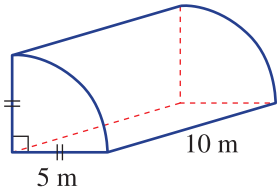
Include the base but not the top.

9 Find the surface area of these cylindrical portions, to 1 decimal place.

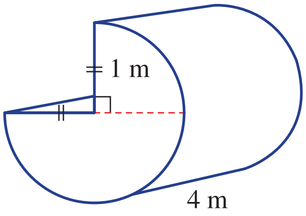
a



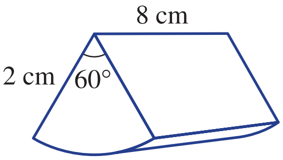
b



c



d



Carefully consider the fraction of a circle made up by the ends, and the fraction of a full cylinder made up by the curved part. You will also need to include any rectangular surfaces created.

ENRICHMENT

– | 10

The steam roller

10 A steamroller has a large, heavy cylindrical barrel that has a breadth of 4 m and a diameter of 2 m.

- **a** Find the area of the curved surface of the barrel, to 2 decimal places.
- **b** After 10 complete turns of the barrel, how much ground would be covered, to 2 decimal places?
- **c** Find the circumference of one end of the barrel, to 2 decimal places.
- **d** How many times would the barrel turn after 1 km of distance, to 2 decimal places?
- **e** What area of ground would be covered if the steamroller travelled 1 km?

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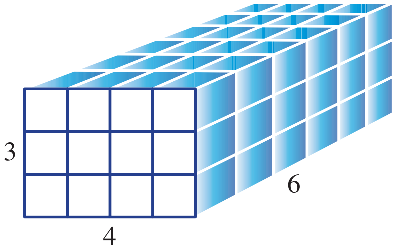
2I Volume of prisms and cylinders

Interactive
Widgets
HOTsheets
Walkthrough

The volume of a solid is the amount of space it occupies within its outside surface. It is measured in cubic units.

For solids with a uniform cross-section, the area of the cross-section multiplied by the perpendicular height gives the volume. Consider the rectangular prism below.

Number of cubic units (base) $= 4 \times 6 = 24$
Area (base) $= 4 \times 6 = 24$ units^2
Volume $=$ area (base) $\times 3 = 24 \times 3 = 72$ units^3



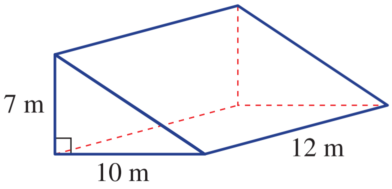
Knowing how to calculate volume is important in the shipping industry.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Volume of a triangular prism

This prism has a triangular cross-section.

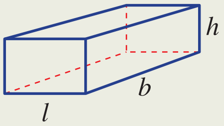
- What is the area of the cross-section?
- What is the 'height' of the prism?
- How can the formula $V = A \times h$ be applied to this prism, where A is the area of the cross-section?



Key ideas

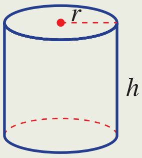
- The **volume** of a solid with a uniform cross-section is given by $V = A \times h$, where:
  A is the area of the cross-section.
  h is the perpendicular (at 90°) height.

Rectangular prism



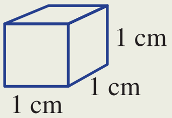
$$V = A \times h$$
$$= lbh$$

Cylinder



$$V = A \times h$$
$$= \pi r^2 h$$

- One cubic centimetre holds one millilitre.



1 cm^3 holds 1 mL

Volume The amount of three-dimensional space within an object

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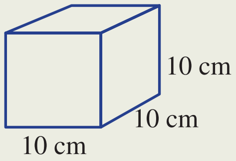
Key ideas

- This cube holds one litre.



1 L = 1000 mL

- One cubic metre holds 1000 litres.

Exercise 2I

UNDERSTANDING AND FLUENCY	1–6	3–5, 7

1 Match the solid (**a**–**c**) with the volume formula (**A**–**C**).

a cylinder	**A** $V = lbh$
b rectangular prism	**B** $V = \frac{1}{2}bh \times \text{length}$
c triangular prism	**C** $V = \pi r^2 h$

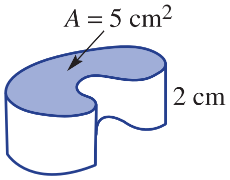
2 Write the missing number.

a There are ________ mL in 1 L.

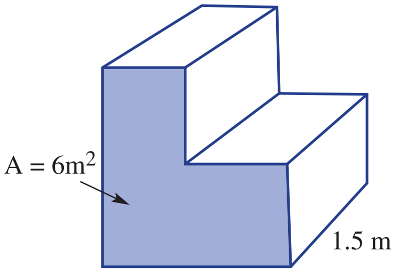
b There are ________ cm^3 in 1 L.

3 The area of the cross-section of this solid is given. Find the solid's volume using $V = A \times h$.

a

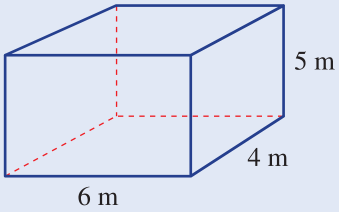


b



Example 20 Finding the volume of a rectangular prism

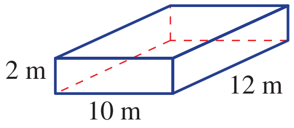
Find the volume of this rectangular prism.



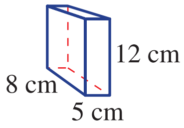
SOLUTION	EXPLANATION
$V = A \times h$	Write the general formula.
$= 6 \times 4 \times 5$	$A = l \times b = 6 \times 4$, and $h = 5$.
$= 120\ \text{m}^3$	Simplify and add units.

4 Find the volume of these rectangular prisms.

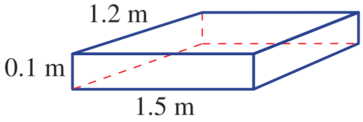
a

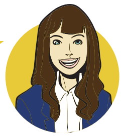


b



c

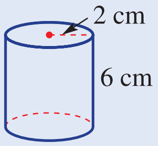




Use $V = lbh$.

Example 21 Finding the volume of a cylinder

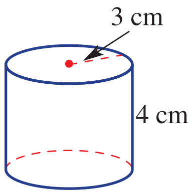
Find the volume of this cylinder, correct to 2 decimal places.



SOLUTION	EXPLANATION
$V = A \times h$	Write the general formula.
$= \pi r^2 \times h$	The cross-section is a circle.
$= \pi(2)^2 \times 6$	Substitute $r = 2$ and $h = 4$.
$= 75.40\text{ cm}^3$ (to 2 d.p.)	Simplify and write your answer as an approximation, with units.

5 Find the volume of these cylinders, correct to 2 decimal places.

a



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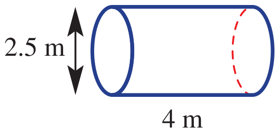

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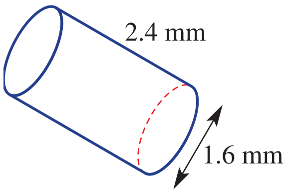
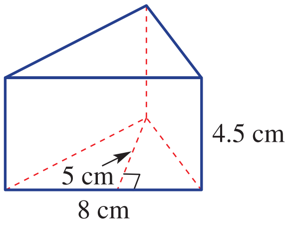


$V = \pi r^2 \times h$

6 A triangle with base 8 cm and height 5 cm forms the base of a prism, as shown. If the prism stands 4.5 cm high, find:

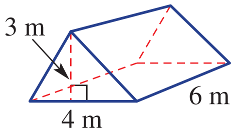
a the area of the triangular base

b the volume of the prism



7 Find the volume of these triangular prisms.

a



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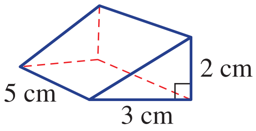

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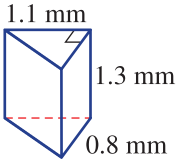
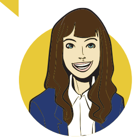


Use $V = A \times h$, where A is the area of a triangle.

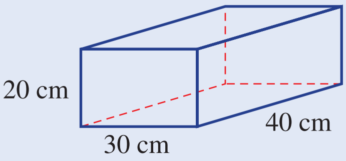


PROBLEM-SOLVING AND REASONING	8–10	9, 10(1/2), 11, 12

8 A cylindrical drum stands on one end with a diameter of 25 cm and water is filled to a height of 12 cm. Find the volume of water in the drum, in cm^3, correct to 2 decimal places.

Example 22 Working with capacity

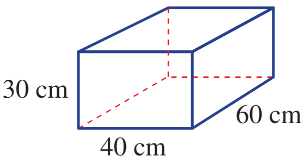
Find the number of litres of water that this container can hold.



SOLUTION	EXPLANATION
$V = 30 \times 40 \times 20$	First work out the volume in cm^3.
$= 24000\text{ cm}^3$	Then divide by 1000 to convert to litres, since
$= 24\text{ L}$	1 cm^3 = 1 mL and there are 1000 mL in 1 litre.

9 Find the number of litres of water that these containers can hold.

a



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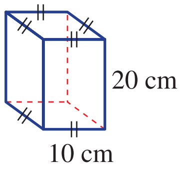

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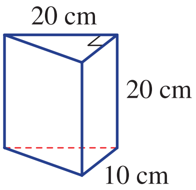
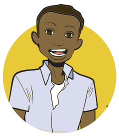
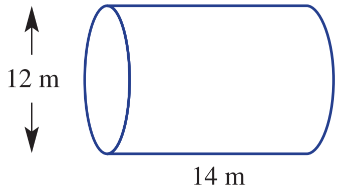


Use 1 L = 1000 cm^3.



10 Find the volume of these prisms, rounding your answers to 2 decimal places where necessary.

a



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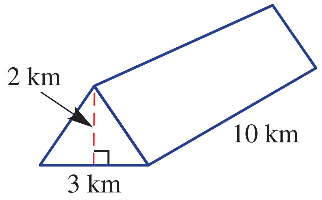
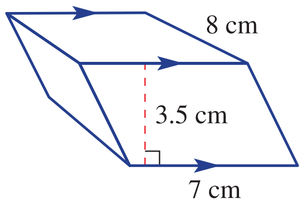


Find the area of the cross-section first.

c



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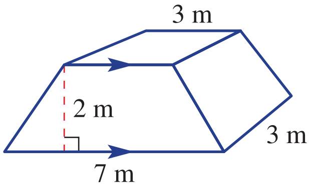
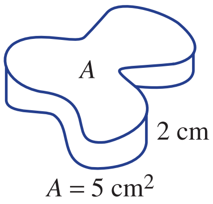


e



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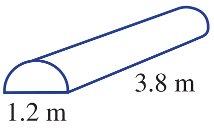
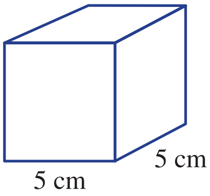
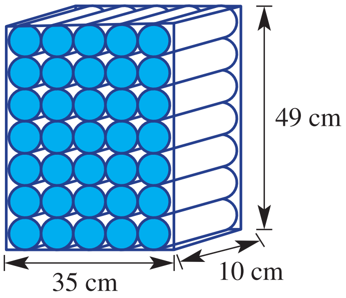


11 100 cm^3 of water is to be poured into this cube.



a Find the area of the base of the container.
b Find the depth of water in the container.

12 In a scientific experiment, solid cylinders of ice are removed from a solid block carved out of a glacier. The ice cylinders have diameter 7 cm and length 10 cm. The dimensions of the solid block are shown in the diagram.



a Find the volume of ice in the original ice block.
b Find the volume of ice in one ice cylinder, to 2 decimal places.
c Find the number of ice cylinders that can be removed from the ice block using the configuration shown.
d Find the volume of ice remaining after the ice cylinders are removed from the block, to 2 decimal places.

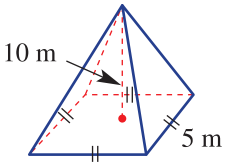
ENRICHMENT		–	13

Volume of pyramids and cones

13 The volume of a pyramid or cone is exactly one-third the volume of the prism with the same base area and height; i.e. $V = \frac{1}{3} \times A \times h$.

Find the volume of these pyramids and cones. Round to 1 decimal place where necessary.

a



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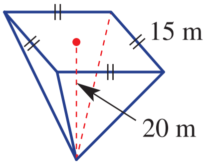

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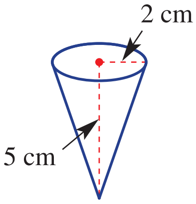

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2J Further problems involving surface area, volume and capacity of solids

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

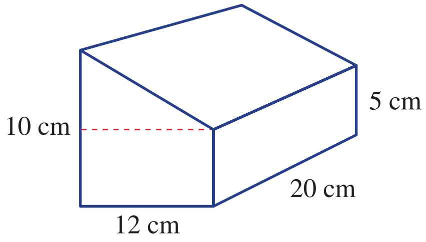
Recall that when working with composite shapes we can find perimeters and areas by considering the combination of the more basic shapes that, together, form the composite shape. Similarly, we can work with composite solids by looking at the combination of more basic solids, like prisms and cylinders. This leads to finding surface areas, volumes and capacity of solids.

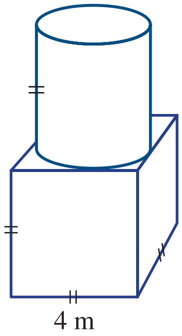
The well-known European artists Christo and Jeanne-Claude had their hands full with composite objects when they wrapped the Reichstag (Parliament building), Berlin in 1995. They used more than 100 000 square metres of fabric and 15 km of rope.

The German parliament, the Reichstag, was wrapped in fabric in 1995 to create a temporary work of art.

Let's start: Which solids?

Look at these composite solids.





- What are the basic solids that make up each composite solid?
- Explain a method for finding the volume of each solid.
- Explain a method for finding the surface area of each solid.
- Is there enough information provided in each diagram to find the volume and surface area? Discuss.

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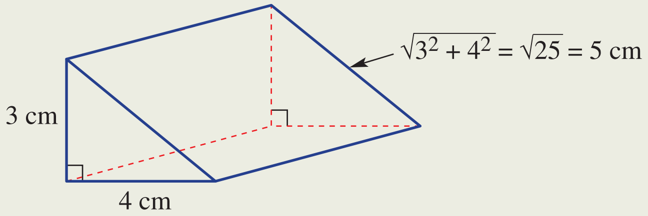
Key ideas

- Composite solids are made up of more than one basic solid.
- Volumes and surface areas of composite solids can be found by considering the volumes and surface areas (or part there-of) of the basic solids contained within.
- Pythagoras' theorem may be used to help find particular lengths, provided that a right-angled triangle is given.



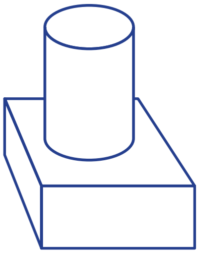
- Recall these common unit conversions for capacity.
  - 1 L = 1000 mL = 1000 cm^3
  - 1 m^3 = 1000 L

Exercise 2J

UNDERSTANDING AND FLUENCY 1–4 2–5

1 Name the two basic solids that make up each of these composite shapes.

a



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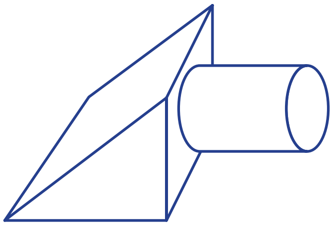

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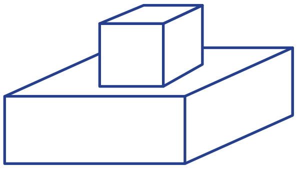
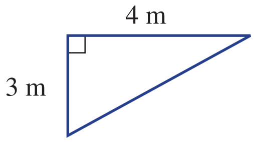


2 Use Pythagoras' theorem to find the length of the hypotenuse in these right-angled triangles.

a



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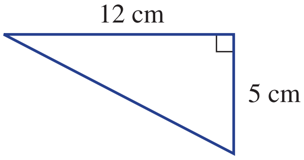

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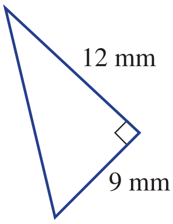

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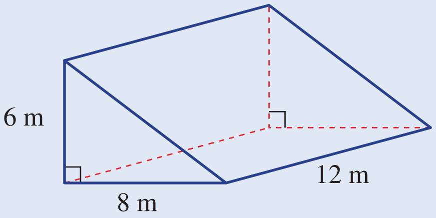
Example 23 Using Pythagoras' theorem to find the surface area of a triangular prism

Find the surface area of this triangular prism.



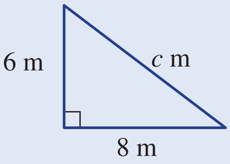
SOLUTION

$$c^2 = a^2 + b^2$$
$$= 6^2 + 8^2$$
$$= 100$$
$$c = \sqrt{100}$$
$$= 10$$

$$\text{Surface area} = 2 \times \frac{1}{2} \times 8 \times 6 + 8 \times 12 + 6 \times 12 + 10 \times 12$$
$$= 48 + 96 + 72 + 120$$
$$= 336\text{ m}^2$$

EXPLANATION

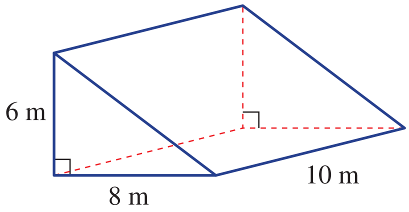
Use Pythagoras' theorem to find the length of the slanting edge.

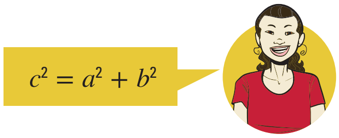


The surface area is made up of two congruent triangular ends and three different rectangles.

3 Use Pythagoras' theorem to help find the surface area of these triangular prisms.

a





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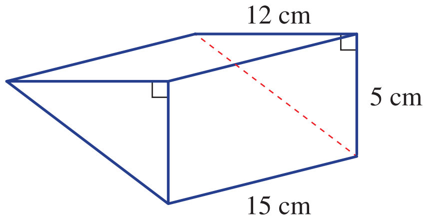

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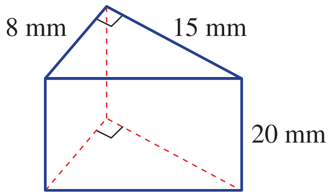

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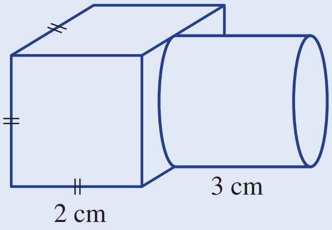
Example 24 Finding the surface area and volume of a composite solid

Find the surface area and volume of this composite solid, correct to 2 decimal places.



SOLUTION

Surface area $= 6 \times 2^2 + 2\pi(1)(3)$
$= 24 + 6\pi$
$= 42.85$ cm^2 (to 2 d.p.)

Volume $= 2^3 + \pi(1)^2(3)$
$= 8 + 3\pi$
$= 17.42$ cm^3 (to 2 d.p.)

EXPLANATION

The surface area is made up of 5 square faces plus one more, which is made up of the remaining part of the right side face and the end of the cylinder. The curved surface of the cylinder ($2\pi rh$) is also included.

The radius is half the diameter; i.e. $r = 1$.

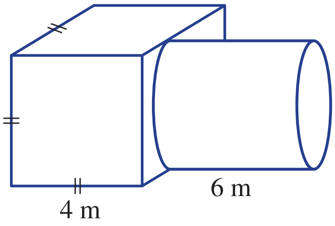
The volume consists of the sum of a cube (s^3) and a cylinder ($\pi r^2 h$).

4 For these composite solids, find:

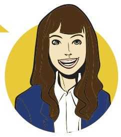
i the surface area **ii** volume

Give your answer correct to 2 decimal places.

a



Include only exposed surfaces in the surface area.



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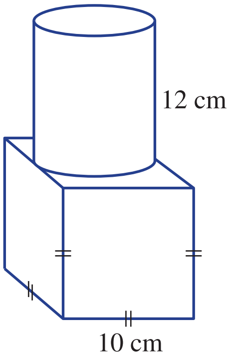

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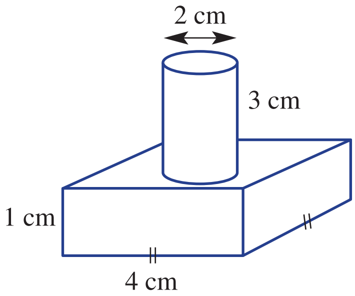
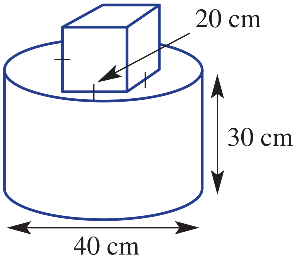


5 Find the capacity of these composite solids, in litres. Round your answer to 2 decimal places where necessary.

a



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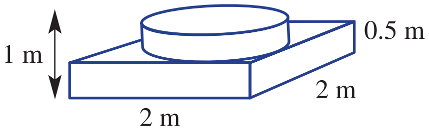
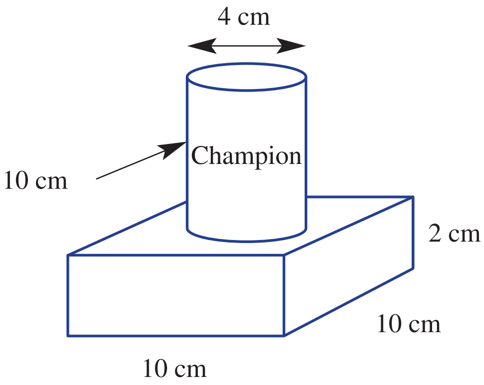


Recall:
1 L = 1000 cm³
1 m³ = 1000 L

PROBLEM-SOLVING AND REASONING 6–8 6, 9–11

6 Here is a design of a glass tennis trophy. The base and the cylindrical part are both made of glass.



a Find the surface area of the trophy, to the nearest cm^2.

b Find the volume of glass, to the nearest cm^3, required to make the trophy.

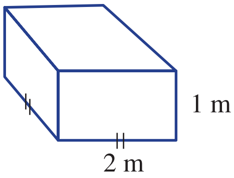
7 When solids are painted, the outer surface area needs to be considered to help find the amount of paint required for the job. Assume that 1 L of paint covers 10 m^2.

Complete for each of these objects.

i Find the surface area in m^2, rounding your answer to 2 decimal places where necessary.

ii Find the amount of paint that must be purchased, assuming that you can buy only a whole number of litres.

a



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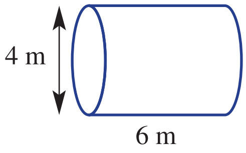

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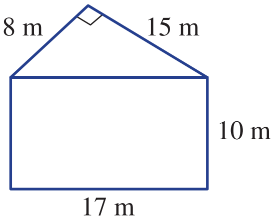

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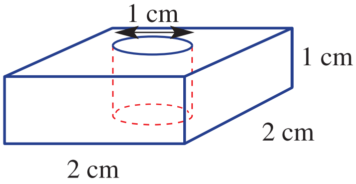
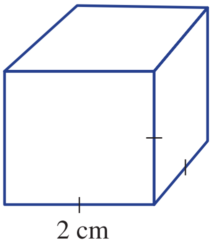
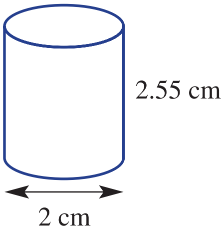
8 When solids are hollow, the inside surface areas are exposed to the air. Find the surface area (i.e. inner and outer combined) of a pipe of diameter 0.3 m and length 3 m. Assume that the inner and outer diameters are the same. (Round your answer to 1 decimal place.)

9 This nut is a square-based prism with a cylindrical hole removed from the centre. The hole has a diameter of 1 cm. The nut is coated with anti-rust paint. What area is painted, including the inner cylindrical surface? (Round your answer to 1 decimal place.)



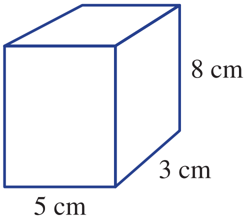
10 These solids have approximately the same volume.

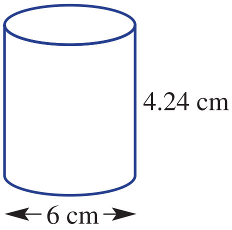




Which has the larger surface area? Do some calculations to find out.

11 A company wishes to design a container for packaging and selling lollies. The two designs are shown here.





a Make some calculations to show that the two containers have approximately the same volume.

b Which design has the least surface area? Justify your answer.

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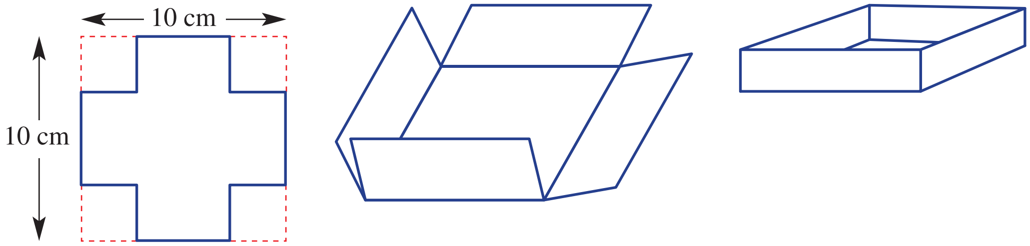
ENRICHMENT – 12

Maximising volume

12 Imagine that a company asks you to make a tray out of a square piece of card, measuring 10 cm by 10 cm, by cutting out four corner squares and folding them to form a tray, as shown.

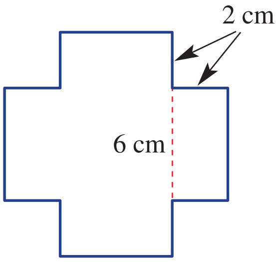


a What will be the volume of the tray if the side length of the square cut-outs is:

i 1 cm?

ii 2 cm?

iii 3 cm?



b Which square cut-out from part **a** gives the largest tray volume?

c Can you find another sized cut-out that gives a larger volume than any of those in part **a**?

d What sized cut-out gives the maximum volume?

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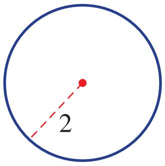
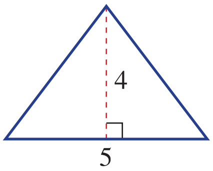
1 'I am the same shape all the way through. What am I?' Find the area of each shape. Match the letters to the answers below to solve the riddle.

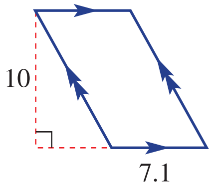
R



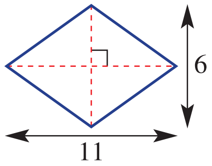
M



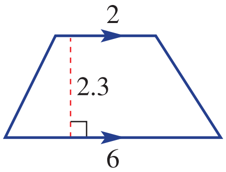
S



P



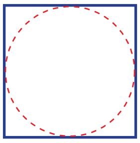
I



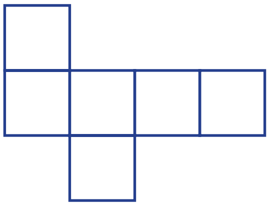
☐	☐	☐	☐	☐
33	12.57	9.2	71	10

2 1 L of water is poured into a container, which is in the shape of a rectangular prism. The dimensions of the prism are 8 cm by 12 cm by 11 cm. Will the water overflow?

3 A circular piece of pastry is removed from a square sheet of side length 30 cm. What percentage of pastry remains?

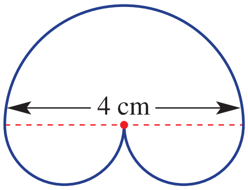


4 How many different nets are there for a cube?
Do not count reflections or rotations of the same net. Shown is one example.



5 Give the radius of a circle whose value for the circumference is equal to the value for the area.

6 Find the area of this special shape.



7 A cube's surface area is 54 cm^2. What is its volume?

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Measurement

Conversion of units

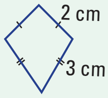
$$\begin{tikzcd}
\text{km} \arrow[r, bend left, "\times 1000"] & \text{m} \arrow[l, bend left, "\div 1000"] \arrow[r, bend left, "\times 100"] & \text{cm} \arrow[l, bend left, "\div 100"] \arrow[r, bend left, "\times 10"] & \text{mm} \arrow[l, bend left, "\div 10"]
\end{tikzcd}$$

$$\begin{tikzcd}
\text{km}^2 \arrow[r, bend left, "\times 1000^2"] & \text{m}^2 \arrow[l, bend left, "\div 1000^2"] \arrow[r, bend left, "\times 100^2"] & \text{cm}^2 \arrow[l, bend left, "\div 100^2"] \arrow[r, bend left, "\times 10^2"] & \text{mm}^2 \arrow[l, bend left, "\div 10^2"]
\end{tikzcd}$$

$$\begin{tikzcd}
\text{km}^3 \arrow[r, bend left, "\times 1000^3"] & \text{m}^3 \arrow[l, bend left, "\div 1000^3"] \arrow[r, bend left, "\times 100^3"] & \text{cm}^3 \arrow[l, bend left, "\div 100^3"] \arrow[r, bend left, "\times 10^3"] & \text{mm}^3 \arrow[l, bend left, "\div 10^3"]
\end{tikzcd}$$

Perimeter

The distance around the outside of a shape.

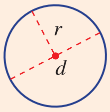


$P = 2 \times 2 + 2 \times 3$
$= 10$ cm

Circumference

The distance around the outside of a circle.

$C = 2\pi r$ or $C = \pi d$



Area of basic shapes

Square: $A = s^2$

Rectangle: $A = lb$

Triangle: $A = \frac{1}{2}bh$

Rhombus: $A = \frac{1}{2}xy$

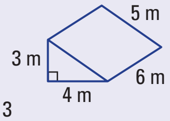
Parallelogram: $A = bh$

Trapezium: $A = \frac{h}{2}(a + b)$

Surface area

Draw a net and sum the surface areas.

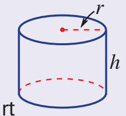
Triangular prism



$A = 2 \times \frac{1}{2} \times 4 \times 3$
$+ 6 \times 4 + 6 \times 3 + 6 \times 5$
$= 84$ m^2

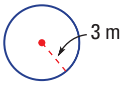
Cylinder

$A = \underset{\text{2 ends}}{2\pi r^2} + \underset{\text{curved part}}{2\pi rh}$



Area of a circle

$A = \pi r^2$
$= \pi \times 3^2$
≈ 28.27 m^2



Volume

Rectangular prism $V = lbh$

Cylinder $V = \pi r^2 h$

Capacity: 1 L = 1000 mL

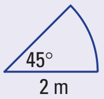
1 cm^3 = 1 mL

Accuracy

Accuracy of measurement is affected by human error and measuring instruments.
Limits of accuracy give upper and lower boundaries for measurement.
Usually, ± 0.5 × smallest unit of measurement.

Area of sectors

$A = \frac{45}{360} \times \pi r^2$
$= \frac{1}{8} \times \pi \times 2^2$
≈ 1.57 m^2



Multiple-choice questions

1 The number of centimetres in a kilometre is:

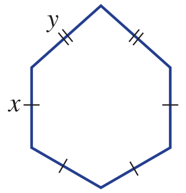
A 10 **B** 100 **C** 1000 **D** 10 000 **E** 100 000

2 The perimeter of a square with side lengths 2 cm is:

A 4 cm **B** 8 cm **C** 4 cm^2 **D** 8 cm^2 **E** 16 cm

3 The perimeter of the shape shown is given by the formula:

A $x - y$ **B** $2x + y$ **C** $4x + 2y$
D $x - 2y$ **E** $4x + y$



4 A correct expression for determining the circumference of a circle with diameter 6 cm is:

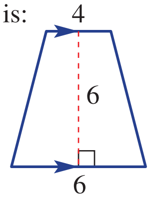
A $\pi \times 6$ **B** $\pi \times 3$ **C** $2 \times \pi \times 6$ **D** 2×6 **E** $\pi \times 6^2$

5 The area of a rectangle with side lengths 3 cm and 4 cm is:

A 12 cm^2 **B** 12 cm **C** 7 cm^2 **D** 14 cm **E** 14 cm^2

6 The correct expression for calculating the area of this trapezium is:

A $(6 - 4) \times 6$ **B** $\frac{6}{2}(6 + 4)$ **C** $\frac{6}{2} \times (6 \times 4)$
D $6 \times 6 - 4$ **E** $6 \times 6 + 6 \times 4$

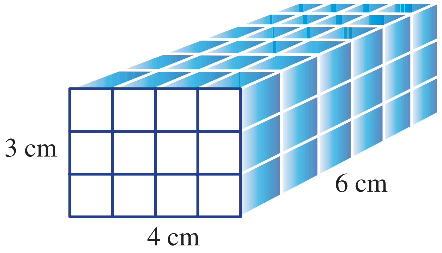


7 A sector's centre angle measures 90°. This is equivalent to:

A $\frac{1}{5}$ of a circle **B** $\frac{1}{2}$ of a circle **C** $\frac{3}{4}$ of a circle
D $\frac{2}{3}$ of a circle **E** $\frac{1}{4}$ of a circle

8 The volume of the shape shown is:

A 13 cm^3 **B** 27 cm^3 **C** 72 cm^2
D 72 cm^3 **E** 27 cm^2

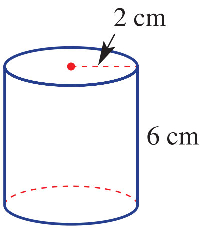


9 The volume of a cube of side length 3 cm is:

A 9 cm^3 **B** 27 cm^3 **C** 54 cm^2 **D** 54 cm^3 **E** 27 cm^2

10 The curved surface area of this cylinder is closest to:

A 87.96 cm^2 **B** 12.57 cm^2 **C** 75.40 cm^2
D 75.39 cm^2 **E** 113.10 cm^2



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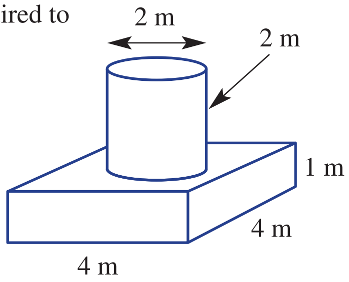
11 If 1 L of paint covers 10 m^2, the number of litres of paint required to paint this solid, correct to 1 decimal place, is:

A 60.0 L **B** 60 L **C** 6.1 L
D 5.4 L **E** 54.3 L



Short-answer questions

1 Convert these measurements to the units shown in the brackets.

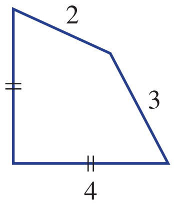
a 5.3 km (m) **b** 27 000 cm^2 (m^2) **c** 0.04 cm^3 (mm^3)
d 1 day (s) **e** 0.125 s (ms) **f** 89 000 000 KB (TB)

2 Give the limits of accuracy for these measurements.

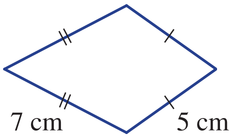
a 6 cm **b** 4.2 kg **c** 16.21 cm

3 Find the perimeter of these shapes.

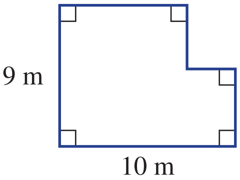
a



b

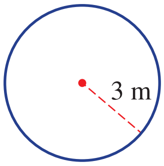


c



4 For the circle, find, to 2 decimal places:

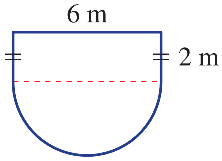
a the circumference
b the area



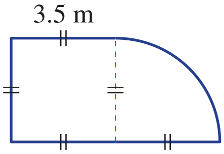
5 For these composite shapes, find, to 2 decimal places:

i the perimeter **ii** the area

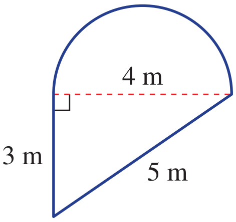
a



b

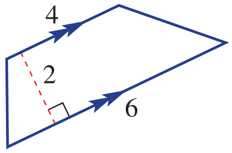


c

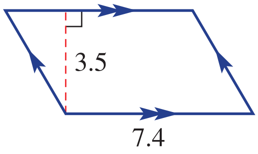


6 Find the area of these shapes.

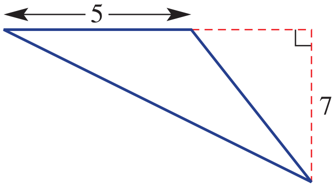
a



b



c



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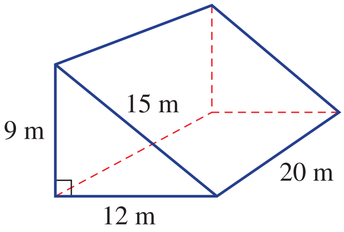
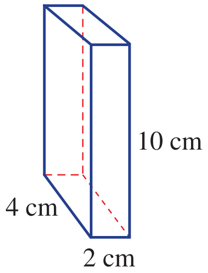
7 Find the surface area of these prisms.

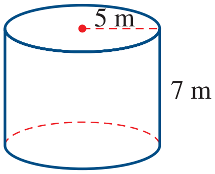
a



b

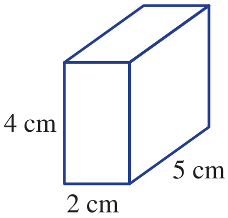


8 Determine the surface area of this cylinder, to 2 decimal places.

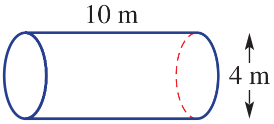


9 Find the volume of these solids, to 2 decimal places where necessary.

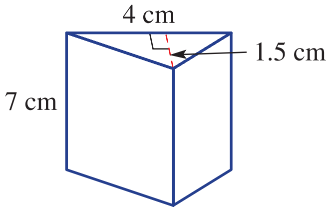
a



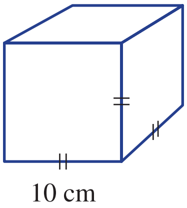
b

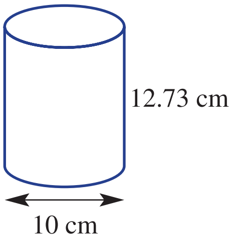


c



10 These two solids are to be packaged with the minimum amount of fabric. Which one requires less fabric?

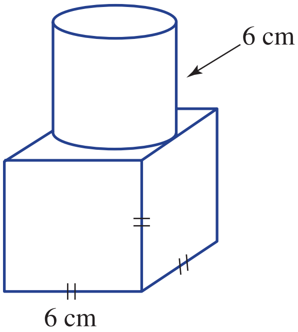




11 For the composite solid shown, find the following, correct to 1 decimal place.

a the surface area

b the volume



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Extended-response questions

1 A cylindrical tank has diameter 8 m and height 2 m.

a Find the surface area of the curved part of the tank, to 2 decimal places.

b Find the surface area, including the top and the base, to 2 decimal places.

c Find the total volume of the tank, to 2 decimal places.

d Find the total volume of the tank in litres, to 2 decimal places. Note: There are 1000 litres in 1 m^3.

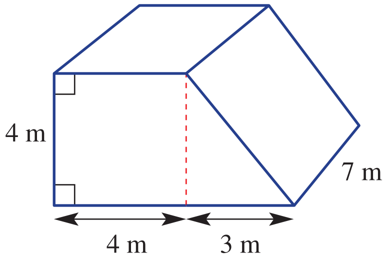
2 A rabbit hutch is to be built in the shape shown.

a Use Pythagoras' theorem to find the slant height of the hutch.

b The hutch will be covered in chicken wire. Determine, in square metres, the amount of chicken wire required. Do not include the base.

c If chicken wire costs \$6 per m^2, find the cost of covering the hutch.

d What is the volume of the hutch?



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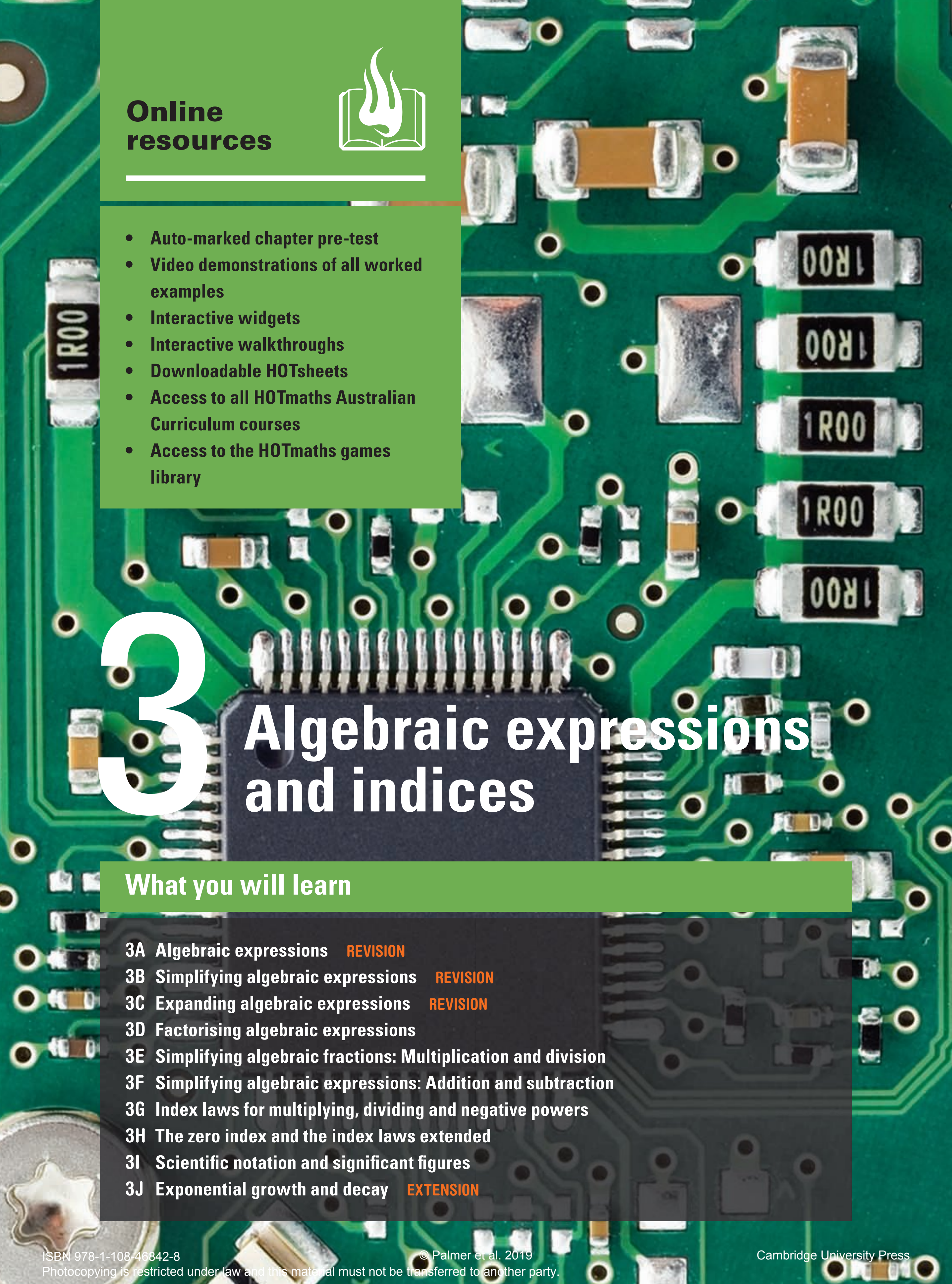
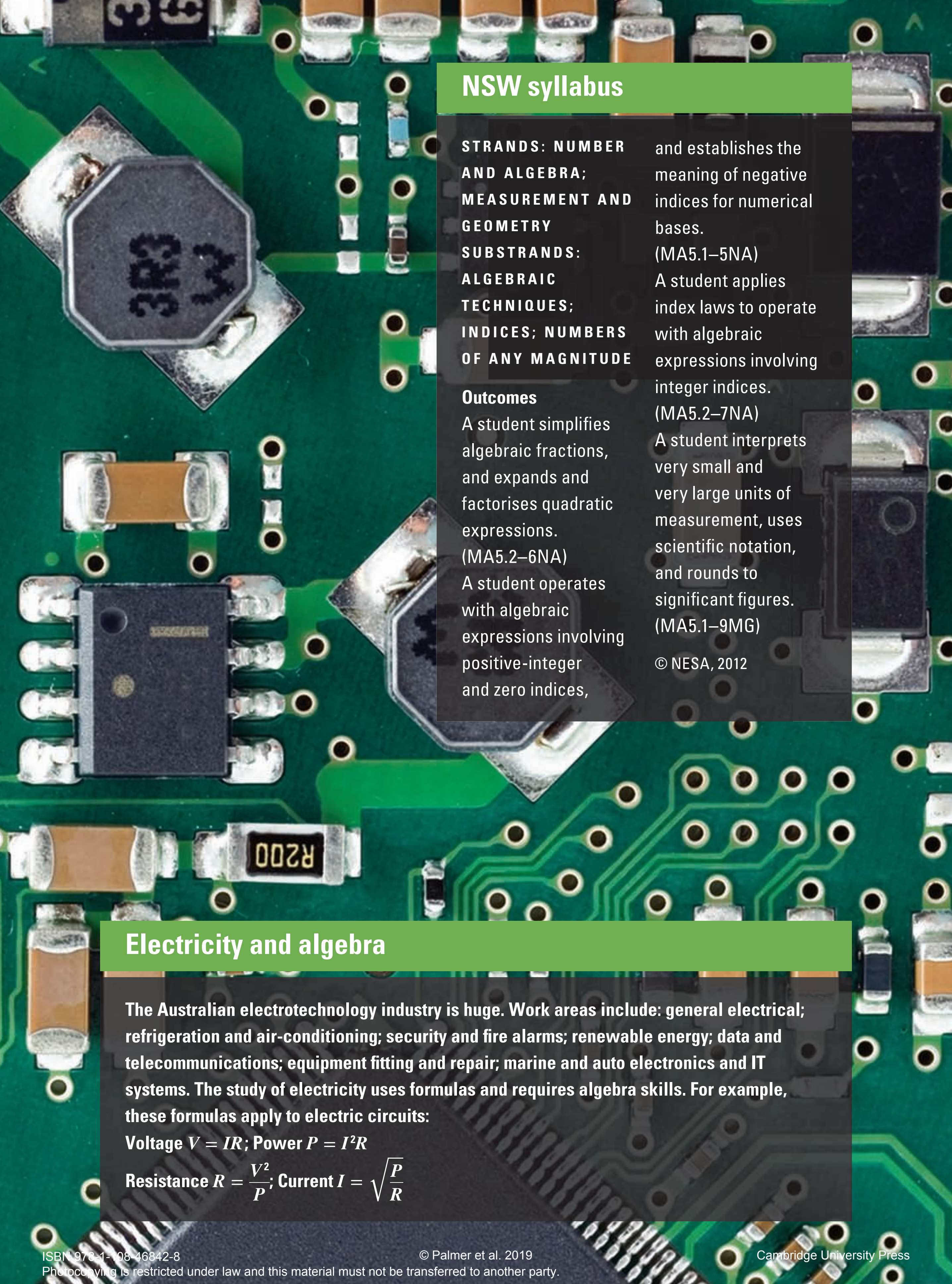


Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

3 Algebraic expressions and indices

What you will learn



NSW syllabus

STRANDS: NUMBER AND ALGEBRA; MEASUREMENT AND GEOMETRY

SUBSTRANDS: ALGEBRAIC TECHNIQUES; INDICES; NUMBERS OF ANY MAGNITUDE

Outcomes

A student simplifies algebraic fractions, and expands and factorises quadratic expressions.
(MA5.2–6NA)

A student operates with algebraic expressions involving positive-integer and zero indices, and establishes the meaning of negative indices for numerical bases.
(MA5.1–5NA)

A student applies index laws to operate with algebraic expressions involving integer indices.
(MA5.2–7NA)

A student interprets very small and very large units of measurement, uses scientific notation, and rounds to significant figures.
(MA5.1–9MG)

Electricity and algebra

The Australian electrotechnology industry is huge. Work areas include: general electrical; refrigeration and air-conditioning; security and fire alarms; renewable energy; data and telecommunications; equipment fitting and repair; marine and auto electronics and IT systems. The study of electricity uses formulas and requires algebra skills. For example, these formulas apply to electric circuits:

Voltage $V = IR$; **Power** $P = I^2R$

Resistance $R = \frac{V^2}{P}$; **Current** $I = \sqrt{\frac{P}{R}}$

Pre-test

1 Write algebraic expressions for the following.

a 3 lots of x
b one more than a
c 5 less than $2m$
d 4 times the sum of x and y

2 Find the value of the following if $x = 4$ and $y = 7$.

a $5x$
b $2y + 3$
c $xy - 5$
d $2(x + y)$

3 Decide whether the following pairs of terms are like terms.

a $6x$ and 8
b $3a$ and $7a$
c $4xy$ and $2yx$
d $3x^2$ and $10x$

4 Simplify:

a $3m + 5m$
b $8ab - 3ab$
c $4x + 3y + 2x + 5y$
d $2 \times 4 \times x$
e $5 \times a \times 3 \times b$
f $6y \div 2$

5 Expand:

a $2(x + 5)$
b $3(y - 2)$
c $4(2x - 3)$
d $x(3x + 1)$

6 Find the HCF (highest common factor) of these pairs of terms.

a 8, 12
b 18, 30
c $7a$, $14a$
d $2xy$ and $8xz$
e $5x$ and $8x^2$

7 Simplify:

a $\frac{3}{8} + \frac{2}{5}$
b $\frac{6}{7} - \frac{1}{3}$
c $\frac{5}{9} \times \frac{6}{25}$
d $\frac{2}{3} \div \frac{4}{9}$

8 Write each of the following in index form (e.g. $5 \times 5 \times 5 = 5^3$).

a $7 \times 7 \times 7 \times 7$
b $m \times m \times m$
c $x \times x \times y \times y \times y$
d $3a \times 3a \times 3a \times 3a \times 3a$

9 Evaluate:

a 7^2
b 3^3
c 2^4
d 4^3

10 Write the following as 3 raised to a single power.

a $3^4 \times 3^3$
b $3^7 \div 3^5$
c $(3^2)^5$
d 1
e $\frac{1}{3^2}$

11 Complete the following.

a $3.8 \times 10 =$ ______
b $2.31 \times 1000 =$ ________
c $17.2 \div 100 =$ ______
d $0.18 \times 100 =$ ________
e $3827 \div$ ______ $= 3.827$
f $6.49 \times$ ________ $= 64\,900$

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3A Algebraic expressions REVISION

Interactive

Widgets

HOTsheets

Walkthrough

Algebra involves the use of pronumerals, which are letters that represent numbers.

If a ticket to an art gallery costs \$12, then the cost for y visitors is given by the expression $\$12 \times y = \$12y$. By substituting values for y we can find the costs for different numbers of visitors. For example, if there are five visitors, then $y = 5$ and $\$12y = \$12 \times 5 = \$60$.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Expressions at the gallery

Ben, Alea and Victoria are visiting the art gallery. The three of them combined have \$$c$ between them. Drinks cost \$$d$ and Ben has bought x postcards in the gift shop.

Write expressions for the following.

- The cost of two drinks
- The amount of money each person has if the money is shared equally
- The number of postcards Alea and Victoria bought if Alea bought three more than Ben and Victoria bought five less than twice the number Ben bought.

Key ideas

- Algebraic **expressions** are made up of one or more terms connected by addition or subtraction. For example: $3a + 7b$, $\frac{x}{2} + 3y$, $3x - 4$.
  - A **term** is a group of numbers and pronumerals connected by multiplication and division. For example: $2x$, $\frac{y}{4}$, $5x^2$.
  - A **constant term** is a number with no attached pronumerals. For example: 7, −3.
  - The **coefficient** is the number multiplied by the pronumerals in the term. For example: 3 is the coefficient of y in $2x + 3y$.
    −4 is the coefficient of x in $5 - 4x$.
    1 is the coefficient of x^2 in $2x + x^2$.
    The following expression has 3 terms.

$$3x - 2y + 4$$

3 is the coefficient of x

−2 is the coefficient of y

4 is the constant term

Expression A group of mathematical terms containing no equals sign

Term A number or pronumeral in an expression

Constant term The part of an equation or expression without any pronumerals

Coefficient A numeral placed before a pronumeral, showing that the pronumeral is multiplied by that factor

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Key ideas

- Operations
  - The operations for addition and subtraction are written with ‘+’ and ‘−’.
  - Multiplication is written without the sign.
    For example: $3 \times y = 3y$.
  - Division is sometimes written as a fraction.
    For example: $y \div 4 = \frac{y}{4}$ or $\frac{1}{4}y$.
- The value of an expression can be found by **substituting** a value for each pronumeral. The order of operations is followed.
  For example: If $x = 2$ and $y = 3$,

$$\begin{aligned}4xy - y^2 &= 4 \times 2 \times 3 - 3^2\\ &= 24 - 9\\ &= 15\end{aligned}$$

Substitute To replace pronumerals with numerical values

Exercise 3A REVISION

UNDERSTANDING AND FLUENCY 1, 2, 3–4(½), 5, 6–7(½) 4(½), 5, 6–7(½)

1 Fill in the missing word(s) in the sentences using these words:
expression, term, constant term, coefficient

a An algebraic ________ is made up of one or more terms connected by addition and subtraction.
b A term without a pronumeral part is a ________.
c A number multiplied by the pronumerals in a term is a ________.
d Numbers and pronumerals connected by multiplication and division form a ________.

2 Substitute the value 3 for the pronumeral x in the following and evaluate.

a $x + 4$
b $5x$
c $8 - x$
d x^2
e $\frac{18}{x}$

3 Evaluate:

a $2 \times (-3)$ **b** -4×5 **c** $2 - 8$
d $4 - 11$ **e** $7 - (-2)$ **f** $8 - (-10)$
g $-9 + 3$ **h** $-9 + 16$ **i** $-3 - 4$
j $-6 - 7$ **k** $-8 \div 2$ **l** $20 \div (-4)$

positive × negative = negative
To subtract a negative, add its opposite: $2 - (-3) = 2 + 3$.

4 Substitute $a = -6$ into the following expressions.

a $a + 9$ **b** $a - 8$ **c** $-a$ **d** $-a + 10$
e $12 - a$ **f** $5a$ **g** $-2a$ **h** $\frac{24}{a}$
i a^2 **j** $-a^2$ **k** $(-a)^2$ **l** $(a + 6)^2$

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Example 1 Naming parts of an expression

Consider the expression $\frac{xy}{2} - 4x + 3y^2 - 2$. Determine:

a the number of terms

b the constant term

c the coefficient of:

- **i** y^2
- **ii** x

SOLUTION	EXPLANATION
a 4	There are four terms with different combinations of pronumerals and numbers, separated by + or −.
b −2	The term with no pronumerals is −2. The negative is included.
c **i** 3	The number multiplied by y^2 in $3y^2$ is 3.
ii −4	The number multiplied by x in $-4x$ is −4. The negative sign belongs to the term that follows.

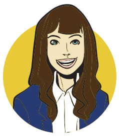
5 For these algebraic expressions, determine:

- **i** the number of terms
- **ii** the constant term
- **iii** the coefficient of y

a $4xy + 5y + 8$

b $2xy + \frac{1}{2}y^2 - 3y + 2$

c $2x^2 - 4 + y$



The coefficient is the number multiplied by the pronumerals in each term. The constant term has no pronumerals.

Example 2 Writing algebraic expressions

Write algebraic expressions for the following.

a three more than x

b 4 less than 5 times y

c the sum of c and d is divided by 3

d the product of a and the square of b

SOLUTION	EXPLANATION
a $x + 3$	More than means add (+).
b $5y - 4$	Times means multiply ($5 \times y = 5y$) and less than means subtract (−).
c $\frac{c + d}{3}$	Sum c and d first (+), then divide by 3(÷). Division is written as a fraction.
d ab^2	'Product' means 'multiply'. The square of b is b^2 (i.e. $b \times b$). $a \times b^2 = ab^2$.

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6 Write an expression for the following.

- **a** two more than x
- **b** four less than y
- **c** the sum of ab and y
- **d** three less than 2 lots of x
- **e** the product of x and 5
- **f** twice m
- **g** three times the value of r
- **h** half of x
- **i** three-quarters of m
- **j** the quotient of x and y
- **k** the sum of a and b is divided by 4
- **l** the product of the square of x and y

Quotient is ÷.
Product is ×.
$\frac{1}{2}x = \frac{x}{2}$

Example 3 Substituting values

Find the value of these expressions if $x = 2$, $y = 3$ and $z = -5$.

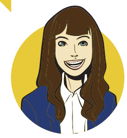
a $xy + 3y$ **b** $y^2 - \frac{8}{x}$ **c** $2x - yz$

SOLUTION	EXPLANATION
a $xy + 3y = 2 \times 3 + 3 \times 3$ $= 6 + 9$ $= 15$	Substitute for each pronumeral: $x = 2$ and $y = 3$. Recall: $xy = x \times y$ and $3y = 3 \times y$. Simplify, following order of operations, by multiplying first.
b $y^2 - \frac{8}{x} = 3^2 - \frac{8}{2}$ $= 9 - 4$ $= 5$	Substitute $y = 3$ and $x = 2$. $3^2 = 3 \times 3$ and $\frac{8}{2} = 8 \div 2$. Do subtraction last.
c $2x - yz = 2 \times 2 - 3 \times (-5)$ $= 4 - (-15)$ $= 4 + 15$ $= 19$	Substitute for each pronumeral. $3 \times (-5) = -15$ To subtract a negative number, add its opposite.

7 Find the value of these expressions if $a = 4$, $b = -2$ and $c = 3$.

- **a** ac
- **b** $2a - 5$
- **c** $3a - c$
- **d** $a^2 - 2c$
- **e** $ac + b$
- **f** $3b + a$
- **g** $ab + c^2$
- **h** $\frac{a}{2} - b$
- **i** $\frac{ac}{b}$
- **j** $2a - b$
- **k** $a + bc$
- **l** $\frac{6bc}{a}$

$12 + (-2) = 12 - 2$
$2 - (-2) = 2 + 2$



PROBLEM-SOLVING AND REASONING 8–10 9–12

8 Write an expression for the following.

- **a** The cost of 5 pencils at x cents each
- **b** The cost of y apples at 35 cents each
- **c** One person's share if \$500 is divided among n people
- **d** The cost of a pizza (\$11) shared between m people
- **e** Paul's age in x years' time if he is 11 years old now

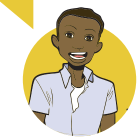
9 A taxi in Sydney has a pick-up charge (flag fall) of \$3.40 and charges \$2 per km.

a Write an expression for the taxi fare for a trip of d kilometres.

b Use your expression in part **a** to find the cost of a trip that is:

i 10 km **ii** 22 km

The taxi fare has initial cost + cost per km × number of km.



10 Ye thinks of a number, which we will call x.

a Write an expression for each of the following stages.

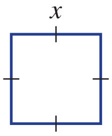
i He doubles the number.

ii He decreases the result by 3.

iii He multiplies the result by 3.

b If $x = 5$, use your answer to part **a iii** to find the final number.

11 A square of side length x is turned into a rectangle by increasing the length by 1 and decreasing the breadth by 1.



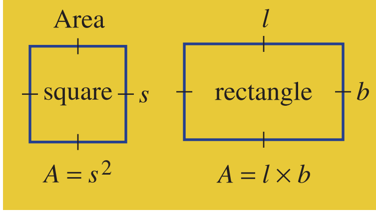
a Write an expression for the new length and breadth of the rectangle.

b Is there any change in the perimeter of the shape?

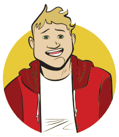
c **i** Write an expression for the area of the rectangle.

ii Use trial and error to determine whether the area of the rectangle is more or less than the original square. By how much?

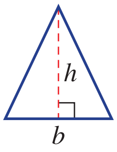
Perimeter is the sum of the side lengths.



$A = s^2$ $A = l \times b$



12 The area of a triangle is given by $\frac{1}{2}bh$.



a If $b = 6$ and $h = 7$, what is the area?

b If the area is 9, what are the possible whole number values for b if h is also a whole number?

ENRICHMENT – 13

Area and perimeter

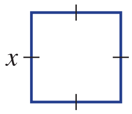
13 For the shapes shown, write an expression for the:

i perimeter

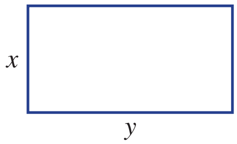
ii area

Perimeter = sum of the side lengths
Area of a rectangle = length × breadth
Area of triangle = $\frac{1}{2}$ × base × height

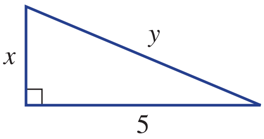
a



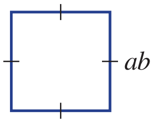
b



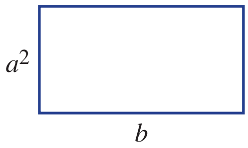
c



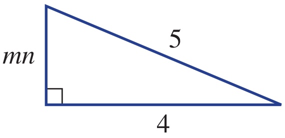
d



e



f



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3B Simplifying algebraic expressions REVISION

Interactive

Widgets

HOTsheets

Walkthrough

Stage

5.3#

5.3

5.3§

5.2

5.2◊

5.1

4

Many areas of finance and industry involve complex algebraic expressions. Often these expressions can be made simpler by applying the operations of addition, subtraction, multiplication and division.

Just as we would write 3 + 3 + 3 + 3 as 4 × 3, we write $x + x + x + x$ as $4 \times x$ or $4x$. Similarly, $3x + 2x = 5x$ and $3x - 2x = 1x$ ($1x$ is written as x). We also know that $2 \times 3 = 3 \times 2$ and $(2 \times 3) \times 4 = 2 \times 3 \times 4 = 3 \times 4 \times 2$ etc., so $2 \times x \times 4 = 2 \times 4 \times x = 8x$. By writing a division as a fraction, we can also cancel common factors.

For example, $9x \div 3 = \frac{9x}{3} = 3x$.

Let's start: Equivalent expressions

Split these expressions into two groups that are equivalent by simplifying them first.

$3x + 6x$	$17x - 5x$	$x + 7x + x$	$4x + 3 + 5x - 3$
$2 \times 6x$	$\frac{24xy}{2y}$	$3x \times 3$	$3x - 2y + 9x + 2y$
$8x + 6x - 2x$	$18x \div 2$	$\frac{9x^2}{x}$	$6x - (-6x)$

Key ideas

- **Like terms** have the exact same pronumeral factors, including powers.
  For example: $3x$ and $7x$, and $4x^2y$ and $-3x^2y$.
  - Since $x \times y = y \times x$, $3xy$ and $2yx$ are like terms.
- Expressions in which like terms are added or subtracted can be simplified.
  For example: $5x + 7x = 12x$
  $7ab - 6ab = 1ab = ab$
  But $3x + 2y$ cannot be simplified.
- Like terms are not required when multiplying and dividing.
  - In multiplication, deal with numerals and pronumerals separately.
    For example: $2 \times 8a = 2 \times 8 \times a = 16a$
    $6x \times 3y = 6 \times 3 \times x \times y = 18xy$
- When dividing, write as a fraction and cancel common factors.
  For example: $\frac{\cancel{8}^{4}x}{\cancel{2}^{1}} = 4x$
  $6x^2 \div (3x) = \frac{6x^2}{3x} = \frac{\cancel{6}^{2} \times \cancel{x}^{1} \times x}{\cancel{3}^{1} \times \cancel{x}^{1}} = 2x$

Like terms Terms with the same pronumerals and the same powers

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Exercise 3B REVISION

UNDERSTANDING AND FLUENCY	1–8(½)	5–8(½)

1 Are the following sets of terms like terms? Answer yes (Y) or no (N).

a $3x, 2x, -5x$ **b** $2ax, 3xa, -ax$

c $2ax^2, 2ax, 62a^2x$ **d** $-3p^2q, 2pq^2, 4pq$

e $3ax^2y, 2ayx^2, -x^2ay$ **f** $\frac{3}{4}x^2, 2x^2, \frac{x^2}{3}$

2 Simplify the following.

a $8g + 2g$ **b** $3f + 2f$ **c** $12e - 4e$

d $3h - 3h$ **e** $5x + x$ **f** $14st + 3st$

g $7ts - 4ts$ **h** $4ab - ab$ **i** $9xy - 8xy$

Add or subtract the numerals in like terms.

3 Simplify the following.

a $3 \times 2x$

b $4 \times 3a$

c $2 \times 5m$

d $-3 \times 6y$

4 Simplify these fractions by cancelling.

a $\frac{4a}{8}$ **b** $\frac{12b}{3}$ **c** $\frac{24c}{8}$

d $\frac{12d}{18}$ **e** $\frac{14e}{21}$ **f** $\frac{35f}{15}$

g $\frac{27g}{36}$ **h** $\frac{18h}{45}$ **i** $\frac{20i}{24}$

Choose the highest common factor to cancel.

Example 4 Identifying like terms

Write down the like terms in the following lists.

a $3x, 6a, 2ax, 3a, 5xa$

b $-2ax, 3x^2a, 3a, -5x^2a, 3x$

SOLUTION	EXPLANATION
a $6a$ and $3a$	Both terms contain a.
$5xa$ and $2ax$	Both terms contain ax. Note: $x \times a = a \times x$.
b $3x^2a$ and $-5x^2a$	Both terms contain x^2a.

5 Write down the like terms in the following lists.

a $3ac, 2a, 5x, -2ac$ **b** $4pq, 3qp, 2p^2, -4p^2q$

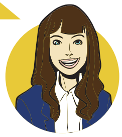
c $7x^2y, -3xy^2, 2xy^2, 4yx^2$ **d** $2r^2, 3rx, -r^2, 4r^2x$

e $-2ab, 5bx, 4ba, 7xa$ **f** $3p^2q, -4pq^2, \frac{1}{2}pq, 4qp^2$

g $\frac{1}{3}lm, 2l^2m, \frac{lm}{4}, 2lm^2$ **h** $x^2y, yx^2, -xy, yx$

Like terms have the same pronumeral factors.

$x \times y = y \times x$, so $3xy$ and $5yx$ are like terms.



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Example 5 Collecting like terms

Simplify the following.

a $4a + 5a + 3$

b $3x + 2y + 5x - 3y$

c $5xy + 2xy^2 - 2xy + xy^2$

SOLUTION	EXPLANATION
a $4a + 5a + 3 = 9a + 3$	Collect like terms ($4a$ and $5a$) and add coefficients.
b $3x + 2y + 5x - 3y = 3x + 5x + 2y - 3y$ $= 8x - y$	Collect like terms in x (i.e. $3 + 5 = 8$) and in y (i.e. $2 - 3 = -1$). Note that $-1y$ is written as $-y$.
c $5xy + 2xy^2 - 2xy + xy^2$ $= 5xy - 2xy + 2xy^2 + xy^2$ $= 3xy + 3xy^2$	Collect like terms. In xy, the negative belongs to $2xy$. In xy^2, recall that xy^2 is $1xy^2$.

6 Simplify the following by collecting like terms.

a $4t + 3t + 10$
b $5g - g + 1$
c $3x - 5 + 4x$
d $4m + 2 - 3m$
e $2x + 3y + x$
f $3x + 4y - x + 2y$
g $8a + 4b - 3a - 6b$
h $2m - 3n - 5m + n$
i $3de + 3de^2 + 2de + 4de^2$
j $6kl - 4k^2l - 6k^2l - 3kl$
k $3x^2y + 2xy^2 - xy^2 + 4x^2y$
l $4fg - 5g^2f + 4fg^2 - fg$

Example 6 Multiplying algebraic terms

Simplify the following.

a $2a \times 7d$

b $-3m \times 8mn$

SOLUTION	EXPLANATION
a $2a \times 7d = 2 \times 7 \times a \times d$ $= 14ad$	Multiply coefficients and collect the pronumerals: $2 \times a \times 7 \times d = 2 \times 7 \times a \times d$. Multiplication can be done in any order.
b $-3m \times 8mn = -3 \times 8 \times m \times m \times n$ $= -24m^2n$	Multiply coefficients ($-3 \times 8 = -24$) and pronumerals. Recall: $m \times m$ can be written as m^2.

7 Simplify:

a $3r \times 2s$
b $2h \times 3u$
c $4w \times 4h$
d $2r^2 \times 3s$
e $-2e \times 4s$
f $5h \times (-2v)$
g $-3c \times (-4m^2)$
h $-7f \times (-5l)$
i $2x \times 4xy$
j $3ab \times 8a$
k $xy \times 3y$
l $-2a \times 8ab$
m $-3m^2n \times 4n$
n $-5xy^2 \times (-4x)$
o $5ab \times 4ab$
p $-8xy \times 6xy$

Multiply the numerals and collect the pronumerals.
$a \times b = ab$

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Example 7 Dividing algebraic terms

Simplify the following.

a $\frac{18x}{6}$

b $12a^2b \div (8ab)$

SOLUTION

a $\frac{\overset{3}{\cancel{18}}x}{\cancel{6}_1} = 3x$

b $12a^2b \div (8ab) = \frac{12a^2b}{8ab}$

$= \frac{{}^3\cancel{12} \times a \times \cancel{a}_1 \times \cancel{b}_1}{{}_2\cancel{8} \times \cancel{a}_1 \times \cancel{b}_1}$

$= \frac{3a}{2}$

EXPLANATION

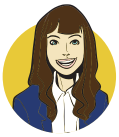
Cancel the highest common factor of numerals; i.e. 6.

Write division as a fraction.
Cancel the highest common factor of 12 and 8 and cancel an a and b.

8 Simplify by cancelling common factors.

a $\frac{7x}{14}$
b $\frac{6a}{2}$
c $3a \div 9$
d $2ab \div 8$
e $\frac{4ab}{2a}$
f $\frac{15xy}{5y}$
g $4xy \div (8x)$
h $28ab \div (35b)$
i $\frac{8x^2}{20x}$
j $\frac{12xy^2}{18y}$
k $30a^2b \div (10a)$
l $12mn^2 \div (36mn)$

Write each division as a fraction first, where necessary.

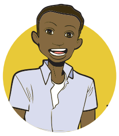


PROBLEM-SOLVING AND REASONING 9, 10 10–12

9 A rectangle's length is three times its breadth, x. Write a simplified expression for the rectangle's:

a perimeter
b area

Draw a rectangle and label the breadth x and the length $3 \times x = 3x$.



10 Fill in the missing term to make the following true.

a $8x + 4 - \square = 3x + 4$
b $3x + 2y - \square + 4y = 3x - 2y$
c $3b \times \square = 12ab$
d $4xy \times (\square) = -24x^2y$
e $12xy \div (\square) = 6y$
f $\square \div (15ab) = \frac{2a}{3}$

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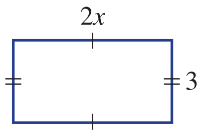
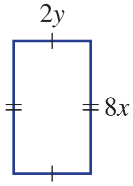
11 Find expressions in simplest form for the perimeter (P) and area (A) of these shapes.

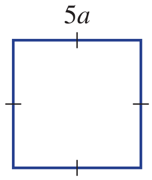
a



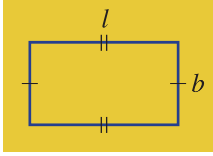
b

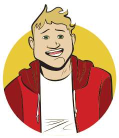


c

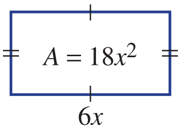


Perimeter is the sum of all the sides.
Area = $l \times b$





12 A rectangular garden bed has its length given by $6x$ and area $18x^2$. What is the breadth of the garden bed?



The opposite of × is ÷.

ENRICHMENT – 13(½)

Order of operations

13 Simplify the following expressions using order of operations.

a $4 \times 3x \div 2$

b $2 + 4a \times 2 + 5a \div a$

c $5a \times 2b \div a - 6b$

d $8x^2 \div (4x) + 3 \times 3x$

e $2x \times (4x + 5x) \div 6$

f $5xy - 4x^2y \div (2x) + 3x \times 4y$

g $(5x - x) \times (16xy \div (8y))$

h $9x^2y \div (3y) + 4x \times (-8x)$

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3C Expanding algebraic expressions REVISION

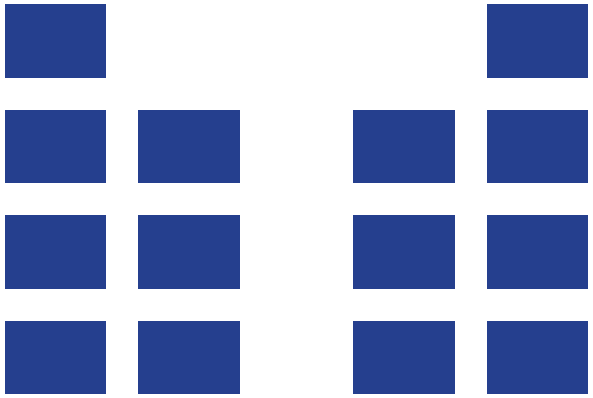
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

When an expression is multiplied by a term, each term in the expression must be multiplied by the term. Brackets are used to show this. For example, to double $4 + 3$ we write $2 \times (4 + 3)$, and each term within the brackets (both 4 and 3) must be doubled. The expanded version of this expression is $2 \times 4 + 2 \times 3$.

Similarly, to double the expression $x + 1$, we write $2(x + 1) = 2 \times x + 2 \times 1$. This expansion of brackets uses the distributive law.

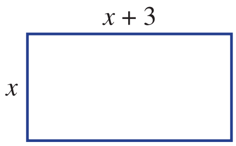
In this diagram, 7 blue blocks are doubled in groups of 4 and 3.

$$2 \times (4 + 3) = 2 \times 4 + 2 \times 3$$



Let's start: Rectangle brackets

A rectangle's length is 3 more than its height.



Write down as many expressions as you can, both with and without brackets, for the rectangle's:

- perimeter
- area

Can you explain why all the expressions for the perimeter or area are equivalent?

Key ideas

- The **distributive law** is used to expand and remove brackets.
- The terms inside the brackets are multiplied by the term outside the brackets.

$$a(b + c) = ab + ac \qquad a(b - c) = ab - ac$$

For example:
$$\begin{aligned} 2(x + 4) &= 2 \times x + 2 \times 4 \\ &= 2x + 8 \end{aligned}$$

Distributive law Adding numbers and then multiplying the total gives the same answer as multiplying each number first and then adding the products

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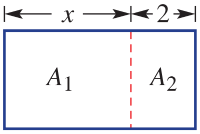
Exercise 3C REVISION

UNDERSTANDING AND FLUENCY 1, 2–7(½) 4–7(½)



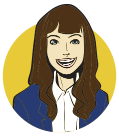
1 Consider the diagram shown.

- **a** Write an expression for the area A_1.
- **b** Write an expression for the area A_2.
- **c** Add your results from parts **a** and **b** to give the area of the rectangle.
- **d** Write an expression for the total length of the rectangle.
- **e** Using part **d**, write an expression for the area of the rectangle.
- **f** Combine your results to complete this statement: $4(x + 2) = \square + \square$.

2 Multiply the following expressions involving negatives.

- **a** $2 \times (-4)$ **b** $3 \times (-6)$
- **c** $3 \times (-x)$ **d** $4 \times (-2x)$
- **e** -4×5 **f** $-2 \times 8x$
- **g** $-5 \times (-3)$ **h** $-6 \times (-4)$
- **i** $-2x \times (-3)$

negative × positive = negative
negative × negative = positive



3 Complete the following.

a $3(x + 4) = 3 \times \square + 3 \times \square$
$= 3x + \square$

b $2(x - 5) = 2 \times \square + \square \times (-5)$
$= \square - 10$

c $2(4x + 3) = 2 \times \square + \square \times 3$
$= \square + 6$

d $x(x - 3) = x \times \square + \square \times (\square)$
$= \square - \square$

4 Simplify the following.

- **a** $3 \times 2x$ **b** $4x \times 2y$ **c** $3x \times 5x$
- **d** $5 + 2x + 4$ **e** $3x + 9 + 4x - 4$ **f** $5x + 10 - 2x - 14$

Example 8 Expanding expressions with brackets

Expand the following.

a $2(x + 5)$ **b** $3(2x - 3)$ **c** $3y(2x + 4y)$

SOLUTION

a $2(x + 5) = 2 \times x + 2 \times 5$
$= 2x + 10$

b $3(2x - 3) = 3 \times 2x + 3 \times (-3)$
$= 6x - 9$

c $3y(2x + 4y) = 3y \times 2x + 3y \times 4y$
$= 6xy + 12y^2$

EXPLANATION

a Multiply each term inside the brackets by 2.

b Multiply $2x$ and -3 by 3.
$3 \times 2x = 3 \times 2 \times x = 6x$

c Multiply $2x$ and $4y$ by $3y$.
$3y \times 2x = 3 \times 2 \times x \times y$ and
$3y \times 4y = 3 \times 4 \times y \times y$.
Recall: $y \times y$ is written as y^2.

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5 Expand the following.

a $2(x + 4)$ **b** $3(x + 7)$ **c** $4(y - 3)$
d $5(y - 2)$ **e** $2(3x + 2)$ **f** $4(2x + 5)$
g $3(3a - 4)$ **h** $7(2y - 5)$ **i** $5(2a + b)$
j $3(4a - 3b)$ **k** $2x(x + 5)$ **l** $3x(x - 4)$
m $2a(3a + 2b)$ **n** $2y(3x - 4y)$ **o** $3b(2a - 5b)$

Use the distributive law:

$$\begin{aligned} a(b + c) &= a \times b + a \times c \\ &= ab + ac \end{aligned}$$

$$\begin{aligned} a(b - c) &= a \times b + a \times (-c) \\ &= ab - ac \end{aligned}$$

Example 9 Expanding expressions with a negative out the front

Expand the following.

a $-3(x - 4)$ **b** $-2x(3x - 2y)$

SOLUTION

a $$\begin{aligned} -3(x - 4) &= -3 \times x + (-3) \times (-4) \\ &= -3x + 12 \end{aligned}$$

b $$\begin{aligned} -2x(3x - 2y) &= -2x \times 3x + (-2x) \times (-2y) \\ &= -6x^2 + 4xy \end{aligned}$$

EXPLANATION

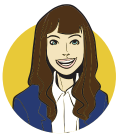
a Multiply each term inside the brackets by −3.
$-3 \times (-4) = +12$
If there is a negative sign outside the brackets, the sign of each term inside the brackets is changed when expanded.

b $-2x \times 3x = -2 \times 3 \times x \times x$ and
$-2x \times (-2y) = -2 \times (-2) \times x \times y$

6 Expand the following.

a $-2(x + 3)$ **b** $-5(m + 2)$ **c** $-3(w + 4)$
d $-4(x - 3)$ **e** $-2(m - 7)$ **f** $-7(w - 5)$
g $-(x + y)$ **h** $-(x - y)$ **i** $-2x(3x + 4)$
j $-3x(2x + 5)$ **k** $-4x(2x - 2)$ **l** $-3y(2y - 9)$
m $-2x(3x - 5y)$ **n** $-3x(3x + 2y)$ **o** $-6y(2x + 3y)$

A negative out the front will change the sign of each term inside the brackets when expanded.
$-2(x - 3) = -2x + 6$



Example 10 Simplifying expressions by removing brackets

Expand and simplify the following.

a $8 + 3(2x - 3)$ **b** $3(2x + 2) - 4(x + 4)$

SOLUTION

a $$\begin{aligned} 8 + 3(2x - 3) &= 8 + 6x - 9 \\ &= 6x - 1 \end{aligned}$$

b $$\begin{aligned} 3(2x + 2) - 4(x + 4) &= 6x + 6 - (4x + 16) \\ &= 6x + 6 - 4x - 16 \\ &= 2x - 10 \end{aligned}$$

EXPLANATION

a Expand the brackets: $3 \times 2x + 3 \times (-3) = 6x - 9$.
Collect like terms: $8 - 9 = -1$.

b Expand the brackets first.
Note that $$\begin{aligned} -4(x + 4) &= -4 \times x + (-4) \times 4 \\ &= -4x - 16. \end{aligned}$$
Collect like terms: $6x - 4x = 2x$ and $6 - 16 = -10$.

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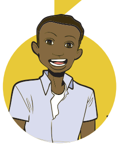
7 Expand and simplify the following.

a $2 + 5(x + 3)$ **b** $3 + 7(x + 2)$ **c** $5 + 2(x - 3)$
d $7 - 2(x + 3)$ **e** $21 - 5(x + 4)$ **f** $4 + 3(2x - 1)$
g $3 + 2(3x + 4)$ **h** $8 - 2(2x - 3)$ **i** $12 - 3(2x - 5)$
j $3(x + 2) + 4(x + 3)$ **k** $2(p + 2) + 5(p - 3)$ **l** $4(x - 3) + 2(3x + 4)$
m $3(2s + 3) - 2(s + 2)$ **n** $4(3f + 2) - 2(6f + 2)$ **o** $3(2x - 5) - 2(2x - 4)$

Expand first, then collect like terms.



PROBLEM-SOLVING AND REASONING		
	8, 9	8, 10, 11

8 Fill in the missing term/number to make each statement true.

a $\square(x + 4) = 2x + 8$ **b** $\square(2x - 3) = 8x - 12$ **c** $\square(2x + 3) = 6x^2 + 9x$
d $4(\square + 5) = 12x + 20$ **e** $4y(\square - \square) = 4y^2 - 4y$ **f** $-2x(\square + \square) = -4x^2 - 6xy$

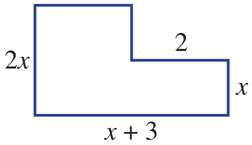
9 Four rectangular rooms in a house have floor side lengths listed below.

Find an expression for the area of each floor in expanded form.

a 2 and $x - 5$ **b** x and $x + 3$
c $2x$ and $x + 4$ **d** $3x$ and $2x - 1$

Area of rectangle $=$ length × breadth

10 The deck on a house is constructed in the shape shown. Find the area of the deck in expanded form.



11 Virat earns $\$x$, where x is greater than 18 200, but does not have to pay tax on the first \$18 200.

a Write an expression for the amount of money Virat is taxed on.

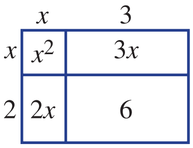
b Virat is taxed 10% of his earnings in part **a**. Write an expanded expression for how much tax he pays.

To find 10% of an amount, multiply by $\frac{10}{100} = 0.1$

ENRICHMENT		
	–	12(½)

Expanding binomial products

12 A rectangle has dimensions $(x + 2)$ by $(x + 3)$, as shown. The area can be found by summing the individual areas:



$$\begin{aligned}(x + 2)(x + 3) &= x^2 + 3x + 2x + 6\\ &= x^2 + 5x + 6\end{aligned}$$

This can be done using the distributive law:

$$\begin{aligned}(x + 2)(x + 3) &= x(x + 3) + 2(x + 3)\\ &= x^2 + 3x + 2x + 6\\ &= x^2 + 5x + 6\end{aligned}$$

Expand and simplify these binomial products using this method.

a $(x + 4)(x + 3)$ **b** $(x + 3)(x + 1)$ **c** $(x + 2)(x + 5)$
d $(x + 2)(x - 4)$ **e** $(x + 5)(x - 2)$ **f** $(x + 4)(2x + 3)$
g $(2x + 3)(x - 2)$ **h** $(x - 3)(x + 4)$ **i** $(4x - 2)(x + 5)$

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3D Factorising algebraic expressions

Interactive
Widgets
HOTsheets
Walkthrough

We know that $3(x + 2)$ can be expanded to give $3x + 6$. Similarly, $3x + 6$ can be factorised to give $3(x + 2)$. Factorising is the opposite of expanding.

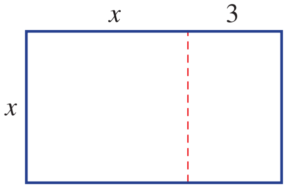
$$\begin{tikzcd} 3(x+2) \arrow[r, bend left, "\text{Expanding}"] & 3x+6 \arrow[l, bend left, "\text{Factorising}"] \end{tikzcd}$$

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Factorised areas

Here is a rectangle of length $(x + 3)$ and breadth x.

- Write an expression for the total area using the given length and breadth.
- Write an expression for the total area by adding up the area of the two smaller regions.
- Are your two expressions equivalent? How could you work from your second expression (expanded) to the first expression (factorised)?



Key ideas

- Factorisation and expansion are opposite processes.
- When **factorising** expressions with common factors, take out the highest common factor (HCF). The HCF could be:
  - a number
    For example: $2x + 10 = 2(x + 5)$
  - a pronumeral
    For example: $x^2 + 5x = x(x + 5)$
  - the product of numbers and variables
    For example: $2x^2 + 10x = 2x(x + 5)$

$$\underbrace{2x + 10}_{\text{expanded form}} = \underbrace{\overset{\text{HCF of } 2x \text{ and } 10}{2}(x + 5)}_{\text{factorised form}}$$

- A factorised expression can be checked by using expansion.
  For example: $2x(x + 5) = 2x^2 + 10x$

Factorise To write an expression as a product

Exercise 3D

UNDERSTANDING AND FLUENCY 1–2(½), 3, 4–7(½) 4–7(½)

1 Write down the highest common factor (HCF) of these pairs of numbers.

a 10 and 16 **b** 4 and 12 **c** 9 and 27
d 18 and 30 **e** 14 and 35 **f** 36 and 48

2 Write down the missing factor.

a $4 \times \square = 4x$ **b** $5 \times \square = 10x$ **c** $x \times \square = 3x^2$
d $3a \times \square = 6ab$ **e** $2x \times \square = 8x^2$ **f** $-4y \times \square = -12y^2$

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3 Consider the expression $4x^2 + 8x$.

a Which of the following factorised forms uses the HCF?

A $2(2x^2 + 4x)$ **B** $4(x^2 + 8x)$ **C** $4x(x + 2)$ **D** $2x(2x + 4)$

b What can be said about the terms inside the brackets once the HCF is removed, that is not the case for the other forms?

Example 11 Finding the HCF

Determine the HCF of the following.

a $8a$ and 20 **b** $3x$ and $6x$ **c** $10a^2$ and $15ab$

SOLUTION	EXPLANATION
a HCF of $8a$ and 20 is 4.	Compare numerals and pronumerals separately. The highest common factor (HCF) of 8 and 20 is 4. a is not a common factor.
b HCF of $3x$ and $6x$ is $3x$.	HCF of 3 and 6 is 3. x is also a common factor.
c HCF of $10a^2$ and $15ab$ is $5a$.	HCF of 10 and 15 is 5. HCF of a^2 and ab is a.

4 Determine the HCF of the following.

a $6x$ and 12 **b** 10 and $15y$

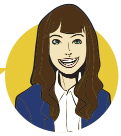
c $8a$ and $12b$ **d** $9x$ and $18y$

e $5a$ and $20a$ **f** $10m$ and $22m$

g $14x$ and $21x$ **h** $8a$ and $40ab$

i $3a^2$ and $9ab$ **j** $4x^2$ and $10x$

k $16y$ and $24xy$ **l** $15x^2y$ and $25xy$



Find the HCF of the numeral and pronumeral factors.

Example 12 Factorising simple expressions

Factorise the following.

a $4x + 20$ **b** $6a - 15b$

SOLUTION	EXPLANATION
a $4x + 20 = 4(x + 5)$	HCF of $4x$ and 20 is 4. Place 4 in front of the brackets and divide each term by 4. Expand to check: $4(x + 5) = 4x + 20$.
b $6a - 15b = 3(2a - 5b)$	HCF of $6a$ and $15b$ is 3. Place 3 in front of the brackets and divide each term by 3.

5 Factorise the following

a $3x + 9$ **b** $4x - 8$ **c** $10y - 20$

d $6a + 30$ **e** $5x + 5y$ **f** $12a + 4b$

g $18m - 27n$ **h** $36x - 48y$ **i** $8x + 44y$

j $24a - 18b$ **k** $121m + 55n$ **l** $14k - 63l$

Check your answer by expanding.

$3(x + 3) = 3x + 9$

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Example 13 Factorising expressions with pronumeral common factors

Factorise the following.

a $8y + 12xy$

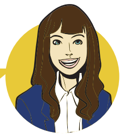
b $4x^2 - 10x$

SOLUTION	EXPLANATION
a $8y + 12xy = 4y(2 + 3x)$	HCF of 8 and 12 is 4, HCF of y and xy is y. Place $4y$ in front of the brackets and divide each term by $4y$. Check that $4y(2 + 3x) = 8y + 12xy$.
b $4x^2 - 10x = 2x(2x - 5)$	HCF of $4x^2$ and $10x$ is $2x$. Place $2x$ in front of the brackets and divide each term by $2x$. Recall: $x^2 = x \times x$.

6 Factorise the following.

a $14x + 21xy$
b $6ab - 15b$
c $32y - 40xy$
d $5x^2 - 5x$
e $x^2 + 7x$
f $2a^2 + 8a$
g $12a^2 + 42ab$
h $9y^2 - 63y$
i $6x^2 + 14x$
j $9x^2 - 6x$
k $16y^2 + 40y$
l $10m - 40m^2$

Place the HCF in front of the brackets and divide each term by the HCF:
$14x + 21xy = 7x(\_\_ + \_\_)$



Example 14 Factorising expressions by removing a common negative

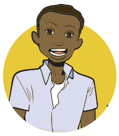
Factorise $-10x^2 - 18x$.

SOLUTION	EXPLANATION
$-10x^2 - 18x = -2x(5x + 9)$	The HCF of $-10x^2$ and $-18x$ is $-2x$, including the common negative. Place $-2x$ in front of the brackets and divide each term by $-2x$. Dividing by a negative changes the sign of each term.

7 Factorise the following, including the common negative.

a $-2x - 6$
b $-4a - 8$
c $-3x - 6y$
d $-7a - 14ab$
e $-x - 10xy$
f $-3b - 12ab$
g $-x^2 - 7x$
h $-4x^2 - 12x$
i $-2y^2 - 10y$
j $-8x^2 - 14x$
k $-12x^2 - 8x$
l $-15a^2 - 5a$

Dividing by a negative changes the sign of the term.



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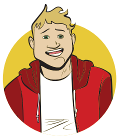
PROBLEM-SOLVING AND REASONING	8, 9	8(½), 9, 10, 11(½)

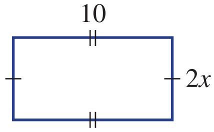
8 Factorise these mixed expressions.

a $7a^2b + ab$
b $4a^2b + 20a^2$
c $xy - xy^2$
d $x^2y + 4x^2y^2$
e $6mn + 18mn^2$
f $5x^2y + 10xy^2$
g $-y^2 - 8yz$
h $-3a^2b - 6ab$
i $-ab^2 - a^2b$

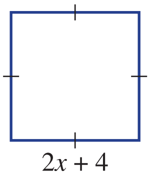

Be sure to find the highest common factor first.

9 Give the perimeter of these shapes, in factorised form.

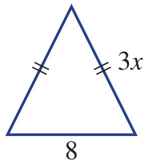
a

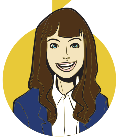


b



c




Find the simplified perimeter first, then factorise.

10 A square sandpit has perimeter $(4x + 12)$ metres. What is the side length of the square?

11 Common factors can be removed from expressions involving more than two terms in a similar way. Factorise these by taking out the HCF.

a $2x + 4y + 6z$
b $3x^2 + 12x + 6$
c $4x^2 + 8xy + 12$
d $6x^2 + 3xy - 9x$
e $10xy - 5xz + 5x$
f $4y^2 - 18y + 14xy$


$4a + 6b + 10c$
$= 2(2a + 3b + 5c)$

ENRICHMENT	–	12(½)

Taking out a binomial factor

A common factor may be a binomial term, such as $(x + 1)$.

For example, $3(x + 1) + x(x + 1)$ has HCF $= (x + 1)$, so $3(x + 1) + x(x + 1) = (x + 1)(3 + x)$, where $(3 + x)$ is what remains when $3(x + 1)$ and $x(x + 1)$ are divided by $(x + 1)$.

12 Use the method above to factorise the following.

a $4(x + 2) + x(x + 2)$
b $x(x + 3) + 2(x + 3)$
c $x(x + 4) - 7(x + 4)$
d $x(2x + 1) - 3(2x + 1)$
e $2x(y - 3) + 4(y - 3)$
f $2x(x - 1) - 3(x - 1)$

3E Simplifying algebraic fractions: Multiplication and division

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Interactive
Widgets
HOTsheets
Walkthrough

Since pronumerals represent numbers, the rules for algebraic fractions are the same as those for simple numerical fractions. This includes processes such as cancelling common factors to simplify the calculation and dividing by multiplying by the reciprocal of a fraction.

The process of cancelling requires cancelling of factors, for example:

$$\frac{8}{12}=\frac{2\times\cancel{4}^{1}}{3\times\cancel{4}_{1}}=\frac{2}{3}$$

For algebraic fractions, you need to factorise the expressions to identify and cancel common factors.

Let's start: Expressions as products of their factors

Factorise these expressions to write them as a product of their factors. Fill in the blanks and simplify.

$$\frac{2x+4}{2}=\frac{\square\left(\boxed{}\right)}{2}=\boxed{} \qquad \frac{6x+9}{3}=\frac{\square\left(\boxed{}\right)}{3}=\boxed{}$$

$$\frac{x^2+2x}{x}=\frac{\square\left(\boxed{}\right)}{x}=\boxed{} \qquad \frac{4x+4}{4}=\frac{\square\left(\boxed{}\right)}{4}=\boxed{}$$

Describe the errors made in these simplifications.

$$\frac{{}^{1}\cancel{3}x+2}{\cancel{3}^{1}}=x+2 \qquad \frac{{}^{1}\cancel{5}x+4}{{}^{1}\cancel{5}}=x+4$$

$$\frac{x^2+\cancel{3x}^{1}}{\cancel{3x}^{1}}=x^2+1 \qquad \frac{6\cancel{x}^{1}+6}{{}^{1}\cancel{x}+1}=\frac{12}{1}=12$$

Key ideas

- Simplify **algebraic fractions** by cancelling common factors in factorised form. For example: $\frac{4x+6}{2}=\frac{\cancel{2}_{1}(2x+3)}{\cancel{2}_{1}}$
  $= 2x+3$

Algebraic fraction A fraction containing pronumerals as well as numbers

- To multiply algebraic fractions:
  - Factorise expressions if possible.
  - Cancel common factors.
  - Multiply numerators and denominators together.

For example:

$$\frac{\cancel{(x+1)}^{1}}{\cancel{10}_{2}}\times\frac{{}^{1}\cancel{5}x}{4\cancel{(x+1)}_{1}}=\frac{x}{8}$$

- To divide algebraic fractions:
  - Multiply by the reciprocal of the fraction following the division sign (e.g. the reciprocal of 6 is $\frac{1}{6}$, the reciprocal of $\frac{a}{b}$ is $\frac{b}{a}$).
  - Follow the rules for multiplication.

For example:

$$\frac{2}{(x-2)}\div\frac{8}{3(x-2)}$$
$$=\frac{\cancel{2}_{1}}{\cancel{(x-2)}_{1}}\times\frac{3\cancel{(x-2)}_{1}}{\cancel{8}_{4}}$$
$$=\frac{3}{4}$$

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Exercise 3E

UNDERSTANDING AND FLUENCY 1–8(½) 4–8(½)

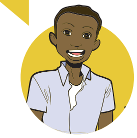
1 Write these fractions in simplest form by cancelling common factors.

a $\frac{14}{21}$ **b** $\frac{9}{12}$ **c** $\frac{8x}{20}$

d $\frac{4x}{10}$ **e** $\frac{4(x+1)}{8}$ **f** $\frac{3(x-2)}{6}$

g $\frac{6(x+4)}{18}$ **h** $\frac{5(x+3)}{25}$

Be sure to cancel the highest common factor.



2 Simplify these fractions.

a $\frac{8}{9} \times \frac{3}{10}$ **b** $\frac{15}{21} \times \frac{14}{25}$ **c** $\frac{4}{27} \div \frac{16}{9}$ **d** $\frac{18}{35} \div \frac{9}{14}$

3 Write the reciprocal of these fractions.

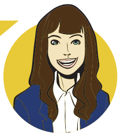
a $\frac{3}{2}$ **b** $\frac{5x}{3}$ **c** 7 **d** $\frac{x+3}{4}$

The reciprocal of $\frac{a}{b}$ is $\frac{b}{a}$.

4 Factorise these by taking out the highest common factor.

a $3x + 6$
b $2x + 4$
c $8x + 12$
d $16 - 8x$
e $x^2 + 3x$
f $4x^2 + 10x$
g $-2x - 6$
h $-x^2 - 5x$

$3x + 6$ has a HCF of 3.
Place 3 in front of the brackets and divide each term by 3.
$3x + 6 = 3(\_\_\_\_\_\_\_\_)$



Example 15 Cancelling common factors

Simplify by cancelling common factors.

a $\frac{8xy}{12x}$ **b** $\frac{3(x+2)}{6(x+2)}$

SOLUTION

a
$$\frac{8xy}{12x} = \frac{{}^{2}\cancel{8} \times \cancel{x}^{1} \times y}{{}^{3}\cancel{12} \times \cancel{x}^{1}}$$
$$= \frac{2y}{3}$$

b
$$\frac{3(x+2)}{6(x+2)} = \frac{{}^{1}\cancel{3} \times \cancel{(x+2)}^{1}}{{}^{2}\cancel{6} \times \cancel{(x+2)}^{1}}$$
$$= \frac{1}{2}$$

EXPLANATION

Cancel the highest common factor of 8 and 12 (which is 4) and cancel the x.

Cancel the highest common factors: 3 and $(x + 2)$.

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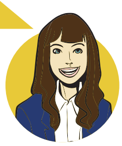
5 Simplify by cancelling common factors.

a $\frac{6xy}{12x}$ **b** $\frac{12ab}{30b}$ **c** $\frac{8x^2}{40x}$ **d** $\frac{25x^2}{5x}$

e $\frac{3(x+1)}{3}$ **f** $\frac{7(x-5)}{7}$ **g** $\frac{4(x+1)}{8}$ **h** $\frac{5(x-2)}{x-2}$

i $\frac{4(x-3)}{x-3}$ **j** $\frac{6(x+2)}{12(x+2)}$ **k** $\frac{9(x+3)}{3(x+3)}$ **l** $\frac{15(x-4)}{10(x-4)}$

Cancel the HCF of the numerals and pronumerals.



Example 16 Simplifying by factorising

Simplify these fractions by factorising first.

a $\frac{9x-12}{3}$ **b** $\frac{4x+8}{x+2}$

SOLUTION

a $\frac{9x-12}{3} = \frac{{}^{1}\cancel{3}(3x-4)}{\cancel{3}_{1}}$

$= 3x - 4$

b $\frac{4x+8}{x+2} = \frac{4(\cancel{x+2})_{1}}{\cancel{x+2}_{1}}$

$= 4$

EXPLANATION

Factorise the expression in the numerator, which has HCF of 3. Then cancel the common factor of 3.

4 is the HCF in the numerator.
After factorising, $(x + 2)$ is the common factor and can be cancelled.

6 Simplify these fractions by factorising first.

a $\frac{4x+8}{4}$ **b** $\frac{6a-30}{6}$ **c** $\frac{8y-12}{4}$ **d** $\frac{14b-21}{7}$

e $\frac{3x+9}{x+3}$ **f** $\frac{4x-20}{x-5}$ **g** $\frac{6x+9}{2x+3}$ **h** $\frac{12x-4}{3x-1}$

i $\frac{x^2+2x}{x}$ **j** $\frac{x^2-5x}{x}$ **k** $\frac{2x^2+6x}{2x}$ **l** $\frac{x^2+4x}{x+4}$

m $\frac{x^2-7x}{x-7}$ **n** $\frac{2x^2-4x}{x-2}$ **o** $\frac{3x^2+6x}{x+2}$ **p** $\frac{2x^2+12x}{x+6}$

Cancel after you have factorised the numerator.

Example 17 Multiplying algebraic fractions

Simplify these products.

a $\frac{12}{5x} \times \frac{10x}{9}$ **b** $\frac{3(x-1)}{10} \times \frac{15}{x-1}$

SOLUTION

a $\frac{\cancel{12}_{4}}{\cancel{5x}_{1}} \times \frac{\cancel{10x}^{2}}{\cancel{9}_{3}}$

$= \frac{8}{3} = 2\frac{2}{3}$

b $\frac{3\cancel{(x-1)}^{1}}{\cancel{10}^{2}} \times \frac{\cancel{15}_{3}}{\cancel{x-1}_{1}}$

$= \frac{9}{2} = 4\frac{1}{2}$

EXPLANATION

Cancel common factors between numerators and denominators: $5x$ and 3.
Then multiply the numerators and the denominators.

Cancel the common factors, which are $(x - 1)$ and 5.
Multiply numerators and denominators.

7 Simplify these products.

a $\frac{3}{x} \times \frac{2x}{9}$

b $\frac{4x}{5} \times \frac{15}{8x}$

c $\frac{9a}{14} \times \frac{7}{6a}$

d $\frac{2x^2}{5} \times \frac{25}{6x}$

e $\frac{4y^2}{7} \times \frac{21}{8y}$

f $\frac{x+1}{6} \times \frac{5}{x+1}$

g $\frac{x+3}{9} \times \frac{4}{x+3}$

h $\frac{4(y-7)}{2} \times \frac{5}{y-7}$

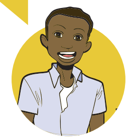
i $\frac{10}{a+6} \times \frac{3(a+6)}{4}$

j $\frac{4(x-2)}{7} \times \frac{14}{5(x-2)}$

k $\frac{3(x+2)}{2x} \times \frac{8}{9(x+2)}$

l $\frac{4(2x+1)}{3x} \times \frac{9x}{2x+1}$

Cancel any common factors between numerators and denominators before multiplying.



Example 18 Dividing algebraic fractions

Simplify the following.

a $\frac{3x^2}{8} \div \frac{9x}{4}$

b $\frac{2(x-2)}{3} \div \frac{x-2}{6}$

SOLUTION

a
$$\frac{3x^2}{8} \div \frac{9x}{4} = \frac{\cancel{3}x^{\cancel{2}1}}{\cancel{8}_2} \times \frac{\cancel{4}_1}{{}_3\cancel{9}\cancel{x}^1}$$
$$= \frac{x}{6}$$

b
$$\frac{2(x-2)}{3} \div \frac{x-2}{6} = \frac{2\cancel{(x-2)}^1}{\cancel{3}^1} \times \frac{\cancel{6}^2}{\cancel{x-2}^1}$$
$$= 4$$

EXPLANATION

Multiply by the reciprocal of the second fraction.

The reciprocal of $\frac{9x}{4}$ is $\frac{4}{9x}$.

Cancel common factors: $3x$ and 4.

Note: $\frac{3x^2}{9x} = \frac{\cancel{3}^1 \times x \times \cancel{x}^1}{{}_3\cancel{9} \times \cancel{x}^1}$

Multiply the numerators and the denominators.

The reciprocal of $\frac{x-2}{6}$ is $\frac{6}{x-2}$.

Cancel the common factors, $(x-2)$ and 3, and multiply.

Recall: $\frac{4}{1} = 4$.

8 Simplify the following.

a $\frac{x}{5} \div \frac{x}{15}$

b $\frac{3x}{10} \div \frac{x}{20}$

c $\frac{4a^2}{9} \div \frac{a}{18}$

d $\frac{3x^2}{10} \div \frac{6x}{5}$

e $\frac{4a}{9} \div \frac{5a^2}{6}$

f $\frac{2x}{7} \div \frac{x^2}{14}$

g $\frac{x+4}{2} \div \frac{x+4}{6}$

h $\frac{5(x-2)}{8} \div \frac{x-2}{4}$

i $\frac{3(x+4)}{10} \div \frac{6(x+4)}{15}$

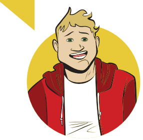
j $\frac{2}{5(2x-1)} \div \frac{10}{2x-1}$

k $\frac{2(x-3)}{x-4} \div \frac{x-3}{5(x-4)}$

l $\frac{3(x+1)}{14(x-1)} \div \frac{6(x+1)}{35(x-1)}$

To divide, multiply by the reciprocal of the fraction following the division sign.

$\frac{x}{5} \div \frac{x}{15} = \frac{x}{5} \times \frac{15}{x}$



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PROBLEM-SOLVING AND REASONING

9, 10(½) 9–11(½)

9 Find the error in the simplification of these fractions and correct it.

a $\frac{3x + \cancel{6}_2}{\cancel{3}_1} = 3x + 2$

b $\frac{x^2 + 2\cancel{x}_1}{\cancel{x}_1} = x^2 + 2$

c $\frac{4x}{5} \div \frac{10x}{3} = \frac{4x}{\cancel{5}_1} \times \frac{{}^2\cancel{10}x}{3}$

$= \frac{8x^2}{3}$

d $\frac{\cancel{x}_1 + 4}{\cancel{15}_5} \times \frac{\cancel{3}_1}{\cancel{x}_1} = \frac{4}{5}$

Remember that common factors can be easily identified when expressions are in factorised form.

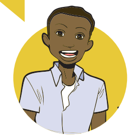
10 Simplify these algebraic fractions by factorising expressions first.

a $\frac{7a + 14a^2}{21a}$ **b** $\frac{4x + 8}{5x + 10}$ **c** $\frac{x^2 + 3x}{4x + 12}$

d $\frac{2m + 4}{15} \times \frac{3}{m + 2}$ **e** $\frac{5 - x}{12} \times \frac{14}{15 - 3x}$ **f** $\frac{x^2 + 2x}{4} \times \frac{8}{3x + 6}$

g $\frac{2x - 1}{10} \div \frac{4x - 2}{25}$ **h** $\frac{2x + 4}{6x} \div \frac{3x + 6}{x^2}$ **i** $\frac{2x^2 - 4x}{3x - 6} \div \frac{6x}{x + 5}$

You may need to factorise numerators and denominators.



11 By removing a negative factor, further simplification is possible.

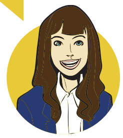
For example, $\frac{-2x - 4}{x + 2} = \frac{-2\cancel{(x + 2)}_1}{\cancel{x + 2}_1} = -2.$

Use this idea to simplify the following.

a $\frac{-3x - 9}{x + 3}$ **b** $\frac{-4x - 10}{2x + 5}$ **c** $\frac{-x^2 - 4x}{x + 4}$

d $\frac{-3x^2 - 6x}{-9x}$ **e** $\frac{-2x + 12}{-2}$ **f** $\frac{-10x + 15}{-5}$

Taking out a negative factor changes the sign of each term inside the brackets.



ENRICHMENT

– 12(½)

Cancelling of powers

12 Just as $\frac{x^{\cancel{2}1}}{\cancel{x}^1} = x$, $\frac{(x + 1)^{\cancel{2}1}}{\cancel{x + 1}_1} = x + 1$. Use this idea to simplify these algebraic fractions. Some will need factorising first.

a $\frac{(x + 1)^2}{8} \times \frac{4}{x + 1}$ **b** $\frac{(x + 1)^2}{7x} \times \frac{14x}{3(x + 1)}$

c $\frac{9}{x - 2} \div \frac{18}{(x - 2)^2}$ **d** $\frac{(x + 2)^2}{10} \times \frac{5}{4x + 8}$

e $\frac{(x - 3)^2}{9x} \times \frac{3x}{4x - 12}$ **f** $\frac{15}{8x + 4} \div \frac{6}{(2x + 1)^2}$

3F Simplifying algebraic fractions: Addition and subtraction

Interactive
Widgets
HOTsheets
Walkthrough

As with multiplying and dividing, the steps for adding and subtracting numerical fractions can be applied to algebraic fractions. The lowest common denominator is required before the fractions can be combined.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Steps for adding fractions

- Write out the list of steps you would give to someone to show them how to add $\frac{3}{5}$ and $\frac{2}{7}$.
- Now repeat your steps to add the fractions $\frac{3x}{5}$ and $\frac{2x}{7}$.
- What is different when these steps are applied to $\frac{x+2}{5}$ and $\frac{x}{7}$?

Key ideas

- To add or subtract algebraic fractions:
  - Determine the lowest common denominator (LCD).
    For example: The LCD of 3 and 5 is 15.
    The LCD of 4 and 12 is 12.
  - Write each fraction as an equivalent fraction by multiplying the denominator(s) to equal the LCD. When denominators are multiplied, numerators must also be multiplied.
  - Add or subtract the numerators.

For example: $\frac{x}{3}+\frac{2x}{5}=\frac{x\,(\times 5)}{3\,(\times 5)}+\frac{2x\,(\times 3)}{5\,(\times 3)}$ (LCD of 3 and 5 is 15.)

$$=\frac{5x}{15}+\frac{6x}{15}$$

$$=\frac{11x}{15}$$

For example: $\frac{2x}{4}-\frac{x}{12}=\frac{2x\,(\times 3)}{4\,(\times 3)}-\frac{x}{12}$ (LCD of 4 and 12 is 12.)

$$=\frac{6x}{12}-\frac{x}{12}$$

$$=\frac{5x}{12}$$

- To express $\frac{x+1}{3}$ with a denominator of 12, both the numerator and denominator must be multiplied by 4 and brackets will be required in the numerator:

$$\frac{(x+1)\,(\times 4)}{3\,(\times 4)}=\frac{4x+4}{12}$$

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Exercise 3F

UNDERSTANDING AND FLUENCY 1–7(½) 4–7(½)

1 Write down the lowest common denominator for these pairs of fractions.

a $\frac{2}{3}, \frac{3}{4}$ **b** $\frac{1}{6}, \frac{4}{9}$ **c** $\frac{3}{4}, \frac{5}{8}$

d $\frac{x}{3}, \frac{x}{12}$ **e** $\frac{2x}{5}, \frac{x}{4}$ **f** $\frac{3x}{10}, \frac{2x}{15}$

The LCD is not always the two denominators multiplied together; e.g. 3 × 6 = 18. The LCD of 3 and 6 is 6.

2 Simplify these fractions by adding or subtracting.

a $\frac{1}{6}+\frac{2}{3}$ **b** $\frac{2}{5}+\frac{3}{8}$ **c** $\frac{1}{4}+\frac{5}{6}$

d $\frac{2}{3}-\frac{3}{7}$ **e** $\frac{15}{16}-\frac{3}{4}$ **f** $\frac{5}{6}-\frac{4}{9}$

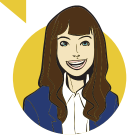
3 Complete these equivalent fractions by giving the missing term.

a $\frac{x}{4}=\frac{\square}{12}$ **b** $\frac{x}{8}=\frac{\square}{40}$

c $\frac{2x}{5}=\frac{\square}{15}$ **d** $\frac{3x}{2}=\frac{\square}{8}$

e $\frac{x+2}{3}=\frac{\square(x+2)}{9}$ **f** $\frac{x-1}{4}=\frac{\square(x-1)}{20}$

For equivalent fractions, whatever the denominator is multiplied by, the numerator must be multiplied by the same amount.



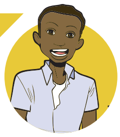
4 Expand and simplify.

a $4(x+2)+3x$ **b** $3(x-4)+2x$

c $4(x+1)-2x$ **d** $3(x+2)+4(x+3)$

e $5(x+2)+2(x-3)$ **f** $4(x-2)+3(x+6)$

$$\begin{aligned}4(x+2) &= 4\times x+4\times 2\\ &= 4x+8\end{aligned}$$



Example 19 Adding and subtracting algebraic fractions

Simplify the following.

a $\frac{x}{2}+\frac{x}{3}$ **b** $\frac{4x}{5}-\frac{x}{2}$ **c** $\frac{x}{2}-\frac{5}{6}$

SOLUTION

a $\frac{x\,(\times 3)}{2\,(\times 3)}+\frac{x\,(\times 2)}{3\,(\times 2)}=\frac{3x}{6}+\frac{2x}{6}$

$=\frac{5x}{6}$

EXPLANATION

The LCD of 2 and 3 is 6.

Express each fraction with a denominator of 6 and add numerators.

b $\frac{4x\,(\times 2)}{5\,(\times 2)}-\frac{x\,(\times 5)}{2\,(\times 5)}=\frac{8x}{10}-\frac{5x}{10}$

$=\frac{3x}{10}$

The LCD of 5 and 2 is 10.

Express each fraction with a denominator of 10 and subtract $5x$ from $8x$.

c $\frac{x\,(\times 3)}{2\,(\times 3)}-\frac{5}{6}=\frac{3x}{6}-\frac{5}{6}$

$=\frac{3x-5}{6}$

The LCD of 2 and 6 is 6. Multiply the numerator and denominator of $\frac{x}{2}$ by 3 to express with a denominator of 6.

Write as a single fraction; $3x-5$ cannot be simplified.

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5 Simplify the following.

a $\frac{x}{3}+\frac{x}{4}$ **b** $\frac{x}{5}+\frac{x}{2}$ **c** $\frac{x}{3}-\frac{x}{9}$ **d** $\frac{x}{5}-\frac{x}{7}$

e $\frac{2x}{3}+\frac{x}{5}$ **f** $\frac{3x}{4}+\frac{5x}{12}$ **g** $\frac{5x}{6}-\frac{4x}{9}$ **h** $\frac{7x}{10}-\frac{3x}{8}$

i $\frac{x}{7}-\frac{x}{2}$ **j** $\frac{x}{10}-\frac{2x}{5}$ **k** $\frac{5x}{6}-\frac{13x}{15}$ **l** $\frac{3x}{10}-\frac{3x}{2}$

Express each fraction with a common denominator using the LCD, then add or subtract numerators.

6 Simplify the following.

a $\frac{x}{2}+\frac{3}{4}$ **b** $\frac{x}{5}+\frac{2}{3}$ **c** $\frac{2x}{15}+\frac{7}{20}$ **d** $\frac{x}{4}-\frac{2}{5}$ **e** $\frac{2x}{3}-\frac{5}{9}$ **f** $\frac{5}{6}-\frac{x}{4}$

Example 20 Adding and subtracting with binomial numerators

Simplify the following algebraic expressions.

a $\frac{x+2}{4}-\frac{x}{6}$ **b** $\frac{x+3}{3}+\frac{x-4}{7}$

SOLUTION

a
$$\frac{x+2}{4}-\frac{x}{6}=\frac{3(x+2)}{12}-\frac{2x}{12}$$
$$=\frac{3x+6-2x}{12}$$
$$=\frac{x+6}{12}$$

b
$$\frac{x+3}{3}+\frac{x-4}{7}=\frac{7(x+3)}{21}+\frac{3(x-4)}{21}$$
$$=\frac{7x+21+3x-12}{21}$$
$$=\frac{10x+9}{21}$$

EXPLANATION

The LCD of 4 and 6 is 12.
Express each fraction with a denominator of 12.
When multiplying $(x+2)$ by 3, brackets are required.
Expand the brackets and collect the terms:
$3x+6-2x=3x-2x+6$

The LCD of 3 and 7 is 21.
Express each fraction with a denominator of 21.
Expand each pair of brackets first and sum by collecting like terms.

7 Simplify these algebraic expressions.

a $\frac{x+2}{3}+\frac{x}{2}$ **b** $\frac{x+4}{5}+\frac{2x}{3}$

c $\frac{x-2}{4}+\frac{3x}{8}$ **d** $\frac{x+4}{3}-\frac{x}{6}$

e $\frac{x+2}{2}-\frac{2x}{5}$ **f** $\frac{6x+7}{12}-\frac{3x}{8}$

g $\frac{x+3}{5}+\frac{x+2}{4}$ **h** $\frac{2x+3}{7}+\frac{x+1}{2}$

i $\frac{x+8}{6}+\frac{x-3}{4}$ **j** $\frac{2x+5}{3}+\frac{x-2}{4}$

k $\frac{x-3}{5}+\frac{x+4}{10}$ **l** $\frac{2x+1}{8}+\frac{x-2}{3}$

LCD of 2 and 3 is 6, so
$\frac{x+2}{3}+\frac{x}{2}=\frac{\square(x+2)}{6}+\frac{\square x}{6}$

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PROBLEM-SOLVING AND REASONING

8–9(½) 8–10(½)

8 Find the error in each of the following and then correct it.

a $\frac{2x}{3}+\frac{3x}{4}=\frac{5x}{12}$

b $\frac{3x}{5}-\frac{x}{2}=\frac{2x}{3}$

c $\frac{x+2}{5}+\frac{x+4}{3}=\frac{3x+2+5x+4}{15}$
$=\frac{8x+6}{15}$

d $\frac{x+4}{2}+\frac{x-3}{6}=\frac{3x+12+x+3}{6}$
$=\frac{4x+15}{6}$

9 Recall that the expansion $-5(x-2)=-5x+10$, so
$6(x+1)-5(x-2)=6x+6-5x+10=x+16$.
Use this method to simplify these subtractions.

a $\frac{x+1}{5}-\frac{x-2}{6}$

b $\frac{x+2}{3}-\frac{x-4}{5}$

c $\frac{x-3}{4}-\frac{x+2}{5}$

d $\frac{x+8}{2}-\frac{x+7}{4}$

10 The LCD of the fractions $\frac{4}{x}+\frac{2}{3}$ is $3\times x=3x$.

Use this to find the LCD and simplify these fractions.

a $\frac{4}{x}+\frac{2}{3}$

b $\frac{3}{4}+\frac{2}{x}$

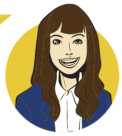
c $\frac{2}{5}+\frac{3}{x}$

d $\frac{3}{7}-\frac{2}{x}$

e $\frac{1}{5}-\frac{4}{x}$

f $\frac{3}{x}-\frac{5}{8}$

$$\frac{4}{x}+\frac{2}{3}=\frac{\square}{3x}+\frac{\square}{3x}$$
$$=\frac{\square}{3x}$$



ENRICHMENT

– 11(½)

Pronumerals in the denominator

As seen in Question **10**, pronumerals may form part of the LCD.

The fractions $\frac{5}{2x}$ and $\frac{3}{4}$ would have an LCD of $4x$, whereas the fractions $\frac{3}{x}$ and $\frac{5}{x^2}$ would have an LCD of x^2.

11 By first finding the LCD, simplify these algebraic fractions.

a $\frac{3}{4}+\frac{5}{2x}$

b $\frac{1}{6}+\frac{5}{2x}$

c $\frac{3}{10}-\frac{1}{4x}$

d $\frac{3}{x}+\frac{5}{x^2}$

e $\frac{4}{x}+\frac{1}{x^2}$

f $\frac{3}{x^2}-\frac{5}{x}$

g $\frac{3}{2x}+\frac{2}{x^2}$

h $\frac{4}{x}+\frac{7}{3x^2}$

i $\frac{3}{4x}-\frac{7}{2x^2}$

3G Index laws for multiplying, dividing and negative powers

When a product has the same number multiplied by itself over and over, index notation can be used to write a simpler expression. For example:

- $5 \times 5 \times 5$ can be written as 5^3
- $x \times x \times x \times x \times x$ can be written as x^5.

Index notation is a way to carry out calculations, such as how much mass is lost over time from ancient stone monuments.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Who has the most?

A person offers you one of two prizes.

- Which offer would you take?
- Try to calculate the final amount for prize B.
- How might you use index notation to help calculate the value of prize B?
- How can a calculator help to find the amount for prize B using the power button?

Prize A
$1000 now

Prize B
1 cent, then the amount is doubled every day for 20 days

Key ideas

- When a number is multiplied by itself many times, that product can be written using **index form**. For example:

Expanded form Index form

$$\overbrace{2 \times 2 \times 2 \times 2 \times 2} = \overbrace{2^5} = 32$$

base index basic numeral

$$x \times x \times x \times x = x^4$$

base index

- The **base** is the factor in the product.
- The **index** is the number of times the factor (base number) appears.
  - 2^2 reads '2 to the power of 2' or '2 squared', where $2^2 = 4$.
  - 2^3 reads '2 to the power of 3' or '2 cubed', where $2^3 = 8$.
  - 2^5 reads '2 to the power of 5', where $2^5 = 32$.

Note that $a^1 = a$. For example: $5^1 = 5$.

- 3^2 does *not* mean $3 \times 2 = 6$.

Index form A way of writing numbers that are multiplied by themselves

Base A number or pronumeral that is being raised to a power

Index The number of times a factor appears

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Key ideas

- Index law for multiplication: $a^m \times a^n = a^{m+n}$
  - When multiplying terms with the same base, add the indices. For example: $7^3 \times 7^2 = 7^{3+2} = 7^5$
- Index law for division: $a^m \div a^n = \frac{a^m}{a^n} = a^{m-n}$
  - When dividing terms with the same base, subtract the indices.

    For example: $8^5 \div 8^3 = \frac{8^5}{8^3} = 8^{5-3} = 8^2$
- Negative indices can be expressed as positive indices using the following rules.

$$a^{-m} = \frac{1}{a^m} \text{ and } a^m = \frac{1}{a^{-m}}$$

For $\frac{3^3}{3^5}$, we get $3^{3-5} = 3^{-2}$ and $\frac{3^3}{3^5} = \frac{\cancel{3}^1 \times \cancel{3}^1 \times \cancel{3}^1}{\cancel{3}^1 \times \cancel{3}^1 \times \cancel{3}^1 \times 3 \times 3} = \frac{1}{3^2}$

So $3^{-2} = \frac{1}{3^2}$.

Exercise 3G

UNDERSTANDING AND FLUENCY 1, 2, 3(½), 4, 5–8(½) 5–8(½)

1 Fill in the missing words.

a In 3^5, 3 is the __________ and 5 is the __________.

b 4^6 is read as 4 to the __________ of 6.

c 7^4 is the __________ form of $7 \times 7 \times 7 \times 7$.

d The power tells you how many times to __________ the base number by itself.

e $6 \times 6 \times 6$ is the __________ form of 6^3.

$5^{\textcircled{4}} = \overbrace{5 \times 5 \times 5 \times 5}^{4\text{ times}}$

index form expanded form

2 Write the following in expanded form.

a 8^3 **b** 7^5 **c** x^6 **d** $(ab)^4$

Example 21 Writing in index form

Write each of the following in index form.

a $5 \times 5 \times 5$ **b** $4 \times x \times x \times 4 \times x$ **c** $a \times b \times b \times a \times b \times b$

SOLUTION	EXPLANATION
a $5 \times 5 \times 5 = 5^3$	The factor 5 appears 3 times.
b $4 \times x \times x \times 4 \times x = 4 \times 4 \times x \times x \times x$ $= 4^2x^3$	Group the factors of 4 together and the factors of x together. The factor x appears 3 times; 4 appears twice.
c $a \times b \times b \times a \times b \times b$ $= a \times a \times b \times b \times b \times b$ $= a^2b^4$	Group the like pronumerals. The factor a appears twice and the factor b appears 4 times.

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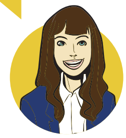
3 Write the following in index form.

- **a** $9 \times 9 \times 9 \times 9$
- **b** $3 \times 3 \times 3 \times 3 \times 3 \times 3$
- **c** $15 \times 15 \times 15$
- **d** $5 \times x \times x \times x \times 5$
- **e** $4 \times a \times 4 \times a \times 4 \times a \times a$
- **f** $b \times 7 \times b \times b \times b$
- **g** $x \times y \times x \times x \times y$
- **h** $a \times b \times a \times b \times b \times b$
- **i** $3 \times x \times 3 \times y \times x \times 3 \times y \times y$
- **j** $4 \times x \times z \times 4 \times z \times x$

Group different bases together and write each base in index form.



4 Complete the following to write each as a single term in index form.

a $$\begin{aligned} 7^3 \times 7^4 &= 7 \times 7 \times 7 \times \boxed{} \\ &= 7^{\square} \end{aligned}$$

b $$\begin{aligned} \frac{5^6}{5^2} &= \frac{5 \times 5 \times \boxed{}}{5 \times 5} \\ &= 5^{\square} \end{aligned}$$

Example 22 Expressing negative indices in positive index form

Express the following with positive indices.

a x^{-2} **b** $4y^{-2}$ **c** $2a^{-3}b^2$

SOLUTION

a $x^{-2} = \dfrac{1}{x^2}$

b $$\begin{aligned} 4y^{-2} &= 4 \times \frac{1}{y^2} \\ &= \frac{4}{y^2} \end{aligned}$$

c $$\begin{aligned} 2a^{-3}b^2 &= 2 \times \frac{1}{a^3} \times b^2 \\ &= \frac{2b^2}{a^3} \end{aligned}$$

EXPLANATION

Use $a^{-m} = \dfrac{1}{a^m}$.

The negative index only applies to y, so $y^{-2} = \dfrac{1}{y^2}$.

$4 \times \dfrac{1}{y^2} = \dfrac{4}{1} \times \dfrac{1}{y^2} = \dfrac{4}{y^2}$

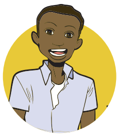
$a^{-3} = \dfrac{1}{a^3}, \dfrac{2}{1} \times \dfrac{1}{a^3} \times \dfrac{b^2}{1}$

Multiply the numerators and the denominators.

5 Express the following with positive indices.

- **a** y^{-3}
- **b** x^{-4}
- **c** x^{-2}
- **d** a^{-5}
- **e** $3x^{-2}$
- **f** $5b^{-3}$
- **g** $4x^{-1}$
- **h** $2m^{-9}$
- **i** $2x^2y^{-3}$
- **j** $3xy^{-4}$
- **k** $3a^{-2}b^4$
- **l** $5m^{-3}n^2$

Use $a^{-m} = \dfrac{1}{a^m}$.



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Example 23 Using $\frac{1}{a^{-m}} = a^m$

Rewrite the following with positive indices only.

a $\frac{1}{x^{-3}}$ **b** $\frac{4}{x^{-5}}$ **c** $\frac{5}{a^2b^{-4}}$

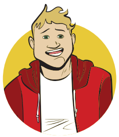
SOLUTION	EXPLANATION
a $\frac{1}{x^{-3}} = x^3$	Use $\frac{1}{a^{-m}} = a^m$.
b $\frac{4}{x^{-5}} = 4 \times \frac{1}{x^{-5}}$ $= 4 \times x^5$ $= 4x^5$	The 4 remains unchanged. $\frac{1}{x^{-5}} = x^5$
c $\frac{5}{a^2b^{-4}} = \frac{5}{a^2} \times \frac{1}{b^{-4}}$ $= \frac{5}{a^2} \times b^4$ $= \frac{5b^4}{a^2}$	The negative index applies to b only. $\frac{1}{b^{-4}} = b^4$ $\frac{5}{a^2} \times b^4 = \frac{5}{a^2} \times \frac{b^4}{1} = \frac{5b^4}{a^2}$

6 Rewrite the following with positive indices only.

a $\frac{1}{b^{-4}}$ **b** $\frac{1}{x^{-7}}$ **c** $\frac{1}{y^{-1}}$

d $\frac{5}{m^{-3}}$ **e** $\frac{2}{y^{-2}}$ **f** $\frac{3}{x^{-4}}$

g $\frac{5a^2}{b^{-3}}$ **h** $\frac{4}{x^2y^{-5}}$ **i** $\frac{10}{a^{-2}b^4}$



Use $\frac{1}{a^{-m}} = a^m$.

Example 24 Using the index law for multiplication

Simplify the following using the index law for multiplication.

a $x^7 \times x^4$ **b** $a^2b^2 \times ab^3$ **c** $3x^2y^3 \times 4x^3y^4$

SOLUTION	EXPLANATION
a $x^7 \times x^4 = x^{7+4}$ $= x^{11}$	To simplify $a^m \times a^n$, add the indices.
b $a^2b^2 \times ab^3 = a^{2+1}b^{2+3}$ $= a^3b^5$	Add the indices of base a and base b. Recall that $a = a^1$.
c $3x^2y^3 \times 4x^3y^4 = (3 \times 4)x^{2+3}y^{3+4}$ $= 12x^5y^7$	Multiply the coefficients and add indices of the common bases x and y.

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7 Simplify the following using the index law for multiplication.

- **a** $x^3 \times x^4$
- **b** $p^5 \times p^2$
- **c** $t^7 \times t^2$
- **d** $d^4 \times d$
- **e** $g \times g^3$
- **f** $f^2 \times f$
- **g** $2p^2 \times p^3$
- **h** $3c^4 \times c^4$
- **i** $2s^4 \times 3s^7$
- **j** $a^2b^3 \times a^3b^5$
- **k** $d^7f^3 \times d^2f^2$
- **l** $v^3z^5 \times v^2z^3$
- **m** $3a^2b \times 5ab^5$
- **n** $2x^2y \times 3xy^2$
- **o** $3e^7r^2 \times 6e^2r$
- **p** $-4p^3c^2 \times 2pc$
- **q** $-2r^2s^3 \times 5r^5s^5$
- **r** $-3d^4f^2 \times (-2f^2d^2)$

$a^m \times a^n = a^{m+n}$
Group common bases and add indices when multiplying.

Example 25 Using the index law for division

Simplify the following using the index law for division.

- **a** $p^5 \div p^3$
- **b** $12m^8 \div (6m^3)$
- **c** $\dfrac{4x^2y^4}{8xy^2}$

SOLUTION

a $p^5 \div p^3 = p^{5-3}$
$= p^2$

b $12m^8 \div (6m^3) = \dfrac{{}^{2}\cancel{12}m^8}{{}^{1}\cancel{6}m^3}$
$= 2m^{8-3}$
$= 2m^5$

c $\dfrac{4x^2y^4}{8xy^2} = \dfrac{{}^{1}\cancel{4} \times x^2 \times y^4}{{}^{2}\cancel{8} \times x \times y^2}$
$= \dfrac{x^{2-1}y^{4-2}}{2}$
$= \dfrac{xy^2}{2}\left(\text{or } \dfrac{1}{2}xy^2\right)$

EXPLANATION

To simplify $a^m \div a^n$, subtract the indices.

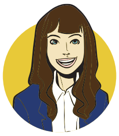
Write in fraction form.
Cancel the highest common factor of 12 and 6.
Subtract the indices.

Cancel the common factors of the numerals and subtract the indices of base x and base y.

8 Simplify the following using the index law for division.

- **a** $a^4 \div a^2$
- **b** $d^7 \div d^6$
- **c** $r^3 \div r$
- **d** $\dfrac{c^{10}}{c^6}$
- **e** $\dfrac{l^4}{l^3}$
- **f** $\dfrac{b^5}{b^2}$
- **g** $\dfrac{4d^4}{d^2}$
- **h** $\dfrac{f^3}{2f^2}$
- **i** $\dfrac{9n^4}{3n}$
- **j** $6p^4 \div (3p^2)$
- **k** $24m^7 \div (16m^3)$
- **l** $10d^3 \div (30d)$
- **m** $\dfrac{8t^4r^3}{2tr^2}$
- **n** $\dfrac{5h^6d^4}{3d^3h^2}$
- **o** $\dfrac{2p^2q^3}{p^2q}$
- **p** $\dfrac{4x^2y^3}{8xy}$
- **q** $\dfrac{3r^5s^2}{9r^3s}$
- **r** $6c^4d^6 \div (15c^3d)$
- **s** $2a^4y^2 \div (4ay)$
- **t** $13m^4n^6 \div (26m^4n^5)$

$a^m \times a^n = a^{m+n}$
or $\dfrac{a^m}{a^n} = a^{m-n}$
When dividing, subtract indices of common bases.



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PROBLEM-SOLVING AND REASONING 9–10(½) 9–10(½), 11

Example 26 Combining the index laws and negative indices

Simplify the following. Express answers with positive indices.

a $\dfrac{2a^3b \times 3a^2b^3}{12a^4b^2}$

b $\dfrac{x^4y^3 \times x^{-2}y^5}{x^5y^4}$

SOLUTION

a

$$\begin{aligned}\frac{2a^3b \times 3a^2b^3}{12a^4b^2} &= \frac{(2 \times 3)a^{3+2}b^{1+3}}{12a^4b^2}\\ &= \frac{\cancel{6}^{1}a^5b^4}{{}^{2}\cancel{12}a^4b^2}\\ &= \frac{a^{5-4}b^{4-2}}{2}\\ &= \frac{ab^2}{2}\end{aligned}$$

EXPLANATION

Simplify numerator first by multiplying coefficients. Then add indices of a and b.

Cancel common factor of numerals and subtract indices of common bases.

b

$$\begin{aligned}\frac{x^4y^3 \times x^{-2}y^5}{x^5y^4} &= \frac{x^{4+(-2)}y^{3+5}}{x^5y^4}\\ &= \frac{x^2y^8}{x^5y^4}\\ &= x^{2-5}y^{8-4}\\ &= x^{-3}y^4\\ &= \frac{y^4}{x^3}\end{aligned}$$

Add indices of x and y in numerator.
$4 + (-2) = 4 - 2 = 2$
Subtract indices in division.

Express with positive indices, so $x^{-3} = \dfrac{1}{x^3}$.
$x^{-3}y^4 = \dfrac{1}{x^3} \times \dfrac{y^4}{1}$

9 Simplify the following using the index laws.

a $\dfrac{x^2y^3 \times x^2y^4}{x^3y^5}$ **b** $\dfrac{m^2w \times m^3w^2}{m^4w^3}$ **c** $\dfrac{r^4s^7 \times r^4s^7}{r^6s^{10}}$

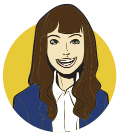
d $\dfrac{16a^8b \times 4ab^7}{32a^7b^6}$ **e** $\dfrac{9x^2y^3 \times 6x^7y^7}{12xy^6}$ **f** $\dfrac{4e^2w^2 \times 12e^2w^3}{12e^4w}$

Simplify the numerator first.

10 Simplify the following, expressing answers using positive indices.

a $\dfrac{a^6b^2 \times a^{-2}b^3}{a^7b}$ **b** $\dfrac{x^5y^3 \times x^2y^{-1}}{x^3y^5}$

c $\dfrac{x^4y^7 \times x^{-2}y^{-5}}{x^4y^6}$ **d** $\dfrac{a^5b^{-2} \times a^{-3}b^4}{a^6b}$



The index laws apply to negative indices also.
$x^5 \times x^{-2} = x^{5+(-2)} = x^3$
$\dfrac{x^4}{x^6} = x^{4-6} = x^{-2} = \dfrac{1}{x^2}$

11 When Billy uses a calculator to raise −2 to the power 4 he gets −16, when in fact the answer is 16. What has he done wrong?

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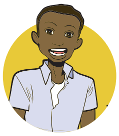
ENRICHMENT – 12, 13(½)

Index laws and calculations

12 Consider the following use of negative numbers.

- **a** Evaluate:
  - **i** $(-3)^2$
  - **ii** -3^2
- **b** What is the difference between your two answers in part **a**?
- **c** Evaluate:
  - **i** $(-2)^3$
  - **ii** -2^3
- **d** What do you notice about your answers in part **c**? Explain.

$(-3)^2 = -3 \times (-3)$
$(-2)^3 = -2 \times (-2) \times (-2)$
Consider order of operations.



13 Evaluate these expressions without the use of a calculator.

- **a** $\frac{13^3}{13^2}$
- **b** $\frac{18^7}{18^6}$
- **c** $\frac{9^8}{9^6}$
- **d** $\frac{3^{10}}{3^7}$
- **e** $\frac{4^8}{4^5}$
- **f** $\frac{2^{12}}{2^8}$

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3H The zero index and the index laws extended

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

The index laws can be used to simplify other expressions.

For example: $(4^2)^3 = 4^2 \times 4^2 \times 4^2$
$= 4^{2+2+2}$
$= 4^6$ (Add indices using the index law for multiplication.)

Therefore, $(4^2)^3 = 4^{2\times3} = 4^6$.

We also have a result for the zero power.

Consider $5^3 \div 5^3$, which clearly equals 1. Using the index law for division, we can see that:
$5^3 \div 5^3 = 5^{3-3} = 5^0$
Therefore $5^0 = 1$, which leads to the zero power rule: $a^0 = 1$ (where $a \neq 0$).

Let's start: Indices with brackets

Brackets are used to show that the power outside the brackets applies to each factor inside the brackets. Consider $(2x)^3 = 2x \times 2x \times 2x$.

- Write this in index form without using brackets.
- Can you suggest the index form of $(3y)^4$ without brackets?

Consider $\left(\frac{3}{5}\right)^4 = \frac{3}{5} \times \frac{3}{5} \times \frac{3}{5} \times \frac{3}{5}$.

- Write the numerator and denominator of this expanded form in index form.
- Can you write the index form of $\left(\frac{x}{4}\right)^5$ without brackets?

Write a rule for removing the brackets of the following.

- $(ab)^m$
- $\left(\frac{a}{b}\right)^m$

Key ideas

■ Index law for a power of a power: $(a^m)^n = a^{m\times n} = a^{mn}$
When raising a term in index form to another power, retain the base and multiply the indices.
For example: $(x^3)^4 = x^{3\times4} = x^{12}$
A power outside brackets applies only to the expression inside those brackets
For example: $5(a^3)^2 = 5a^{3\times2} = 5a^6$ but $(5a^3)^2 = 5^2 \times a^6 = 25a^6$

■ Power of a product: $(a \times b)^m = a^m \times b^m$
Apply the index to each factor in the brackets.
For example: $(3x)^4 = 3^4x^4$

■ Power of a fraction: $\left(\frac{a}{b}\right)^m = \frac{a^m}{b^m}$
Apply the index to the numerator and denominator.
For example: $\left(\frac{y}{3}\right)^5 = \frac{y^5}{3^5}$

Key ideas

- $\left(\frac{a}{b}\right)^{-1} = \frac{b}{a}$

  If the power is -1, simply write down the reciprocal of the fraction.

  For example: $\left(\frac{5}{3}\right)^{-1} = \frac{3}{5}$
- The zero index: $a^0 = 1$, where $a \neq 0$

  Any number (except zero) raised to the power of zero is 1.

  For example: $5^0 = 1$, $y^0 = 1$, $4y^0 = 4 \times 1 = 4$, $(3x)^0 = 1$.

Exercise 3H

UNDERSTANDING AND FLUENCY	1, 2, 3–6(½)	3–6(½)

1 Complete the following.

a Any number (except 0) to the power of zero is ______.

b $(a^m)^n =$ ______.

c $(a \times b)^m =$ ______ $\times$ ______.

d $\left(\frac{a}{b}\right)^m = \frac{\square}{\square}$.

2 Copy and complete the following.

a $(4^2)^3 = 4^2 \times \square \times \square$

$= 4^{\square}$

b $(2a)^3 = 2a \times \square \times \square$

$= 2 \times \square \times \square \times a \times \square \times \square$

$= 2^{\square}a^{\square}$

c $\left(\frac{4}{7}\right)^4 = \frac{4}{7} \times \square \times \square \times \square$

$= \frac{4 \times \square \times \square \times \square}{7 \times \square \times \square \times \square}$

$= \frac{4^{\square}}{7^{\square}}$

Example 27 Using the zero index

Evaluate, using the zero index.

a $4^0 + 2^0$ **b** $3a^0$ **c** $(-3)^0 + 6x^0$

SOLUTION	EXPLANATION
a $4^0 + 2^0 = 1 + 1$ $= 2$	Zero power: $a^0 = 1$, any number to the power zero (except zero) is 1.
b $3a^0 = 3 \times a^0$ $= 3 \times 1$ $= 3$	The zero power only applies to a, so $a^0 = 1$.
c $(-3)^0 + 6x^0 = 1 + 6 \times 1$ $= 7$	Any number to the power of zero is 1. $(-3)^0 = 1$, $6x^0 = 6 \times x^0 = 6 \times 1$.

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3 Evaluate, using the zero index.

a 4^0 **b** 5^0 **c** x^0

d a^0 **e** $3e^0$ **f** $4y^0$

g $3^0 + 6^0$ **h** $10 - 10x^0$ **i** $3d^0 - 2$

j $(-4)^0 + 2x^0$ **k** $\dfrac{2}{m^0}$ **l** $5a^0 + 4b^0$

Any number (except zero) to the power of 0 is 1.
$4a^0 = 4 \times a^0 = 4 \times 1$

Example 28 Using the power of a power rule: $(a^m)^n = a^{m \times n}$

Simplify the following.

a $(x^5)^7$ **b** $3(f^4)^3$

SOLUTION	EXPLANATION
a $(x^5)^7 = x^{5\times 7}$ $= x^{35}$	Multiply indices.
b $3(f^4)^3 = 3f^{4\times 3}$ $= 3f^{12}$	Only the expression in the brackets has a power of 3.

4 Simplify the following using the law for power of a power.

a $(b^3)^4$ **b** $(f^5)^4$ **c** $(k^3)^7$

d $3(x^2)^3$ **e** $5(c^9)^2$ **f** $4(s^6)^3$

Power of a power
$(a^m)^n = a^{m \times n}$

Example 29 Using the power of a product and power of a fraction rules

Simplify the following.

a $(2s)^4$ **b** $(x^2y^3)^5$ **c** $\left(\dfrac{x}{4}\right)^3$ **d** $\left(\dfrac{3}{5}\right)^{-1}$

SOLUTION	EXPLANATION
a $(2s)^4 = 2^4 \times s^4$ $= 16s^4$	$(a \times b)^m = a^m \times b^m$ Evaluate $2^4 = 2 \times 2 \times 2 \times 2$.
b $(x^2y^3)^5 = (x^2)^5 \times (y^3)^5$ $= x^{10}y^{15}$	Apply the index 5 to each factor in the brackets. Multiply indices: $(x^2)^5 = x^{2\times 5}$, $(y^3)^5 = y^{3\times 5}$
c $\left(\dfrac{x}{4}\right)^3 = \dfrac{x^3}{4^3}$ $= \dfrac{x^3}{64}$	$\left(\dfrac{a}{b}\right)^m = \dfrac{a^m}{b^m}$ Evaluate $4^3 = 4 \times 4 \times 4$.
d $\left(\dfrac{3}{5}\right)^{-1} = \dfrac{5}{3}$	If the power is -1, find the reciprocal of the fraction since $\left(\dfrac{3}{5}\right)^{-1} = \dfrac{3^{-1}}{5^{-1}} = 3^{-1} \times \dfrac{1}{5^{-1}} = \dfrac{1}{3} \times 5 = \dfrac{5}{3}$.

5 Simplify the following.

a $(3x)^2$ **b** $(4m)^3$ **c** $(5y)^3$

d $(2x^3)^4$ **e** $(x^2y)^5$ **f** $(3a^3)^3$

g $(x^4y^2)^6$ **h** $(a^2b)^3$ **i** $(m^3n^3)^4$

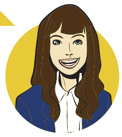
j $\left(\frac{x}{5}\right)^2$ **k** $\left(\frac{y}{3}\right)^4$ **l** $\left(\frac{m}{2}\right)^4$

m $\left(\frac{x^2}{y}\right)^3$ **n** $\left(\frac{x^3}{y^2}\right)^4$ **o** $\left(\frac{x}{y^5}\right)^3$

p $\left(\frac{2}{3}\right)^{-1}$ **q** $\left(\frac{x}{5}\right)^{-1}$ **r** $\left(\frac{x^2}{y}\right)^{-1}$

$(3 \times x)^2 = 3^2 \times x^2$

$\left(\frac{x}{5}\right)^2 = \frac{x^2}{5^2}$



Example 30 Combining index laws and negative indices

Simplify, using index laws, and express with positive indices.

a $\frac{3x^2y \times 2x^3y^2}{10xy^3}$

b $\left(\frac{2x^2}{y}\right)^4$

c $(2x^{-2})^3 + (3x)^0$

SOLUTION

a
$$\begin{aligned}&\frac{3x^2y \times 2x^3y^2}{10xy^3}\\ &= \frac{6x^5y^3}{10xy^3}\\ &= \frac{3x^4y^0}{5}\\ &= \frac{3x^4}{5}\end{aligned}$$

EXPLANATION

Simplify the numerator by multiplying coefficients and adding indices.

Cancel the common factor of 6 and 10 and subtract indices of common bases.

The zero index rule says $y^0 = 1$.

b
$$\begin{aligned}\left(\frac{2x^2}{y}\right)^4 &= \frac{(2x^2)^4}{y^4}\\ &= \frac{2^4 \times (x^2)^4}{y^4}\\ &= \frac{16x^8}{y^4}\end{aligned}$$

Apply the index to the numerator and denominator.

Multiply indices; $(x^2)^4 = x^{2\times 4}$.

c
$$\begin{aligned}(2x^{-2})^3 + (3x)^0 &= 2^3 \times x^{-6} + 3^0 \times x^0\\ &= 8x^{-6} + 1 \times 1\\ &= \frac{8}{x^6} + 1\end{aligned}$$

Apply the power to each factor inside the brackets.

$(x^{-2})^3 = x^{-2\times 3} = x^{-6}$

Any number to the power of zero is 1.

Use $a^{-m} = \frac{1}{a^m}$ to express with a positive index.

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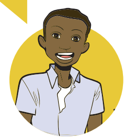
6 Simplify, using index laws.

a $\dfrac{m^2w \times m^3w^2}{m^4w^3}$ **b** $\dfrac{x^3y^2 \times x^2y^7}{10x^5y^4}$ **c** $\dfrac{b^3c^5 \times 4b^5c^3}{3b^4c^8}$

d $\dfrac{9c^4s^2 \times 3c^3s^5}{2c^3s^7}$ **e** $\dfrac{(5r^6)^2}{3r^8}$ **f** $\dfrac{(2p^4)^3}{3p^7}$

g $\left(\dfrac{2s^2}{t^3}\right)^4$ **h** $\left(\dfrac{r^2}{5s^3}\right)^4$ **i** $\left(\dfrac{3x^0}{x^{-2}}\right)^2$

First simplify the numerator, then combine the denominator.



PROBLEM-SOLVING AND REASONING 7–8(½) 7–9(½)

7 Simplify, using index laws, and express with positive indices.

a $(x^{-4})^2$ **b** $(x^3)^{-2}$ **c** $(x^{-2})^0$

d $(2y^{-2})^3$ **e** $(ay^{-3})^2$ **f** $(4x^{-3})^{-2}$

g $(m^{-4}) + 4(ab)^0$ **h** $(2a^{-2})^3 + (4a)^0$ **i** $(5a^{-2})^{-2} \times 5a^0$

Remove brackets using index laws then use $a^{-m} = \dfrac{1}{a^m}$ to express with a positive index.

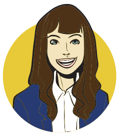
8 Evaluate, without the use of a calculator.

a 2^{-2} **b** $\dfrac{4}{3^{-2}}$ **c** $\dfrac{5}{2^{-3}}$

d $\dfrac{(5^2)^2}{5^4}$ **e** $\dfrac{36^2}{6^4}$ **f** $\dfrac{27^2}{3^4}$

$\dfrac{1}{3^{-2}} = 3^2$

$36^2 = (6^2)^2$



9 Simplify the following.

a $2p^2q^4 \times pq^3$ **b** $4(a^2b)^3 \times (3ab)^3$

c $(4r^2y)^2 \times r^2y^4 \times 3(ry^2)^3$ **d** $2(m^3n)^4 \div m^3$

e $\dfrac{(7s^2y)^2 \times 3sy^2}{7(sy)^2}$ **f** $\dfrac{3(d^4c^3)^3 \times 4dc}{(2c^2d)^3}$

g $\dfrac{4r^2t \times 3(r^2t)^3}{6r^2t^4}$ **h** $\dfrac{(2xy)^2 \times 2(x^2y)^3}{8xy \times x^7y^3}$

ENRICHMENT – 10(½)

All laws together

10 Simplify the following, expressing your answer with positive indices.

a $(a^3b^2)^3 \times (a^2b^4)^{-1}$ **b** $2x^2y^{-1} \times (3xy^4)^3$

c $2(p^2)^4 \times (3p^2q)^{-2}$ **d** $\dfrac{2a^3b^2}{a^{-3}} \times \dfrac{2a^2b^5}{b^4}$

e $\dfrac{(3rs^2)^4}{r^{-3}s^4} \times \dfrac{(2r^2s)^2}{s^7}$ **f** $\dfrac{4(x^{-2}y^4)^2}{x^2y^{-3}} \times \dfrac{xy^4}{2s^{-2}y}$

$(3p^2q)^{-2} = \dfrac{1}{(3p^2q)^2}$

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3I Scientific notation and significant figures

Interactive
Widgets
HOTsheets
Walkthrough

Scientific notation is useful when working with very large or very small numbers. Combined with the use of significant figures, numbers can be written down with an appropriate degree of accuracy and without the need to write all the zeros that define the position of the decimal point. The approximate distance between the Earth and the Sun is 150 million kilometres or 1.5×10^8 km, when written in scientific notation. Negative indices can be used for very small numbers, such as 0.0000382 g $= 3.82 \times 10^{-5}$ g.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Amazing facts large and small

Think of an object, place or living thing that is associated with a very large or small number.

- Give three examples of very large numbers.
- Give three examples of very small numbers.
- Can you remember how to write these numbers using scientific notation? List the rules you remember.

Key ideas

- A number written using **scientific notation** is of the form $a \times 10^m$, where $1 \leq a < 10$ and m is an integer.
- To write numbers using scientific notation, place the decimal point after the first non-zero digit then multiply by the power of 10 corresponding to how many places the decimal point was moved.
  - Large numbers will use positive powers of 10.
    For example: $24\,800\,000 = 2.48 \times 10^7$
    $9\,020\,000\,000 = 9.02 \times 10^9$
  - Small numbers will use negative powers of 10.
    For example: $0.00307 = 3.07 \times 10^{-3}$
    $0.000\,0012 = 1.2 \times 10^{-6}$
- To count significant figures, start counting from the first non-zero digit.
- Zeros on the end of a decimal are *definitely* significant.
  Zeros on the end of a whole number *might* be significant.
  - 0.00**25** definitely has two significant figures.
  - 0.00**250** definitely has three significant figures.
  - 0.**205** definitely has three significant figures.
  - **6.0** definitely has two significant figures.
  - **66** definitely has two significant figures.
  - **60** might have one or two significant figures.
  - **66000** might have 2, 3, 4 or 5 significant figures.

Scientific notation
A way to express very large and very small numbers using [a number between 1 and 10] $\times 10^{\text{power}}$

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Key ideas

- When using scientific notation, the first significant figure sits to the left of the decimal point. For example: 20 190 000 = 2.019 × 10^7 has four significant figures.
- There are keys on calculators that can be used to enter numbers using scientific notation. They are $\boxed{\textbf{Exp}}$ or $\boxed{\times 10^x}$.
  For example, a calculator can be used to confirm that $(6 \times 10^9) \times (5 \times 10^9) = 3 \times 10^{19}$.

Exercise 3I

UNDERSTANDING AND FLUENCY 1–4, 5–7(½) 4, 5–7(½)

1 Evaluate the following.

a 1.24 × 100 **b** 2.8 × 100 **c** 3.02 × 1000
d 4.5 ÷ 100 **e** 3.75 ÷ 1000 **f** 6 ÷ 100

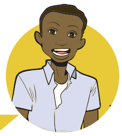
2 Write these numbers as powers of 10.

a 1000 **b** 10 000 000 **c** 0.000001 **d** $\frac{1}{1000}$

3 State whether these numbers would have positive or negative indices when written in scientific notation.

a 7800 **b** 0.0024 **c** 27 000 **d** 0.0009

Move the decimal point as many places as there are zeros.
× means move the decimal point right.
÷ means move the decimal point left.



4 Write the number 4.8721 using the following numbers of significant figures.

a 3 **b** 4 **c** 2

Example 31 Converting from scientific notation to a basic numeral

Write these numbers as a basic numeral.

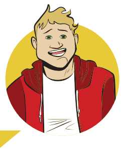
a 5.016×10^5 **b** 3.2×10^{-7}

SOLUTION	EXPLANATION
a $5.016 \times 10^5 = 501\,600$	Move the decimal point 5 places to the right, inserting zeros after the last digit. 5.01600
b $3.2 \times 10^{-7} = 0.000\,000\,32$	Move the decimal point 7 places to the left due to the −7, and insert zeros where necessary.

5 Write these numbers as a basic numeral.

a 3.12×10^3 **b** 5.4293×10^4 **c** 7.105×10^5
d 8.213×10^6 **e** 5.95×10^4 **f** 8.002×10^5
g 1.012×10^4 **h** 9.99×10^6 **i** 2.105×10^8
j 4.5×10^{-3} **k** 2.72×10^{-2} **l** 3.085×10^{-4}
m 7.83×10^{-3} **n** 9.2×10^{-5} **o** 2.65×10^{-1}
p 1.002×10^{-4} **q** 6.235×10^{-6} **r** 9.8×10^{-1}

For a positive index, move the decimal point right (i.e. number gets bigger). For a negative index, move the decimal point left (i.e. number gets smaller).



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Example 32 Writing numbers using scientific notation

Write these numbers in scientific notation.

a 5700000

b 0.0000006

SOLUTION

a $5700000 = 5.7 \times 10^6$

b $0.0000006 = 6 \times 10^{-7}$

EXPLANATION

Place the decimal point after the first non-zero digit (i.e. 5) then multiply by 10^6 as the decimal point has been moved 6 places to the left.

6 is the first non-zero digit. Multiply by 10^{-7} since the decimal point has been moved 7 places to the right.

6 Write these numbers in scientific notation.

a 43000
b 712000
c 901200
d 10010
e 23900
f 703000000
g 0.00078
h 0.00101
i 0.00003
j 0.03004
k 0.112
l 0.00192

For scientific notation, place decimal point after the first non-zero digit and multiply by the power of 10.

Example 33 Converting to scientific notation using significant figures

Write these numbers in scientific notation, using 3 significant figures.

a 5218300

b 0.0042031

SOLUTION

a $5218300 = 5.22 \times 10^6$

b $0.0042031 = 4.20 \times 10^{-3}$

EXPLANATION

Put the decimal point after 5 and multiply by 10^6: 5.218300

The digit following the third digit (i.e. 8) is at least 5, so round the 1 up to 2.

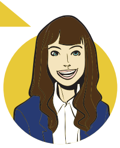
Put the decimal point after 4 and multiply by 10^{-3}: 0.0042031

Round down in this case, since the digit following the third digit (i.e. 3) is less than 5, but retain the zero to show the value of the third significant figure.

7 Write these numbers in scientific notation, using 3 significant figures.

a 6241
b 572644
c 30248
d 423578
e 10089
f 34971863
g 72477
h 356088
i 110438523
j 0.002423
k 0.018754
l 0.000125
m 0.0078663
n 0.0007082
o 0.11396
p 0.000006403
q 0.00007892
r 0.000129983

For three significant figures, count from the first non-zero digit. Look at the digit after the third digit to determine whether you should round up or down.



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PROBLEM-SOLVING AND REASONING

8, 9 | 8, 10, 11(½), 12

8 Write the following numerical facts using scientific notation.

- **a** The area of Australia is about 7 700 000 km^2.
- **b** The number of stones used to build the Pyramid of Khufu is about 2 500 000.
- **c** The greatest distance of Pluto from the Sun is about 7 400 000 000 km.
- **d** The breadth of a human hair is about 0.01 cm.
- **e** The mass of a neutron is about 0.000000000000000000000000001675 kg.
- **f** The mass of a bacterium cell is about 0.00000000000095 g.

Large numbers have a positive index. Small numbers (i.e. less than 1) have a negative index.

9
- **a** Convert 4.5 seconds to nanoseconds, using scientific notation.
- **b** Write the number of seconds in one century, correct to 3 significant figures.
- **c** Convert the mass of the Earth's Sun, which is 2×10^{30} kg, to megatonnes.

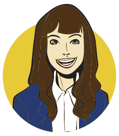
Remember that these units of measurement were first encountered in Chapter 2.

10 Explain why 38×10^7 is not written using scientific notation and convert it to scientific notation.

11 Use a calculator to evaluate the following, giving the answers in scientific notation using 3 significant figures.

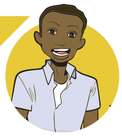
- **a** $(2.31)^{-7}$
- **b** $(5.04)^{-4}$
- **c** $(2.83 \times 10^2)^{-3}$
- **d** $5.1 \div (8 \times 10^2)$
- **e** $9.3 \times 10^{-2} \times 8.6 \times 10^8$
- **f** $(3.27 \times 10^4) \div (9 \times 10^{-5})$
- **g** $\sqrt{3.23 \times 10^{-6}}$
- **h** $\pi(3.3 \times 10^7)^2$

For questions to do with 10^x, locate the EE or Exp button on your calculator.



12 The speed of light is approximately 3×10^5 km/s and the average distance between Pluto and the Sun is about 5.9×10^9 km. How long does it take for light from the Sun to reach Pluto? Answer correct to the nearest minute. (Divide by 60 to convert seconds to minutes.)

$$\text{Time} = \frac{\text{distance}}{\text{speed}}$$



ENRICHMENT

– | 13

$E = mc^2$

13 $E = mc^2$ is a formula derived by Albert Einstein (1879–1955). The formula relates the energy (E joules) of an object to its mass (m kg), where c is the speed of light (approximately 3×10^8 m/s).

Albert Einstein

Use $E = mc^2$ to answer these questions, using scientific notation.

- **a** Find the energy, in joules (J), contained inside an object with the given masses.
  - **i** 10 kg
  - **ii** 26 000 kg
  - **iii** 0.03 kg
  - **iv** 0.00001 kg
- **b** Find the mass, in kilograms, of an object that contains the given amounts of energy. Give your answer using 3 significant figures.
  - **i** 1×10^{25} J
  - **ii** 3.8×10^{16} J
  - **iii** 8.72×10^4 J
  - **iv** 1.7×10^{-2} J
- **c** The mass of the Earth is about 6×10^{24} kg. How much energy does this convert to?

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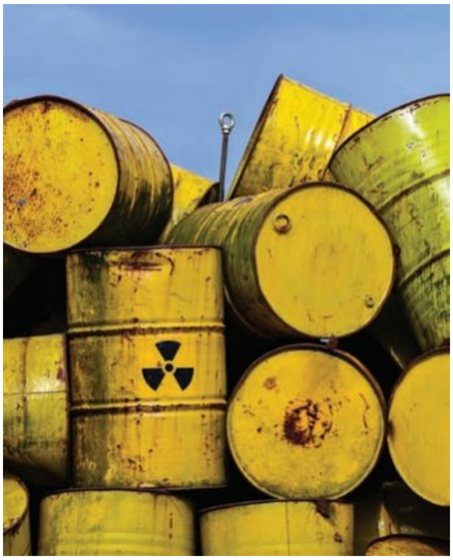
3J Exponential growth and decay EXTENSION



Exponential change occurs when a quantity is continually affected by a constant multiplying factor. The change in quantity is not the same amount each time.

If you have a continual percentage increase, it is called exponential growth. If you have a continual percentage decrease, it is called exponential decay.

Some examples include:

- Compound interest is paid at a rate of 5% per year, where the interest is calculated as 5% of the investment value each year, including the previous year's interest.
- A radioactive element has a 'half-life' of 5 years, which means the element decays at a rate of 50% every 5 years.

Let's start: A compound rule

Imagine that you have an investment valued at \$100 000 and you hope that it will return 10% p.a. (per annum). The 10% return is to be added to the investment balance each year.

- Discuss how to calculate the investment balance in the first year.
- Discuss how to calculate the investment balance in the second year.
- Complete this table.

Year	0	1	2	3
Balance (\$)	100 000	$100\,000 \times 1.1$ = ______	$100\,000 \times 1.1 \times$ ___ = ______	

- Recall how indices can be used to calculate the balance after the second year.
- Discuss how indices can be used to calculate the balance after the 10th year.
- What might be the rule connecting the investment balance (\$$A$) and the time, n years?

Key ideas

- **Exponential growth** and **decay** can be modelled by the rule $A = A_0(1 \pm R)^n$.
  - A is the amount.
  - A_0 is the initial amount (the subscript zero represents time zero).
  - R is the percentage rate of increase or decrease, expressed as a decimal.
  - n is time; how many times the percentage increase/decrease is applied.

  For example:

  For a population increasing at 2% per year, $P = P_0(1.02)^n$.
  For a population decreasing at 3% per year, $P = P_0(0.97)^n$.

Exponential growth Repeatedly increasing a quantity by a constant percentage over time

Exponential decay Repeatedly decreasing a quantity by a constant percentage over time

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Key ideas

- For a growth rate of R p.a., use $1 + R$.
- For a decay rate of R p.a., use $1 - R$.
- Compound interest involves *adding* any interest earned to the balance at the end of each year or other period. The rule for the investment amount ($\$A$) is given by: $A = P(1 + R)^n$.
  - P is the initial amount or principal.
  - R is the interest rate, expressed as a decimal.
  - n is the time.

Exercise 3J EXTENSION

UNDERSTANDING AND FLUENCY

1, 2, 3–4(½), 5, 6

3–4(½), 5–7

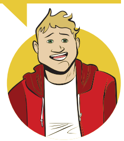
1 An investment of \$1000 is to grow by 5% per year. Round your answers to the nearest cent.

a Find the interest earned in the first year; i.e. 5% of \$1000.

b Find the investment balance at the end of the first year; i.e. investment + interest.

c Find the interest earned in the second year; i.e. 5% of answer to part **b**.

d Find the interest earned in the third year.



5% of $x = 0.05 \times x$

2 The mass of a limestone 5 kg rock exposed to the weather is decreasing at a rate of 2% per annum.

a Find the mass of the rock at the end of the first year.

b Copy and complete the rule for the mass of the rock (M kg) after n years.

$M = 5(1 - \_\_\_)^n = 5 \times \_\_\_^n$

c Use your rule to calculate the mass of the rock after 5 years, correct to 2 decimal places.

For decrease, use $1 - R$.

3 Decide whether the following represent exponential *growth* or exponential *decay*.

a $A = 1000 \times 1.3^n$

b $A = 200 \times 1.78^n$

c $A = 350 \times 0.9^n$

d $P = 50000 \times 0.85^n$

e $P = P_0\left(1 + \frac{3}{100}\right)^n$

f $T = T_0\left(1 - \frac{7}{100}\right)^n$

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Example 34 Writing exponential rules

Form exponential rules for the following situations.

a John invests his \$100 000 in savings at a rate of 14% per annum.

b A city's initial population of 50 000 is decreasing by 12% per year.

SOLUTION	EXPLANATION
a Let A = the amount of money at any time	Define your variables.
n = the number of years the money is invested	The basic formula is $A = P(1 + R)^n$.
P = initial amount invested or principal	
$R = 0.14$	
$P = 100\,000$	
$A = 100\,000(1 + 0.14)^n$	Substitute $R = 0.14$ and $P = 100\,000$ and use '+' since we have growth.
$\therefore A = 100\,000(1.14)^n$	
b Let P = the population at any time	Define your variables.
n = the number of years the population decreases	
P_0 = starting population	The basic formula is $P = P_0(1 - R)^n$.
$R = 0.12$	
$P = 50\,000(1 - 0.12)^n$	Substitute R = 0.12 and $P_0 = 50\,000$ and use '–' since we have decay.
$\therefore P = 50\,000(0.88)^n$	$1 - 0.12 = 0.88$

4 Define variables and form exponential rules for the following situations.

- **a** \$200 000 is invested at 17% per annum.
- **b** A house initially valued at \$530 000 is losing value at 5% per annum.
- **c** The value of a car, bought for \$14 200, is decreasing at 3% per annum.
- **d** A population, initially 172 500, is increasing at 15% per year.
- **e** A tank with 1200 litres of water is leaking at a rate of 10% of the water in the tank every hour.
- **f** A cell of area 0.01 cm^2 doubles its size every minute.
- **g** An oil spill, initially covering an area of 2 square metres, is increasing at 5% per minute.
- **h** A substance of mass 30 g is decaying at a rate of 8% per hour.

The exponential rule is of the form $A = A_0(1 \pm R)^n$

- A is the amount.
- A_0 is the initial amount.
- R is the percentage increase/decrease, as a decimal.
- n is the time.

Use '+' for growth and '–' for decay.

Example 35 Applying exponential rules

House prices are rising at 9% per year and Zoe's flat is currently valued at \$600 000.

a Determine a rule for the value of Zoe's house (\$$V$) in n years' time.

b What will be the value of her house:

- **i** next year?
- **ii** in 3 years' time?

c Use trial and error to find when Zoe's house will be valued at \$900 000, to 1 decimal place.

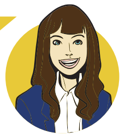
SOLUTION	EXPLANATION
a Let V = value of Zoe's house at any time	Define your variables.
V_0 = starting value \$600 000	The basic formula is $V = V_0(1 \pm R)^n$.
n = number of years from now	
$R = 0.09$	9% = 0.09
$V = V_0(1 + 0.09)^n$	Use '+' since we have growth.
$\therefore V = 600\,000(1.09)^n$	
b **i** $n = 1$, so $V = 600\,000(1.09)^1$	Substitute $n = 1$ for next year.
$= 654\,000$	
Zoe's house would be valued at \$654 000 next year.	Answer in words.
ii $n = 3$, so $V = 600\,000(1.09)^3$	For 3 years, substitute $n = 3$.
$= 777\,017.40$	
In 3 years' time Zoe's house will be valued at about \$777 017.	

c

n	4	5	4.6	4.8	4.7
V	846 949	923 174	891 894	907 399	899 613

Zoe's house will be valued at \$900 000 in about 4.7 years' time.	Try a value of n in the rule. If V is too low, increase your n value; if V is too high, decrease your n value. Continue this process until you get close to 900 000.

5 The value of a house purchased for \$500 000 is expected to grow by 10% per year. Let \$$A$ be the value of the house after n years.



An increase of 10% is 1 + 0.1.

a Copy and complete the rule connecting A and t.

$A = 500\,000 \times \_\_\_^n$

b Use your rule to find the expected value of the house after the following number of years. Round to the nearest cent.

i 3 years **ii** 10 years **iii** 20 years

c Use trial and error to estimate when the house will be worth \$1 million. Round your answer to 1 decimal place.

6 A share portfolio initially worth \$300 000 is reduced by 15% p.a. over a number of years. Let \$$A$ be the share portfolio value after n years.

A decrease of 15% is 1 − 0.15.

a Copy and complete the rule connecting A and n.

$A = \_\_\_\_\_\_ \times 0.85^n$

b Use your rule to find the value of the shares after the following number of years. Round to the nearest cent.

i 2 years **ii** 7 years **iii** 12 years

c Use trial and error to estimate when the share portfolio will be valued at \$180 000. Round your answer to 1 decimal place.

7 A water tank containing 15 000 L has a small hole that reduces the amount of water by 6% per hour.

a Determine a rule for the volume of water (V litres) left after n hours.

b Calculate (to the nearest litre) the amount of water left in the tank after:

i 3 hours **ii** 7 hours

c How much water is left after two days? Round to 2 decimal places.

d Using trial and error, determine when the tank holds less than 500 L of water, rounding your answer to 1 decimal place.

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PROBLEM-SOLVING AND REASONING 8, 9 8–10

8 A certain type of bacteria grows according to the equation $N = 3000(2.6)^n$, where N is the number of cells present after n hours.

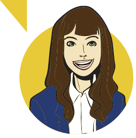
a How many bacteria are there at the start?

b Determine the number of cells (round to the whole number) present after:

i 0 hours **ii** 2 hours **iii** 4.6 hours

c If 50 000 000 bacteria are needed to make a drop of serum, determine by trial and error how long you will have to wait to make a drop (to the nearest minute).

'At the start' is $n = 0$ and $a^0 = 1$.

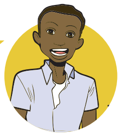


9 A car tyre has 10 mm of tread when new. It is considered unroadworthy when there is only 3 mm left. The rubber wears at 12.5% every 10 000 km.

a Write an equation relating the depth of tread (D) for every 10 000 km travelled.

b Using trial and error, determine when the tyre becomes unroadworthy ($D = 3$), to the nearest 10 000 km.

Use $D = D_0(1 - 0.125)^n$ where n is $\frac{\text{number of km}}{10\,000}$ and D_0 is initial tread.



10 A cup of coffee has an initial temperature of 90°C.

a If the temperature reduces by 8% every minute, determine a rule for the temperature of the coffee (T) after n minutes.

b What is the temperature of the coffee (to 1 decimal place) after:

i 2 minutes? **ii** 90 seconds?

c Using trial and error, when is the coffee suitable to drink if it is best consumed at a temperature of 68.8°C? Give your answer to the nearest second.

The rule is of the form: $T = T_0(1 - R)^n$

ENRICHMENT – 11, 12

Time periods

11 Interest earned on investments can be calculated using different time periods. Consider \$1000 invested at 10% p.a. over 5 years.

- If interest is compounded annually, then $R = 0.1$ and $t = 5$, so $A = 1000(1.1)^5$.
- If interest is compounded monthly, then $R = \frac{0.1}{12}$ and $t = 5 \times 12 = 60$, so $A = 1000\left(1 + \frac{0.1}{12}\right)^{60}$.

a If interest is calculated annually, find the value of the investment, to the nearest cent, after:

i 5 years **ii** 8 years **iii** 15 years

b If interest is calculated monthly, find the value of the investment, to the nearest cent, after:

i 5 years **ii** 8 years **iii** 15 years

12 You are given \$2000 and you invest it in an account that offers 7% p.a. compound interest. What will the investment be worth, to the nearest cent, after 5 years if interest is compounded:

a annually?

b monthly?

c weekly (assume 52 weeks in the year)?

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1 In this magic square, each row and column adds to a sum that is an algebraic expression. Complete the square to find the sum.

$\frac{4x^2}{2x}$	$-y$	$x + 3y$
$x - 2y$		$2y$

2 Write $3^{n-1} \times 3^{n-1} \times 3^{n-1}$ as a single power of 3.

3 You are offered a choice of two prizes:

- one million dollars right now or
- receive 1 cent on the first day of a 30-day month, double your money every day for 30 days and receive the total amount on the 30th day.

Which prize offers the most money?

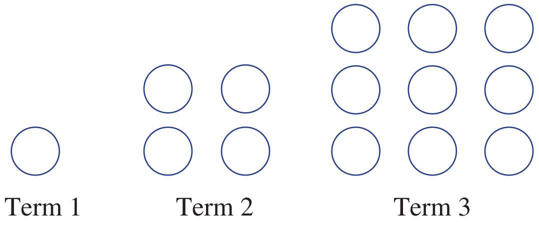
4 Simplify $\frac{25^6 \times 5^4}{125^5}$ without the use of a calculator.

5 Write $(((2^1)^2)^3)^4$ as a single power of 2.

6 How many zeros are there in 100^{100} in expanded form?

7 Simplify $\frac{x}{2} + \frac{3x}{5} - \frac{4x}{3} + \frac{x+1}{6}$.

8 Write a rule for the number of counters in the nth term of the pattern below. Use this to find the number of counters in the 15th term.



Chapter summary

Algebraic expressions

Simplifying expressions

Add/subtract like terms only. Like terms have the same pronumeral factors.

e.g. $3x$ and $7x$, $2xy$ and $4yx$;
not $2x$ and x^2 or $3y$ and $4xy$.

For example:

$$3x + 2y - x + 7y = 3x - x + 2y + 7y$$
$$= 2x + 9y$$

Multiply/Divide

$$3a \times 2b = 3 \times 2 \times a \times b$$
$$= 6ab$$
$$\frac{^{1}\cancel{7}x\cancel{y}^{1}}{_{2}\cancel{14}\cancel{y}_{1}} = \frac{x}{2}$$

Algebraic expressions

$3xy + 7x - 4y + 3$

4 terms

3 is the constant term.
7 is the coefficient of x.
-4 is the coefficient of y.

Expanding

$$a(b + c) = ab + ac$$
$$a(b - c) = ab - ac$$

e.g. $2(4x + 3) = 8x + 6$
$-3x(2x - y) = -6x^2 + 3xy$

Adding/subtracting algebraic fractions

Find the lowest common denominator and combine.

e.g. $\frac{x}{2} + \frac{2x}{3}$ LCD is 6.

$$= \frac{3x}{6} + \frac{4x}{6}$$
$$= \frac{7x}{6}$$

Factorising

This is the opposite of expanding

Factorised form		Expanded form
$2(x + 4)$	=	$2x + 8$

Look for highest common factor of terms

e.g. $3ab + 6a$ HCF is $3a$.
$= 3a(b + 2)$
$-2x^2 - 6x$ HCF is $-2x$.
$= -2x(x + 3)$

Multiplying/Dividing algebraic fractions

Multiply: Cancel common factors in factorised form and then multiply.

e.g. $\frac{3\cancel{(x+4)}^{1}}{\cancel{2}_{1}} \times \frac{^{4}\cancel{8}x}{\cancel{x+4}_{1}}$
$= 12x$

Divide: Multiply by the reciprocal of the fraction following the ÷ sign.

Reciprocal of $\frac{a}{b}$ is $\frac{b}{a}$.

Indices

Index form a^m

a is the base
m is the index/power/exponent

Index form		Expanded form
5^4	=	$5 \times 5 \times 5 \times 5$

e.g. $3 \times a \times b \times a \times a \times b = 3a^3b^2$

Exponential growth and decay

For a repeated percentage increase or decrease, the rule can be

$A = A_0(1 \pm R)^n$, where
A_0 is the initial amount;
R is the rate, as a decimal;
n is the amount of time.
Use '+' for growth and '–' for decay.

Scientific notation

Used for very large and small numbers in the form $a \times 10^m$, where $1 \le a < 10$.

$3\,870\,000 = 3.87 \times 10^6$
$0.00021 = 2.1 \times 10^{-4}$

Negative indices

$$a^{-m} = \frac{1}{a^m}$$

e.g. $x^{-3} = \frac{1}{x^3}$

$$\frac{1}{a^{-m}} = a^m$$

e.g. $\frac{4}{2^{-3}} = 4 \times 2^3 = 32$

Index laws

$a^m \times a^n = a^{m+n}$
$a^m \div a^n = a^{m-n}$
$(a^m)^n = a^{m \times n}$
$(ab)^m = a^m \times b^m$
$\left(\frac{a}{b}\right)^m = \frac{a^m}{b^m}$
Zero power: $a^0 = 1$ if $a \neq 0$.

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Multiple-choice questions

1 The coefficient of x in $3xy - 4x + 7$ is:

A 4
B 7
C -4
D 3
E -1

2 The simplified form of $7ab + 2b - 5ab + b$ is:

A $2ab + 2b^2$
B $2ab + 3b$
C $5ab$
D $2ab + b$
E $12ab + 3b$

3 The expanded form of $2x(3x - 5)$ is:

A $6x^2 - 5$
B $6x - 10$
C $6x^2 - 10x$
D $5x^2 - 10x$
E $-4x$

4 The fully factorised form of $8xy - 24y$ is:

A $4y(2x - 6y)$
B $8(xy - 3y)$
C $8y(x - 24)$
D $8y(x - 3)$
E $8x(y - 24)$

5 The simplified form of $\frac{2(x+1)}{5x} \times \frac{15}{x+1}$ is:

A $\frac{6}{x+1}$
B $\frac{6}{x}$
C $\frac{3(x+1)}{x}$
D $6x$
E $\frac{3x}{x+1}$

6 The sum of the algebraic fractions $\frac{3x}{8} + \frac{x}{12}$ is:

A $\frac{x}{5}$
B $\frac{x}{6}$
C $\frac{x}{24}$
D $\frac{11x}{24}$
E $\frac{9x}{24}$

7 $3x^3y \times 2x^5y^3$ is equal to:

A $5x^{15}y^3$
B $6x^{15}y^3$
C $6x^8y^4$
D $5x^8y^4$
E $6x^8y^3$

8 $12a^4 \div (4a^7)$ simplifies to:

A $3a^3$
B $8a^3$
C $3a^{11}$
D $\frac{8}{a^3}$
E $\frac{3}{a^3}$

9 $(2x^4)^3$ can be written as:

A $2x^{12}$
B $2x^7$
C $6x^{12}$
D $8x^{12}$
E $8x^7$

10 $5x^0 - (2x)^0$ is equal to:

A 4
B 0
C 3
D 2
E -1

11 417 000 converted to scientific notation is:

A 4.17×10^{-5}
B 417×10^3
C 4.17×10^5
D 0.417×10^6
E 41.7×10^{-2}

12 A rule for the amount of money, A, in an account after n years, if \$1200 is invested at 4% per year, is:

A $A = 1200(4)^n$
B $A = 1200(1.4)^n$
C $A = 1200(0.96)^n$
D $A = 1200(1.04)^n$
E $A = 1200(0.04)^n$

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Short-answer questions

1 Consider the expression $3xy - 3b + 4x^2 + 5$.

a How many terms are in the expression?

b What is the constant term?

c State the coefficient of:

i x^2 **ii** b

2 Write an algebraic expression for the following.

a 3 more than y

b 5 less than the product of x and y

c the sum of a and b is divided by 4

3 Evaluate the following if $x = 3$, $y = 5$ and $z = -2$.

a $3x + y$ **b** xyz **c** $y^2 - 5z$

4 Simplify the following expressions.

a $4x - 5 + 3x$ **b** $4a - 5b + 9a + 3b$ **c** $3xy + xy^2 - 2xy - 4y^2x$

d $3m \times 4n$ **e** $-2xy \times 7x$ **f** $\frac{8ab}{12a}$

5 Expand the following and collect like terms where necessary.

a $5(2x + 4)$ **b** $-2(3x - 4y)$ **c** $3x(2x + 5y)$

d $3 + 4(a + 3)$ **e** $3(y + 3) + 2(y + 2)$ **f** $5(2t + 3) - 2(t + 2)$

6 Factorise the following expressions.

a $16x - 40$ **b** $10x^2y + 35xy^2$

c $4x^2 - 10x$ **d** $-2xy - 18x$ (include the common negative)

7 Simplify the following algebraic fractions involving addition and subtraction.

a $\frac{2x}{3} + \frac{4x}{15}$

b $\frac{3}{7} - \frac{a}{2}$

c $\frac{x + 4}{4} + \frac{x - 3}{5}$

8 Simplify these algebraic fractions by first cancelling common factors in factorised form.

a $\frac{5x}{12} \times \frac{9}{10x}$ **b** $\frac{x + 2}{4} \times \frac{16x}{x + 2}$

c $\frac{12x - 4}{4}$ **d** $\frac{x - 3}{4} \div \frac{3(x - 3)}{8}$

9 Simplify the following using the appropriate index laws.

a $3x^5 \times 4x^2$ **b** $4xy^6 \times 2x^3y^{-2}$ **c** $\frac{b^7}{b^3}$ **d** $\frac{4a^3b^5}{6ab^2}$

10 Express the following using positive indices.

a $4x^{-3}$ **b** $3r^4s^{-2}$ **c** $\frac{2x^{-3}y^4}{3}$ **d** $\frac{4}{m^{-5}}$

11 Simplify the following using the appropriate index laws.

a $(b^2)^4$ **b** $(2m^2)^3$ **c** $\left(\frac{x}{7}\right)^2$ **d** $\left(\frac{4y^2}{z^4}\right)^3$

12 Simplify the following using the zero power.

a 7^0 **b** $4x^0$ **c** $5a^0 + (2y)^0$ **d** $(x^2 + 4y)^0$

13 Simplify the following using index laws. Express all answers with positive indices.

a $\dfrac{3x^2y^4 \times 5xy^7}{12x^3y^5}$ **b** $\dfrac{(5x^2y)^2 \times 4xy^2}{8(xy)^2}$

c $\dfrac{2x^3y^2 \times 5x^2y^5}{x^7y^4}$ **d** $\dfrac{4x^2y^5}{8(x^2)^{-3}y^8}$

14 Write these numbers as a basic numeral.

a 4.25×10^3 **b** 3.7×10^7 **c** 2.1×10^{-2} **d** 7.25×10^{-5}

15 Convert these numbers to scientific notation, using 3 significant figures.

a 123 574 **b** 39 452 178 **c** 0.0000090241 **d** 0.00045986

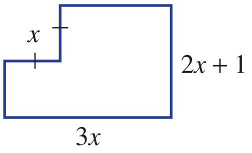
16 Form an exponential equation for the following.

a The population of a colony of kangaroos, which starts at 20 and is increasing at a rate of 10% per year.

b The amount of petrol in a petrol tank fuelling a generator if it starts with 100 000 litres and uses 15% of its fuel every hour.

Extended-response questions

1 A room in a house has the shape and dimensions, in metres, shown.



a Find the perimeter of the room in factorised form.

b If $x = 3$, what is the room's perimeter?

The floor of the room is to be recarpeted.

c Give the area of the floor in terms of x and in expanded form.

d If the carpet costs $20 per square metre and $x = 3$, what is the cost of laying the carpet?

2 During the growing season, a certain type of water lily spreads by 9% per week. The water lily covers an area of 2 m^2 at the start of the growing season.

a Write a rule for the area, A m^2, covered by the water lily after t weeks.

b Calculate the area covered, correct to 4 decimal places, after:

- **i** 2 weeks
- **ii** 5 weeks

c Use trial and error to determine, to 1 decimal place, when there will be coverage of 50 m^2.

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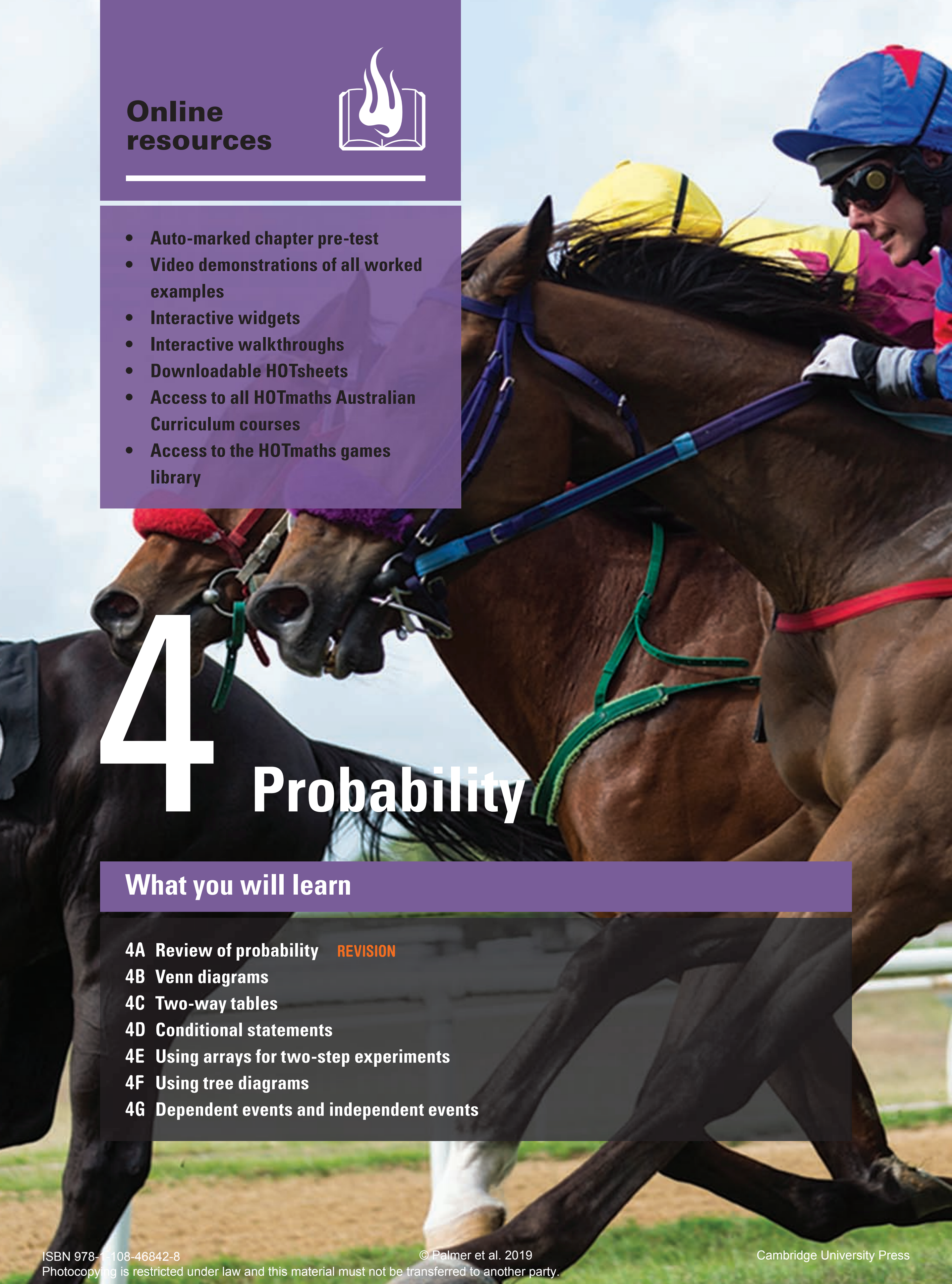


Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

4

Probability

What you will learn

NSW syllabus

STRAND: STATISTICS AND PROBABILITY

SUBSTRAND: PROBABILITY

Outcomes

A student calculates relative frequencies to estimate probabilities of simple and compound events.
(MA5.1–13SP)
A student describes and calculates probabilities in multi-step chance experiments.
(MA5.2–17SP)

Choices and chance

For many of our life choices, the outcome has an element of chance due to random effects.

A punter may choose a horse to bet on based on its past performance. However, random or unknown factors can mean that a horse with odds as low as 1 in 100 can win the Melbourne Cup.

Investing in the share market involves a certain amount of risk, and investors will often buy or sell shares based on recent data about a company's profitability.

The new Bureau of Meteorology 1660 teraflop supercomputer in Victoria generates accurate and fast probability calculations of various weather events. People can make more educated choices when they know the risk level of thunderstorms, wind changes during bushfires or flooding rain.

Pre-test

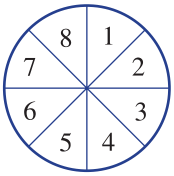
1 A letter is selected from the word PROBABILITY.

a How many letters are there in total?

b Find the chance (i.e. probability) of selecting:

- **i** the letter R
- **ii** the letter B
- **iii** a vowel
- **iv** not a vowel
- **v** a T or an I
- **vi** neither a B nor a P

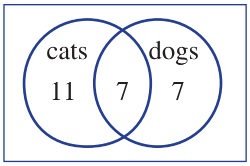
2 A spinning wheel has 8 equal sectors numbered 1 to 8. On one spin of the wheel, find the following probabilities.



- **a** $P(5)$
- **b** $P(\text{even})$
- **c** $P(\text{not even})$
- **d** $P(\text{multiple of } 3)$
- **e** $P(\text{factor of } 12)$
- **f** $P(\text{odd or a factor of } 12)$
- **g** $P(\text{both odd and a factor of } 12)$

3 Arrange from lowest to highest: $\frac{1}{2}$, 0.4, 1 in 5, 39%, $\frac{3}{4}$, 1, 0, $\frac{9}{10}$, 0.62, 71%.

4 This Venn diagram shows the number of people in a group of 25 who own cats and/or dogs.



a State the number of people who own:

- **i** a dog
- **ii** a cat or a dog (including both)
- **iii** only a cat

b If a person is selected at random from this group, find the probability that they will own:

- **i** a cat
- **ii** a cat and a dog
- **iii** only a dog

5 Drew shoots from the free-throw line on a basketball court. After 80 shots, he counts 35 successful throws.

a Estimate the probability that his next throw will be successful.

b Estimate the probability that his next throw will not be successful.

6 Two 4-sided dice are rolled and the sum of the two numbers obtained is noted.

		Roll 1			
		1	**2**	**3**	**4**
Roll 2	**1**				
	2				
	3				
	4				

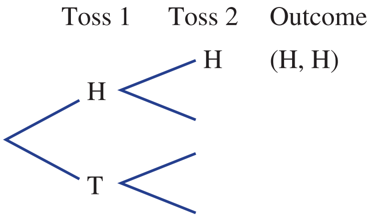
a Copy and complete this grid.

b What is the total number of outcomes?

c Find the probability that the total sum is:

- **i** 2
- **ii** 4
- **iii** less than 5
- **iv** less than or equal to 5
- **v** at most 6
- **vi** no more than 3

7 Two coins are tossed.



a Copy and complete this tree diagram.

b State the total number of outcomes.

c Find the probability of obtaining:

- **i** 2 heads
- **ii** no heads
- **iii** 1 tail
- **iv** at least 1 tail
- **v** 1 of each, a head and a tail
- **vi** at most 2 heads

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4A Review of probability REVISION

Probability is an area of mathematics concerned with the likelihood of particular random events occurring. In some situations, such as rolling a die, we can determine theoretical probabilities because we know the total number of outcomes and the number of favourable outcomes. In other cases we can use statistics and experimental results to describe the chance that an event will occur. The chance that a particular soccer team will win its next match, for example, could be estimated using various results from previous games.


A soccer team could win, lose or draw the next match it plays, but these three outcomes do not necessarily have the same probability.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Name the event

For each number below, describe an event that has that exact or approximate probability. If you think it is exact then give a reason.

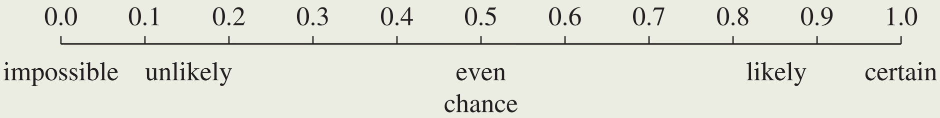
$\frac{1}{2}$ 25% 0.2 0.00001 $\frac{99}{100}$

Key ideas

- Key terms used in probability are given below.
  - A **chance experiment** is an activity that may produce a variety of different results that occur randomly. Rolling a die is a single-step experiment.
  - A **trial** is a single occurrence of an experiment, such as a single roll of a die.
  - The **sample space** is the list of all possible outcomes from an experiment.
  - An **outcome** is a possible result of an experiment.
  - An **event** is either one outcome or a collection of outcomes.
  - **Equally likely outcomes** are events that have the same chance of occurring.

Trial	One occurrence of an experiment
Sample space	All the possible outcomes of an event
Outcome	One of the possibilities from a chance experiment
Chance	The likelihood of an event happening

- In the study of probability, a numerical value based on a scale from 0 to 1 is used to describe levels of **chance**.



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Key ideas

- The theoretical probability of an event in which outcomes are equally likely is calculated as follows.

$$P(\text{event}) = \frac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$$

- A probability can be written as a fraction, decimal or percentage.
- Experimental probability is calculated in the same way as theoretical probability but uses the results of an experiment:

$$P(\text{event}) = \frac{\text{number of favourable outcomes}}{\text{total number of trials}}$$

  - If the number of trials is large, the experimental probability should be very close to the theoretical probability.

Exercise 4A REVISION

UNDERSTANDING AND FLUENCY		
	1–4, 6	3–7

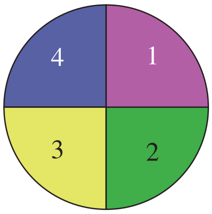
1 Order these events (**A** to **D**) from least likely to most likely.

A The chance that it will rain every day for the next 10 days.
B The chance that a member of class is ill on the next school day.
C The chance that school is cancelled next year.
D The chance that the Sun comes up tomorrow.

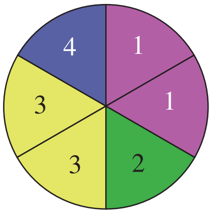
2 For the following spinners, find the probability that the outcome will be a 4.

$P(4) = \dfrac{\text{number of 4s}}{\text{total number of sections}}$

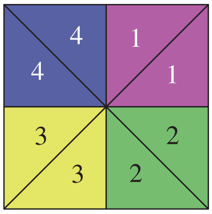
a



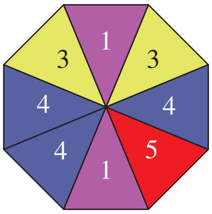
b



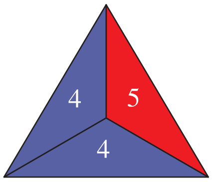
c



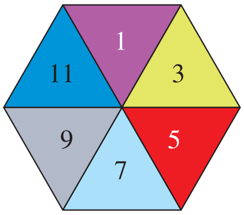
d



e



f



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3 A coin is flipped once.

- **a** How many different outcomes are possible from a single flip of the coin?
- **b** What are the possible outcomes from a single flip of the coin (i.e. list the sample space)?
- **c** Are the possible outcomes equally likely?
- **d** What is the probability of obtaining a tail?
- **e** What is the probability of not obtaining a tail?
- **f** What is the probability of obtaining a tail or a head?

Example 1 Calculating simple theoretical probabilities

A letter is chosen randomly from the word TELEVISION.

- **a** How many letters are there in the word TELEVISION?
- **b** Find the probability that the letter is:
  - **i** a V
  - **ii** an E
  - **iii** not an E
  - **iv** an E or a V

SOLUTION	EXPLANATION
a 10	The sample space includes 10 letters.
b i $P(\text{V}) = \frac{1}{10}\ (= 0.1)$	$P(\text{V}) = \frac{\text{number of Vs}}{\text{total number of letters}}$
ii $P(\text{E}) = \frac{2}{10}$	There are 2 Es in the word TELEVISION.
$= \frac{1}{5}\ (= 0.2)$	Simplify the fraction.
iii $P(\text{not an E}) = \frac{8}{10}$ $= \frac{4}{5}(= 0.8)$	If there are 2 Es in the word TELEVISION, which has 10 letters, then there must be 8 letters that are not E.
iv $P(\text{an E or a V}) = \frac{3}{10}\ (= 0.3)$	The number of letters that are either E or V is 3.

4 A letter is chosen from the word TEACHER.

- **a** How many letters are there in the word TEACHER?
- **b** Find the probability that the letter is:
  - **i** an R
  - **ii** an E
  - **iii** not an E
  - **iv** an R or an E

5 A letter is chosen from the word EXPERIMENT. Find the probability that the letter is:

- **a** an E
- **b** a vowel
- **c** not a vowel
- **d** an X or a vowel

The vowels are A, E, I, O and U.

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Example 2 Calculating simple experimental probabilities

An experiment involves tossing three coins and counting the number of heads. Here are the results after running the experiment 100 times.

Number of heads	0	1	2	3
Frequency	11	40	36	13

a How many times did 2 heads occur?

b How many times did fewer than 2 heads occur?

c Find the experimental probability of obtaining:

- **i** 0 heads
- **ii** 2 heads
- **iii** fewer than 2 heads
- **iv** at least one head

SOLUTION	EXPLANATION
a 36	From the table you can see that 2 heads has a frequency of 36.
b $11 + 40 = 51$	Fewer than 2 means obtaining 0 heads or 1 head.
c i $P(0\text{ heads}) = \frac{11}{100} = 0.11$	$P(0\text{ heads}) = \frac{\text{number of times 0 heads is observed}}{\text{total number of trials}}$
ii $P(2\text{ heads}) = \frac{36}{100} = 0.36$	$P(2\text{ heads}) = \frac{\text{number of times 2 heads is observed}}{\text{total number of trials}}$
iii $P(\text{fewer than 2 heads}) = \frac{11 + 40}{100} = \frac{51}{100} = 0.51$	Fewer than 2 heads means to observe 0 or 1 head.
iv $P(\text{at least one head}) = \frac{40 + 36 + 13}{100} = \frac{89}{100} = 0.89$	At least 1 head means that 1, 2 or 3 heads can be observed.

6 An experiment involves tossing three coins and counting the number of heads. Here are the results after running the experiment 100 times.

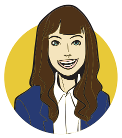
Number of heads	0	1	2	3
Frequency	9	38	43	10

a How many times did 2 heads occur?

b How many times did fewer than 2 heads occur?

c Find the experimental probability of obtaining:

- **i** 0 heads
- **ii** 2 heads
- **iii** fewer than 2 heads
- **iv** at least one head



The total number of outcomes is 100.

7 An experiment involves rolling two dice and counting the number of sixes. Here are the results after running the experiment 100 times.

Number of sixes	0	1	2
Frequency	62	35	3

Find the experimental probability of obtaining:

a 0 sixes
b 2 sixes
c fewer than 2 sixes
d at least 1 six

PROBLEM-SOLVING AND REASONING		8, 9	8, 10, 11

8 A 10-sided die numbered 1 to 10 is rolled once. Find these probabilities.

a $P(8)$ **b** $P(\text{odd})$
c $P(\text{even})$ **d** $P(\text{less than } 6)$
e $P(\text{prime})$ **f** $P(3 \text{ or } 8)$
g $P(8, 9 \text{ or } 10)$ **h** $P(\text{at least } 2)$

1 2 3
4 5
6 7 8
9 10

Prime numbers less than 10 are 2, 3, 5 and 7.

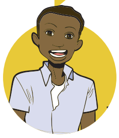
9 Thomas is a prizewinner in a competition and will be randomly awarded a single prize chosen from a collection of 50 prizes. The type and number of prizes to be handed out are listed below.

Prize	Car	Holiday	iPad	Blu-ray player
Number	1	4	15	30

Find the probability that Thomas will be awarded the following.

a a car
b an iPad
c a prize that is not a car

Remember that the total number of prizes is 50.



10 Many of the 50 cars inspected at an assembly plant contained faults. The results of the inspection were as follows.

Number of faults	0	1	2	3	4
Number of cars	30	12	4	3	1

Find the experimental probability that a car selected from the assembly plant will have:

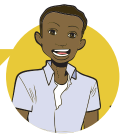
a 1 fault
b 4 faults
c fewer than 2 faults
d 1 or more faults
e 3 or 4 faults
f at least 2 faults

11 A bag contains red and yellow counters. A counter is drawn from the bag and then replaced. This happens 100 times and 41 of the counters drawn were red.

a How many counters drawn were yellow?

b If there were 10 counters in the bag, how many do you expect were red? Give a reason.

c If there were 20 counters in the bag, how many do you expect were red? Give a reason.



$\frac{41}{100}$ were red.

ENRICHMENT

– 12

Cards probability

12 A card is chosen from a standard deck of 52 playing cards that includes 4 aces, 4 kings, 4 queens and 4 jacks. Find the following probabilities.

a $P(\text{heart})$

b $P(\text{king})$

c $P(\text{king of hearts})$

d $P(\text{heart or club})$

e $P(\text{king or jack})$

f $P(\text{heart or king})$

g $P(\text{not a king})$

h $P(\text{neither a heart nor a king})$

There are 4 suits in a deck of cards: hearts, diamonds, spades and clubs.

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4B Venn diagrams

Interactive
Widgets
HOTsheets
Walkthrough

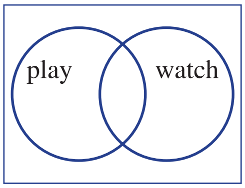
Sometimes we need to work with situations where there are overlapping events. A TV station, for example, might be collecting statistics regarding whether or not a person watches cricket and/or tennis or neither over a certain period of time. The estimated probability that a person will watch cricket *or* tennis will therefore depend on how many people responded *yes* to watching both cricket *and* tennis. Venn diagrams are a useful tool when dealing with such events.

Stage
- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

Let's start: How many like both?

Of 20 students in a class, 12 people like to play tennis and 15 people like to watch tennis. Two people like neither playing nor watching tennis. Some like both playing and watching tennis.

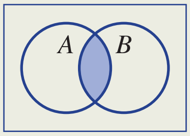
- Is it possible to represent this information in a Venn diagram?
- How many students like to play and watch tennis?
- How many students only like to watch tennis?
- From the group of 20 students, what would be the probability of selecting a person that likes watching tennis only?



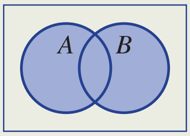
Key ideas

■ A **Venn diagram** illustrates how all elements in the sample space are distributed among the events.

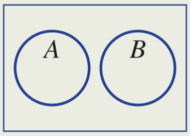
- All elements that belong to both A *and* B.



- All elements that belong to either events A *or* B.



- The two sets A and B are **mutually exclusive** if they have no elements in common.



- For an event A, the complement of A is A' (or 'not A'). $P(A') = 1 - P(A)$

Venn diagram A diagram using circles to show the relationships between two or more sets of data

Mutually exclusive Two events that cannot both occur at the same time

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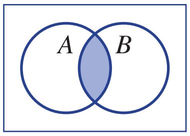
Exercise 4B

UNDERSTANDING AND FLUENCY 1–4, 6 3–7

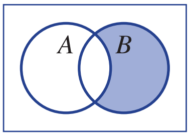
1 Match the descriptions (**a**–**e**) to the pictures (**A**–**E**).

a A or B
b A
c not A
d A and B
e B only

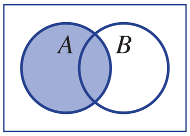
A



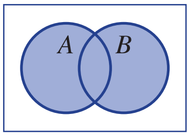
B



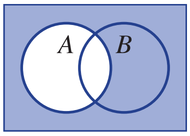
C



D



E



2 Decide whether the events A and B are mutually exclusive.

a $A = \{1, 3, 5, 7\}$
$B = \{5, 8, 11, 14\}$

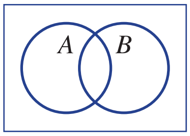
b $A = \{-3, -2, \ldots, 4\}$
$B = \{-11, -10, \ldots, -4\}$

c $A = \{\text{prime numbers}\}$
$B = \{\text{even numbers}\}$

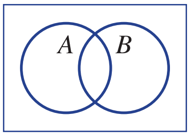
Mutually exclusive events have nothing in common.

3 Copy these Venn diagrams and shade the region described by each of the following.

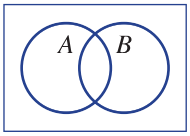
a A



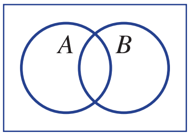
b B



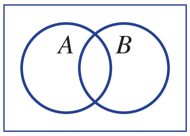
c A and B



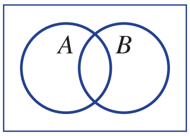
d A or B



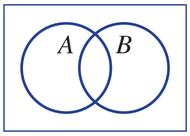
e A only



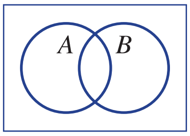
f B only



g not A



h neither A nor B



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Example 3 Listing sets

Consider the given events A and B that involve numbers taken from the first 10 positive integers.

$$A = \{1, 2, 3, 4, 5, 6\} \qquad B = \{1, 3, 7, 8\}$$

a Represent the two events A and B in a Venn diagram.

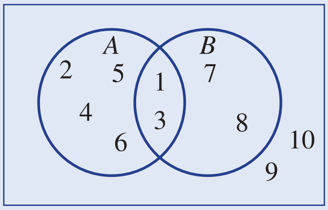
b List the sets:

i A and B **ii** A or B

c If a number from the first 10 positive integers is randomly selected, find the probability that the following events occur.

i A **ii** A and B **iii** A or B

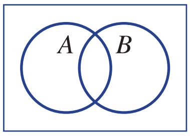
d Are the events A and B mutually excusive? Why or why not?

SOLUTION	EXPLANATION
a 	The elements 1 and 3 are common to both sets A and B. The elements 9 and 10 belong to neither set A nor set B.
b **i** A and $B = \{1, 3\}$	1 and 3 are in A and B.
ii A or $B = \{1, 2, 3, 4, 5, 6, 7, 8\}$	These numbers are in either A or B or both.
c **i** $P(A) = \frac{6}{10} = \frac{3}{5}$	There are 6 numbers in A.
ii $P(A \text{ and } B) = \frac{2}{10} = \frac{1}{5}$	A and B contains 2 numbers.
iii $P(A \text{ or } B) = \frac{8}{10} = \frac{4}{5}$	A or B contains 8 numbers.
d The sets A and B are not mutually exclusive since there are numbers inside A and B.	The set A and B contains at least 1 number.

4 Consider the given events A and B, which involve numbers taken from the first 10 positive integers.

$$A = \{1, 2, 4, 5, 7, 8, 10\} \qquad B = \{2, 3, 5, 6, 8, 9\}$$

a Represent events A and B in a Venn diagram, as shown below.



b List the following sets.

i A and B **ii** A or B

c If a number from the first 10 positive integers is randomly selected, find the probability that the following events occur.

i A **ii** A and B **iii** A or B

d Are the events A and B mutually exclusive? Why or why not?

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5 The elements of the events A and B described below are numbers taken from the first 10 prime numbers.

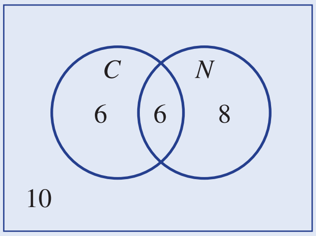
$$A = \{2, 5, 7, 11, 13\} \qquad B = \{2, 3, 13, 17, 19, 23, 29\}$$

- **a** Represent events A and B in a Venn diagram.
- **b** List the elements belonging to the following.
  - **i** A and B
  - **ii** A or B
- **c** If a number from the first 10 prime numbers is selected, find the probability that these events occur.
  - **i** A
  - **ii** B
  - **iii** A and B
  - **iv** A or B

Example 4 Using Venn diagrams

From a class of 30 students, 12 enjoy cricket (C), 14 enjoy netball (N) and 6 enjoy both cricket and netball.

- **a** Illustrate this information in a Venn diagram.
- **b** State the number of students who enjoy:
  - **i** netball only
  - **ii** neither cricket nor netball
- **c** Find the probability that a person chosen at random will enjoy:
  - **i** netball
  - **ii** netball only
  - **iii** both cricket and netball

SOLUTION	EXPLANATION
a 	First, place the 6 in the intersection (6 enjoy cricket and netball) and then determine the other values according to the given information. The total must be 30, with 12 in the cricket circle and 14 in netball.
b i 8	Includes students in N but not in C.
ii 10	These are the students outside both C and N.
c i $P(N) = \frac{14}{30} = \frac{7}{15}$	14 of the 30 students enjoy netball.
ii $P(N \text{ only}) = \frac{8}{30} = \frac{4}{15}$	8 of the 30 students enjoy netball but not cricket.
iii $P(C \text{ and } N) = \frac{6}{30} = \frac{1}{5}$	6 students like both cricket and netball.

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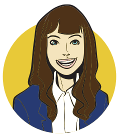
6 From a group of 50 adults, 35 enjoy reading fiction (F), 20 enjoy reading non-fiction (N) and 10 enjoy reading both fiction and non-fiction.

- **a** Illustrate the information in a Venn diagram.
- **b** State the number of people who enjoy:
  - **i** fiction only
  - **ii** neither fiction nor non-fiction
- **c** Find the probability that a person chosen at random will enjoy reading:
  - **i** non-fiction
  - **ii** non-fiction only
  - **iii** both fiction and non-fiction

First enter the '10' in the intersection, then fill in all the other regions. $35 - 10 = 25$ enjoy fiction only.

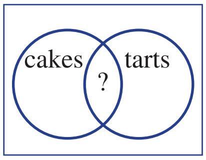


7 At a show, 45 children have the choice of riding on the Ferris wheel (F) and/or the Big Dipper (B). Thirty-five of the children wish to ride on the Ferris wheel, 15 children want to ride on the Big Dipper and 10 children want to ride on both.

- **a** Illustrate the information in a Venn diagram.
- **b** State the number of children who want to:
  - **i** ride on the Ferris wheel only
  - **ii** ride on neither the Ferris wheel nor the Big Dipper
- **c** For a child chosen at random from the group, find the probability that they will want to ride on:
  - **i** the Ferris wheel
  - **ii** both the Ferris wheel and the Big Dipper
  - **iii** the Ferris wheel or the Big Dipper
  - **iv** not the Ferris wheel
  - **v** neither the Ferris wheel nor the Big Dipper

PROBLEM-SOLVING AND REASONING		8, 9	9, 10

8 In a group of 12 chefs, all enjoy baking cakes and/or tarts. In fact, 7 enjoy baking cakes and 8 enjoy baking tarts. Find out how many chefs enjoy baking both cakes and tarts.



9 In a group of 32 car enthusiasts, all collect either vintage cars or modern sports cars. Of the group, 18 collect vintage cars and 19 collect modern sports cars. How many collect both vintage cars and modern sports cars?

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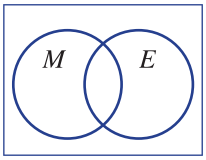
10 Mario and Elisa are choosing a colour to paint the interior walls of their house. They have six colours to choose from:

white (w), cream (c), navy (n), sky blue (s), maroon (m) and violet (v).

Mario would be happy with white or cream and Elisa would be happy with cream, navy or sky blue, but they can't decide, so a colour is chosen at random for them.

Let M be the event that Mario will be happy with the colour and E be the event that Elisa will be happy with the colour.

a Represent the events M and E in a Venn diagram.



b Find the probability that the following events occur.

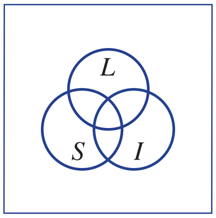
- **i** Mario will be happy with the colour choice; i.e. find $P(M)$.
- **ii** Mario will not be happy with the colour choice.
- **iii** Both Mario and Elisa will be happy with the colour choice.
- **iv** Mario or Elisa will be happy with the colour choice.
- **v** Neither Mario nor Elisa will be happy with the colour choice.

ENRICHMENT		–	11

Courier companies

11 Of 15 chosen courier companies, 9 offer a local service (L), 7 offer an interstate service (S) and 6 offer an international service (I). Two companies offer all three services, 3 offer both local and interstate services, 5 offer only local services and 1 offers only an international service.

a Draw a Venn diagram displaying the given information.



b Find the number of courier companies that offer neither local, interstate nor international services.

c If a courier is chosen at random from the 15 initially examined, find the following probabilities.

- **i** $P(L)$
- **ii** $P(L \text{ only})$
- **iii** $P(L \text{ or } S)$
- **iv** $P(L \text{ and } S \text{ only})$

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4C Two-way tables

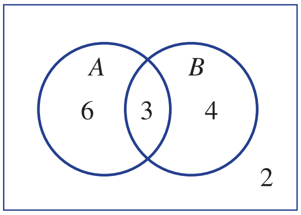
Interactive
Widgets
HOTsheets
Walkthrough

Like a Venn diagram, two-way tables are useful tools for the organisation of overlapping events. The totals at the end of each column and row help to find the unknown numbers required to solve various problems.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Comparing Venn diagrams with two-way tables

Here is a Venn diagram and an incomplete two-way table.



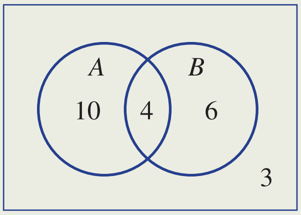
	A	not *A*	Total
B		4	
not *B*			8
Total	9		15

- First, can you complete the two-way table?
- Describe what each box in the two-way table means.
- Was it possible to find all the missing numbers in the two-way table without referring to the Venn diagram?

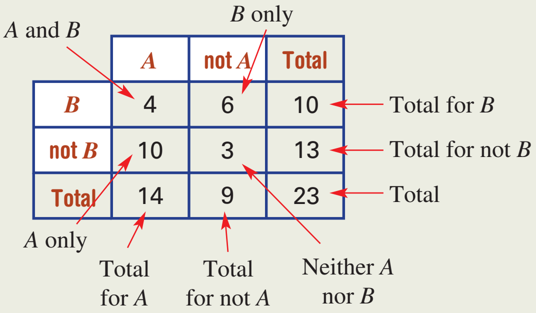
Key ideas

■ Two-way tables use rows and columns to describe the number of elements in different regions of overlapping events.

Venn diagram



Two-way table



	A	not *A*	Total
B	4	6	10
not *B*	10	3	13
Total	14	9	23

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Exercise 4C

UNDERSTANDING AND FLUENCY 1–4 2–5

1 Match the shaded two-way tables (**A**–**D**) with each description (**a**–**d**).

a *A* and *B* **b** *B* only **c** *A* **d** *A* or *B*

A

	A	not *A*	Total
B		▨	
not *B*			
Total			

B

	A	not *A*	Total
B	▨		
not *B*			
Total			

C

	A	not *A*	Total
B	▨	▨	
not *B*	▨		
Total			

D

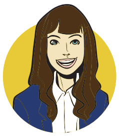
	A	not *A*	Total
B			
not *B*			
Total	▨		

2 Look at this two-way table.

a State the number of elements in these events.

	A	not *A*	Total
B	4	3	7
not *B*	6	1	7
Total	10	4	14

A only means *A* and not *B*.



i *A* and *B* **ii** *A* only **iii** *B* only **iv** neither *A* nor *B*

v *A* **vi** *B* **vii** not *A* **viii** not *B*

b *A* or *B* includes *A* and *B*, *A* only and *B* only. Find the total number of elements in *A* or *B*.

Example 5 Using two-way tables

The Venn diagram shows the distribution of elements in two sets, *A* and *B*.

a Transfer the information in the Venn diagram to a two-way table.

b Find the number of elements for these regions.

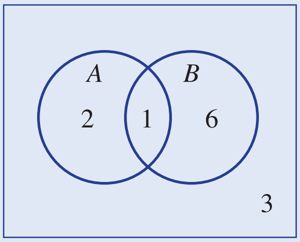
i *A* and *B* **ii** *B* only **iii** *A* only

iv neither *A* nor *B* **v** *A* **vi** not *B*

vii *A* or *B*

c Find:

i $P(A \text{ and } B)$ **ii** $P(\text{not } A)$ **iii** $P(A \text{ only})$



SOLUTION

a

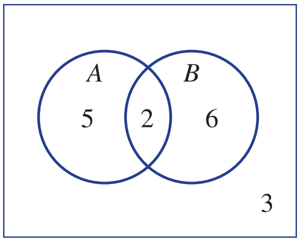
	A	not *A*	Total
B	1	6	7
not *B*	2	3	5
Total	3	9	12

EXPLANATION

	A	not *A*	Total
B	*A* and *B*	*B* only	Total the row
not *B*	*A* only	Neither *A* nor *B*	Total the row
Total	Total the column	Total the column	Overall total

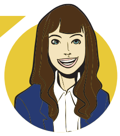
b **i**	1	In both A and B
ii	6	In B but not A
iii	2	In A but not B
iv	3	In neither A nor B
v	3	Total of A; $2 + 1 = 3$
vi	5	Total not in B; $2 + 3 = 5$
vii	$2 + 1 + 6 = 9$	In A only or B only or both (three regions)
c **i**	$P(A \text{ and } B) = \frac{1}{12}$	When calculating probabilities, you will need to divide the number of elements in each set by the number of elements in the sample space, which is 12.
ii	$P(\text{not } A) = \frac{9}{12} = \frac{3}{4}$	
iii	$P(A \text{ only}) = \frac{2}{12} = \frac{1}{6}$	

3 The Venn diagram shows the distribution of elements in two sets, A and B.



A two-way table has these headings:

	A	not A	Total
B			
not B			
Total			



a Transfer the information in the Venn diagram to a two-way table.

b Find the number of elements in these regions.

- **i** A and B
- **ii** B only
- **iii** A only
- **iv** neither A nor B
- **v** A
- **vi** not B
- **vii** A or B

c Find:

- **i** $P(A \text{ and } B)$
- **ii** $P(\text{not } A)$
- **iii** $P(A \text{ only})$

4 From a total of 10 people, 5 like oranges (O), 6 like grapes (G) and 4 like both oranges and grapes.

a Draw a Venn diagram for the 10 people.

b Draw a two-way table for the 10 people.

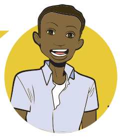
c Find the number of people who like:

- **i** only grapes
- **ii** oranges
- **iii** oranges and grapes
- **iv** oranges or grapes

d Find:

- **i** $P(G)$
- **ii** $P(O \text{ and } G)$
- **iii** $P(O \text{ only})$
- **iv** $P(\text{not } G)$
- **v** $P(O \text{ or } G)$

Once you have your Venn diagram, you can transfer the information to the two-way table.



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5 Of 12 people interviewed at a train station, 7 like staying in hotels, 8 like staying in apartments and 4 like staying in hotels and apartments.

- **a** Draw a two-way table for the 12 people.
- **b** Find the number of people who like staying in:
  - **i** only hotels
  - **ii** neither hotels nor apartments
- **c** Find the probability that one of the people likes staying in:
  - **i** hotels or apartments
  - **ii** only apartments

PROBLEM-SOLVING AND REASONING

6–8	7–10

6 Complete the following two-way tables.

a

	A	not A	Total
B		3	6
not B			
Total		4	11

b

	A	not A	Total
B	2	7	
not B			3
Total	4		

All the rows and columns should add up correctly.

7 In a class of 24 students, 13 like Mathematics, 9 like English and 3 like both.

- **a** Find the probability that a randomly selected student from this class likes both Mathematics and English.
- **b** Find the probability that a randomly selected student from this class likes neither Mathematics nor English.

8 Two sets, A and B, are mutually exclusive.

- **a** Find $P(A \text{ and } B)$.
- **b** Now complete this two-way table.

	A	not A	Total
B		6	
not B			12
Total	10		18

9 Of 32 cars at a show, 18 cars have four-wheel drive, 21 are sports cars and 27 have four-wheel drive or are sports cars.

- **a** Find the probability that a randomly selected car from the show is both four-wheel drive and a sports car.
- **b** Find the probability that a randomly selected car from the show is neither four-wheel drive nor a sports car.

10 A card is selected from a standard deck of 52 playing cards. Find the probability that the card is:

a a heart or a king
b a club or a queen
c a black card or an ace
d a red card or a jack

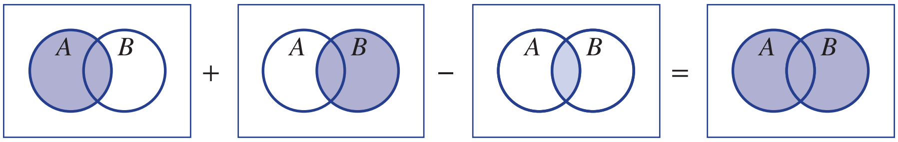
Make sure you don´t count some cards twice; e.g. the king of hearts in part **a**.

ENRICHMENT – 11

The addition rule

For some of the problems above you will have noticed the following, which is called the addition rule.

$$A \quad + \quad B \quad - \quad A \text{ and } B \quad = \quad A \text{ or } B$$



11 Use the addition rule to find A or B in these problems.

a Of 20 people at a sports day, 12 people like hurdles (H), 14 like discus (D) and 8 like both hurdles and discus (H and D). How many like hurdles or discus?

b Of 100 households, 84 have wide screen TVs, 32 have tube TVs and 41 have both. How many have wide screen or tube TVs?

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4D Conditional statements

Interactive
Widgets
HOTsheets
Walkthrough

The mathematics associated with the probability that an event occurs, given that another event has already occurred, is called conditional probability.

Consider, for example, a group of primary school students who own bicycles. Some of the bicycles have gears, some have suspension and some have both gears and suspension. Consider these two questions.

- What is the probability that a randomly selected bicycle has gears?
- What is the probability that a randomly selected bicycle has gears, given that it has suspension?

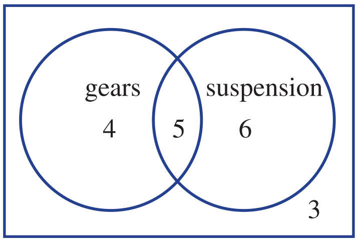
The second question is conditional, in that we already know that the bicycle has suspension.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Gears and suspension

Suppose that, in a group of 18 bicycles, 9 have gears, 11 have suspension and 5 have both gears and suspension. Discuss the solution to the following question by considering the points below.

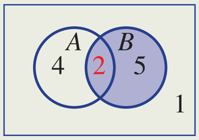
What is the probability that a randomly selected bicycle will have gears, given that it has suspension?



- First look at the information in a Venn diagram.
- How many of the bicycles that have suspension also have gears?
- Out of the 11 that have suspension, what is the probability that a bike will have gears?
- What would be the answer to the question in reverse; i.e. what is the probability that a bicycle will have suspension, given that it has gears?

Key ideas

- The probability of event A occurring given that event B has occurred is denoted by $P(A|B)$, which reads 'the probability of A given B'.
- $P(A \text{ given } B) = \dfrac{\text{number of elements in } A \text{ and } B}{\text{number of elements in } B}$



$$P(A|B) = \frac{2}{7}$$

	A	not A	Total
B	2	5	7
not B	4	1	5
Total	6	6	12

$$P(A|B) = \frac{2}{7}$$

- $P(B \text{ given } A) = \dfrac{\text{number of elements in } A \text{ and } B}{\text{number of elements in } A}$

  For the diagrams above, $P(B|A) = \dfrac{2}{6} = \dfrac{1}{3}$.

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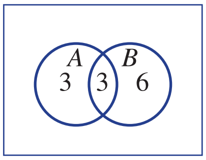
Exercise 4D

UNDERSTANDING AND FLUENCY	1–5	3–5

1 Consider this Venn diagram.

- **a** What fraction of the elements in A are also in B? (This finds $P(B|A)$.)
- **b** What fraction of the elements in B are also in A? (This finds $P(A|B)$.)



2 Use this two-way table to answer these questions.

- **a** What fraction of the elements in A are also in B? (This finds $P(B|A)$.)
- **b** What fraction of the elements in B are also in A? (This finds $P(A|B)$.)

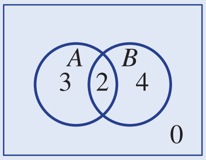
	A	not A	Total
B	7	5	12
not B	3	1	4
Total	10	6	16

3 In a group of 20 people, 15 are wearing jackets and 10 are wearing hats; 5 are wearing both a jacket and a hat.

- **a** What fraction of the people who are wearing jackets are wearing hats?
- **b** What fraction of the people who are wearing hats are wearing jackets?

Example 6 Finding conditional probabilities using a Venn diagram

Consider this Venn diagram, displaying the number of elements belonging to the events A and B.



Find the following probabilities.

- **a** $P(A)$
- **b** $P(A \text{ and } B)$
- **c** $P(A|B)$
- **d** $P(B|A)$

SOLUTION	EXPLANATION
a $P(A) = \frac{5}{9}$	There are 5 elements in A and 9 in total.
b $P(A \text{ and } B) = \frac{2}{9}$	There are 2 elements common to A and B.
c $P(A|B) = \frac{2}{6} = \frac{1}{3}$	2 of the 6 elements in B are in A.
d $P(B|A) = \frac{2}{5}$	2 of the 5 elements in A are in B.

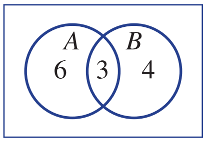
4 The following Venn diagrams display information about the number of elements associated with the events A and B. For each Venn diagram, find:

- **i** $P(A)$
- **ii** $P(A \text{ and } B)$
- **iii** $P(A|B)$
- **iv** $P(B|A)$

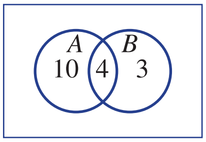
$$P(A|B) = \frac{\text{number in } A \text{ and } B}{\text{number in } B}$$

$$P(B|A) = \frac{\text{number in } A \text{ and } B}{\text{number in } A}$$

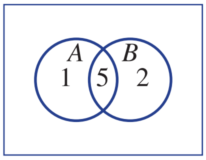
a



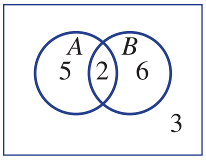
b



c



d



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Example 7 Finding conditional probabilities using a two-way table

From a group of 15 hockey players at a game of hockey, 13 played on the field, 7 sat on the bench and 5 both played and sat on the bench.

A hockey player is chosen at random from the team.

Let A be the event 'the person played on the field' and B be the event 'the person sat on the bench'.

a Represent the information in a two-way table.

b Find the probability that the person only sat on the bench.

c Find the probability that the person sat on the bench, given that they played on the field.

d Find the probability that the person played on the field, given that they sat on the bench.

SOLUTION

a

	A	not A	Total
B	5	2	7
not B	8	0	8
Total	13	2	15

b $P(\text{bench only}) = \dfrac{2}{15}$

c $P(B|A) = \dfrac{5}{13}$

d $P(A|B) = \dfrac{5}{7}$

EXPLANATION

A and B has 5 elements, A has a total of 13 and B has a total of 7. There are 15 players in total.

Two people sat on the bench and did not play on the field.

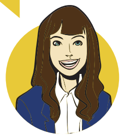
$$P(B|A) = \frac{\text{number in } A \text{ and } B}{\text{number in } A}$$

$$P(A|B) = \frac{\text{number in } A \text{ and } B}{\text{number in } B}$$

5 The following two-way tables show information about the number of elements in the events A and B. For each two-way table, find:

- **i** $P(A)$
- **ii** $P(A \text{ and } B)$
- **iii** $P(A|B)$
- **iv** $P(B|A)$

First decide on the total that gives the denominator of your fraction in each case.



a

	A	not A	Total
B	2	8	10
not B	5	3	8
Total	7	11	18

b

	A	not A	Total
B	1	4	5
not B	3	1	4
Total	4	5	9

c

	A	not A	Total
B	7	3	10
not B	1	6	7
Total	8	9	17

d

	A	not A	Total
B	4	2	6
not B	8	2	10
Total	12	4	16

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PROBLEM-SOLVING AND REASONING 6, 7 6, 8–11

6 Of a group of 20 English cricket fans at a match, 13 purchased a pie, 15 drank beer, and 9 purchased a pie and drank beer.
Let A be the event 'the fan purchased a pie'.
Let B be the event 'the fan drank beer'.

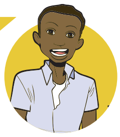
	A	not A	Total
B	9		
not B			
Total			20

- **a** Copy and complete this two-way table.
- **b** Find the probability that a fan only purchased a pie (and did not drink beer).
- **c** Find the probability that a fan purchased a pie, given that they drank beer.
- **d** Find the probability that a fan drank beer, given that they purchased a pie.

7 Of 15 musicians surveyed to find out whether they play the violin or the piano, 5 play the violin, 8 play the piano and 2 play both instruments.
- **a** Represent the information in a Venn diagram.
- **b** How many of the musicians surveyed do not play either the violin or the piano?
- **c** Find the probability that one of the 15 musicians plays piano, given they play the violin.
- **d** Find the probability that one of the 15 musicians plays the violin, given they play piano.

8 Rachel rolled a fair die and says, "My number is less than 5."
What is the probability that Rachel's number is a 2?

Remember to use the extra information: 'My number is less than 5.'

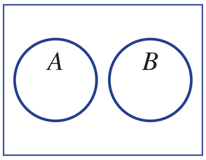


9 When two coins are tossed there are four outcomes: HH, TH, HT, TT. Sofia tosses two coins but can see only one of them. It is showing heads. What is the probability that the other coin is not showing heads?

10 A card is drawn from a deck of 52 playing cards. Find the probability that:
- **a** the card is a king given that it is a heart
- **b** the card is a jack given that it is a red card

13 of the cards are hearts. There are 4 kings, including one king of hearts.

11 Two events, A and B, are mutually exclusive. What can be said about the probability of A given B (i.e. $P(A|B)$) or the probability of B given A (i.e. $P(B|A)$)? Give a reason.



ENRICHMENT – 12

Cruise control and airbags

12 On a car production line, 30 cars are due to be completed by the end of the day. Fifteen of the cars have cruise control and 20 have airbags, and 6 have both cruise control and airbags.
- **a** Represent the information provided in a Venn diagram or two-way table.
- **b** Find the probability that a car chosen at random will contain:
  - **i** cruise control only
  - **ii** airbags only
- **c** Given that the car chosen has cruise control, find the probability that the car will have airbags.
- **d** Given that the car chosen has airbags, find the probability that the car will have cruise control.

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4E Using arrays for two-step experiments

Interactive
Widgets
HOTsheets
Walkthrough

Some experiments involve two steps. Examples include:

- tossing two coins
- rolling two dice
- tossing a coin once and rolling a die once
- choosing two chocolates from a box

This section will look at probabilities associated with such events.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Two prizes, three people

Two special prizes are to be awarded in some way to Bill, May and Li for their efforts in helping at the school fête. This table shows how the prizes might be awarded.

		2nd prize		
		Bill	**May**	**Li**
1st prize	**Bill**	(B, B)	(B, M)	(B, L)
	May	(M, B)		
	Li			

- Complete the table to show how the two prizes can be awarded.
- Does the table show that the same person can be awarded both prizes?
- What is the probability that Bill and Li are both awarded a prize?
- How would the table change if the same person could not be awarded both prizes?
- How do the words 'with replacement' and 'without replacement' relate to the situation above? Discuss.

Key ideas

- An array can be used to list the sample space for two-step experiments.
- In some two-step experiments, the first item chosen *can* be chosen again. This is called 'with replacement'.
- If replacement is allowed, then outcomes from each selection can be repeated.
- If selections are made without replacement, then outcomes from each selection cannot be repeated.
  For example: Two selections are made from the digits $\{1, 2, 3\}$.

With replacement

		1st		
		1	**2**	**3**
2nd	**1**	(1, 1)	(2, 1)	(3, 1)
	2	(1, 2)	(2, 2)	(3, 2)
	3	(1, 3)	(2, 3)	(3, 3)

9 outcomes

Without replacement

		1st		
		1	**2**	**3**
2nd	**1**	×	(2, 1)	(3, 1)
	2	(1, 2)	×	(3, 2)
	3	(1, 3)	(2, 3)	×

6 outcomes

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Exercise 4E

UNDERSTANDING AND FLUENCY	1–3, 5	2–5

1 Two letters are chosen from the word DOG.

a Complete a table listing the sample space if selections are made:

i with replacement

		1st		
		D	O	G
2nd	D	(D, D)	(O, D)	
	O			
	G			

ii without replacement

		1st		
		D	O	G
2nd	D	×	(O, D)	
	O		×	
	G			×

b State the total number of outcomes if selection is made:

i with replacement

ii without replacement

c If selection is made with replacement, find the probability that:

i the two letters are the same

ii there is at least one D

iii there is not an O

iv there is a D or a G

v there is a D and a G

d If selection is made without replacement, find the probability that:

i the two letters are the same

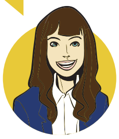
ii there is at least one D

iii there is not an O

iv there is a D or a G

v there is a D and a G

Count up your favourable outcomes and divide by the total.



2 Two digits are selected from the set $\{2, 3, 4\}$ to form a two-digit number. Find the number of two-digit numbers that can be formed if the digits are selected:

a with replacement

	2	3	4
2	22	32	
3			
4			

b without replacement

	2	3	4
2	×	32	
3		×	
4			×

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Example 8 Constructing a table with replacement

A six-sided die is rolled twice.

a List all the outcomes, using a table.

b State the total number of outcomes.

c Find the probability of obtaining the outcome (1, 5).

d Find:

- **i** $P(\text{double})$
- **ii** $P(\text{sum of at least 10})$
- **iii** $P(\text{sum not equal to 7})$

SOLUTION

a

		Roll 2					
		1	**2**	**3**	**4**	**5**	**6**
Roll 1	**1**	(1, 1)	(1, 2)	(1, 3)	(1, 4)	(1, 5)	(1, 6)
	2	(2, 1)	(2, 2)	(2, 3)	(2, 4)	(2, 5)	(2, 6)
	3	(3, 1)	(3, 2)	(3, 3)	(3, 4)	(3, 5)	(3, 6)
	4	(4, 1)	(4, 2)	(4, 3)	(4, 4)	(4, 5)	(4, 6)
	5	(5, 1)	(5, 2)	(5, 3)	(5, 4)	(5, 5)	(5, 6)
	6	(6, 1)	(6, 2)	(6, 3)	(6, 4)	(6, 5)	(6, 6)

b 36 outcomes

c $P(1, 5) = \frac{1}{36}$

d **i** $P(\text{double}) = \frac{6}{36}$

$$= \frac{1}{6}$$

ii $P(\text{sum of at least 10}) = \frac{6}{36} = \frac{1}{6}$

iii $P(\text{sum not equal to 7}) = 1 - \frac{6}{36}$

$$= \frac{30}{36}$$

$$= \frac{5}{6}$$

EXPLANATION

Be sure to place the number from roll 1 in the first position for each outcome.

There is a total of $6 \times 6 = 36$ outcomes.

Only one outcome is (1, 5).

Six outcomes have the same number repeated.

Six outcomes have a sum of either 10, 11 or 12.

This is the complement of having a sum of 7. Six outcomes have a sum of 7.
$P(\text{not } A) = 1 - P(A)$

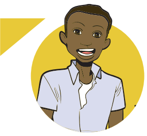
3 A 4-sided die is rolled twice.

a List all the outcomes, using a table.

b State the total number of possible outcomes.

c Find the probability of obtaining the outcome (2, 4).

Questions **3** and **4** are making selections 'with replacement' because outcomes can be repeated.



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d Find the probability of:

i a double **ii** a sum of at least 5 **iii** a sum not equal to 4

		1st roll			
		1	**2**	**3**	**4**
2nd roll	**1**	(1, 1)	(2, 1)		
	2				
	3				
	4				

4 Two coins are tossed, each landing with a head (H) or tail (T).

a List all the outcomes, using a table.

b State the total number of possible outcomes.

c Find the probability of obtaining the outcome (H, T).

d Find the probability of obtaining:

i exactly one tail **ii** at least one tail

e If the two coins were tossed 1000 times, how many times would you expect to get two tails?

		1st toss	
		H	**T**
2nd toss	**H**	(H, H)	(T, H)
	T		

Example 9 Constructing a table without replacement

Two letters are chosen from the word KICK, without replacement.

a Construct a table to list the sample space.

b Find the probability of:

i obtaining the outcome (K, C) **ii** selecting two Ks

iii selecting a K and a C

SOLUTION

a

		1st			
		K	**I**	**C**	**K**
2nd	**K**	×	(I, K)	(C, K)	(K, K)
	I	(K, I)	×	(C, I)	(K, I)
	C	(K, C)	(I, C)	×	(K, C)
	K	(K, K)	(I, K)	(C, K)	×

EXPLANATION

Selection is without replacement, so the same letter (from the same position) cannot be chosen twice.

b **i**

$$\begin{aligned} P(\text{K, C}) &= \frac{2}{12} \\ &= \frac{1}{6} \end{aligned}$$

Two of the 12 outcomes are (K, C).

ii

$$\begin{aligned} P(\text{K, K}) &= \frac{2}{12} \\ &= \frac{1}{6} \end{aligned}$$

Two of the outcomes are K and K, which use different Ks from the word KICK.

iii

$$\begin{aligned} P(\text{K and C}) &= \frac{4}{12} \\ &= \frac{1}{3} \end{aligned}$$

Four outcomes contain a K and a C.

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5 Two letters are chosen from the word SET, without replacement.
- **a** Complete this table.
- **b** Find the probability of:
  - **i** obtaining the outcome (E, T)
  - **ii** selecting one T
  - **iii** selecting at least one T
  - **iv** selecting an S and a T
  - **v** selecting an S or a T

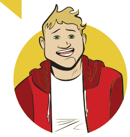
		1st		
		S	**E**	**T**
2nd	**S**	×	(E, S)	(T, S)
	E		×	
	T			×

PROBLEM-SOLVING AND REASONING

6, 7 7–9

6 A letter is chosen from the word LEVEL without replacement and then a second letter is chosen from the same word.
- **a** Draw a table displaying the sample space for the pair of letters chosen.
- **b** State the total number of outcomes possible.
- **c** State the number of outcomes that contain exactly one of the following letters.
  - **i** V **ii** L **iii** E
- **d** Find the probability that the outcome will contain exactly one of the following letters.
  - **i** V **ii** L **iii** E
- **e** Find the probability that the two letters chosen will be the same.

Remember that this is 'without replacement'.



7 In a quiz, Min guessed that the probability of rolling a sum of 10 or more from two 6-sided dice is 10%. Complete the following to decide whether or not this guess is correct.
- **a** Copy and complete the table representing all the outcomes for possible totals that can be obtained.
- **b** State the total number of outcomes.
- **c** Find the number of the outcomes that represent a sum of:
  - **i** 3 **ii** 7 **iii** less than 7
- **d** Find the probability that the following sums are obtained.
  - **i** 7 **ii** less than 5 **iii** greater than 2 **iv** at least 11
- **e** Find the probability that the sum is at least 10, and decide whether or not Min's guess is correct.

		Die 2					
		1	**2**	**3**	**4**	**5**	**6**
Die 2	**1**	2	3	…			
	2	3	…				
	3	4					
	4	⋮					
	5	⋮					
	6						

8 The 10 students who completed a special flying course are waiting to see if they will be awarded the one Distinction or the one Merit award available for their efforts.
- **a** In how many ways can the two awards be given out if:
  - **i** the same person can receive both awards?
  - **ii** the same person cannot receive both awards?
- **b** Assuming that a person cannot receive both awards, find the probability that a particular person receives:
  - **i** the Distinction award **ii** the Merit award **iii** neither award
- **c** Assuming that a person can receive both awards, find the probability that they receive at least one award.

For part **a**, you might want to start a table but not complete it.

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9 Decide whether the following situations would naturally involve selections with replacement or without replacement.

- **a** Selecting two people to play in a team
- **b** Tossing a coin twice
- **c** Rolling two dice
- **d** Choosing two chocolates to eat

ENRICHMENT		–	10

Random weights

10 In a gym, Justine considers choosing two weights to fit onto a leg weights machine to make the load heavier. She can choose from 2.5 kg, 5 kg, 10 kg or 20 kg, and there are plenty of each weight available. Justine's friend randomly chooses both weights, with equal probability that she will choose each weight, and places them on the machine. Justine then attempts to operate the machine without knowing which weights were chosen.

- **a** Complete a table that displays all possible total weights that could be placed on the machine.
- **b** State the total number of outcomes.
- **c** How many of the outcomes deliver a total weight described by the following?
  - **i** equal to 10 kg
  - **ii** less than 20 kg
  - **iii** at least 20 kg
- **d** Find the probability that Justine will be attempting to lift each of the following weights.
  - **i** 20 kg
  - **ii** 30 kg
  - **iii** no more than 10 kg
  - **iv** less than 10 kg
- **e** If Justine is unable to lift more than 22 kg, what is the probability that she will not be able to operate the leg weights machine?

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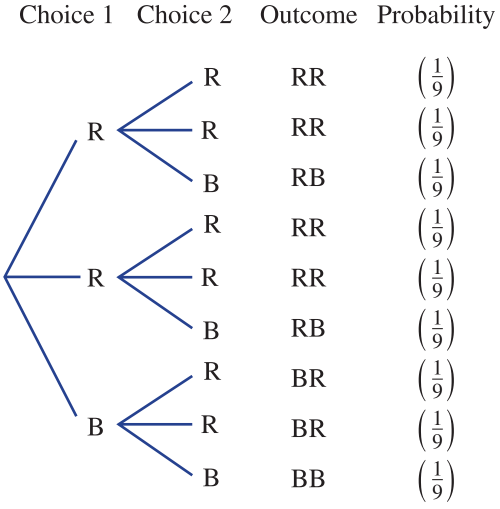
4F Using tree diagrams

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

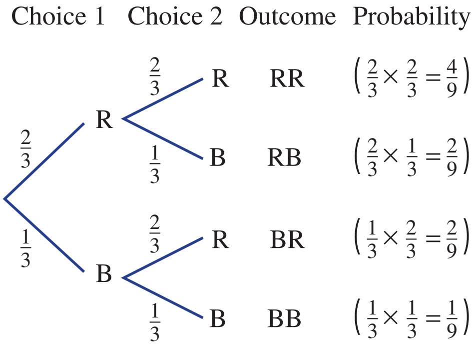
Tree diagrams also can be used to help list outcomes for two-step and three-step experiments. Suppose that a bag contains two red counters and one blue counter and that two counters are selected at random with replacement. One way to display the outcomes is with a tree diagram in which all equally likely outcomes are listed in columns, as shown in *method 1*. A more efficient way, however, is to group similar outcomes and write their corresponding probabilities on the branches, as shown in *method 2*.

Method 1



$P(\text{R, B}) = \frac{2}{9}$

Method 2



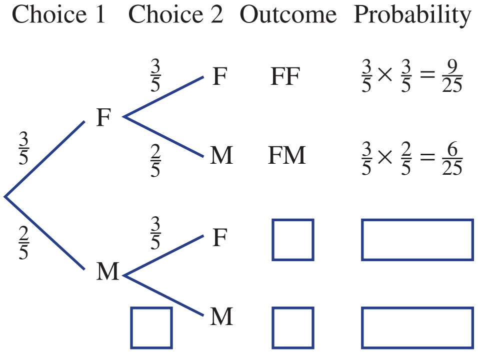
$P(\text{R, B}) = \frac{2}{9}$

In method 2, the probability of each outcome is obtained by multiplying the branch probabilities. This also applies when selection is made without replacement.

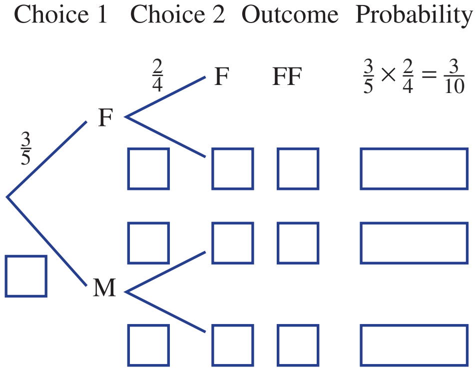
Let's start: Trees with and without replacement

Suppose that two selections are made from a group of 2 male (M) and 3 female (F) workers to complete two extra tasks.

With replacement



Without replacement



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- Complete the two tree diagrams to show how these selections can be made, both with and without replacement.
- Explain where the branch probabilities come from on each branch of the tree diagrams.
- What is the total of all the probabilities on each tree diagram?

Key ideas

- Tree diagrams can be used to list the sample space for experiments involving two, three or more steps.
  - Branch probabilities are used to describe the chance of each outcome at each step.
  - The probability of each outcome for the experiment is obtained by multiplying the branch probabilities.
  - Branch probabilities will depend on whether selection is made with or without replacement. For *experiments with replacement*, probabilities do not change. For *experiments without replacement*, probabilities do change.

Exercise 4F

UNDERSTANDING AND FLUENCY 1–5 3–6

1 A coin is tossed three times and a head or tail is obtained each time.

a How many outcomes are there?

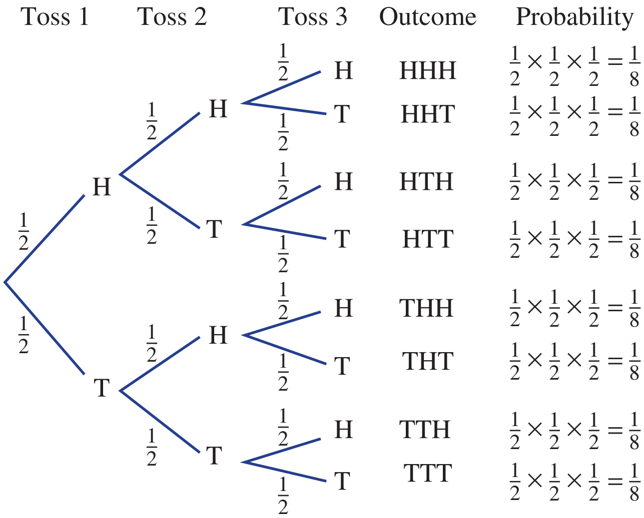
b What is the probability of the outcome HHH?

c How many outcomes obtain:

i 2 tails?

ii 2 or 3 heads?

d What is the probability of obtaining at least one tail?



2 A box contains 2 white (W) and 3 black (B) counters.

a A single counter is drawn at random. Find the probability that it is:

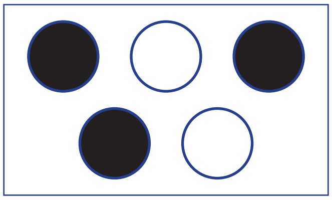
i white **ii** black

b Two counters are now drawn at random. The first one is replaced before the second one is drawn. Find the probability that the second counter is:

i white **ii** black

c Two counters are drawn and the first counter is not replaced before the second one is drawn. If the first counter is white, find the probability that the second counter is:

i white **ii** black



After one white counter is taken out, how many of each remain?

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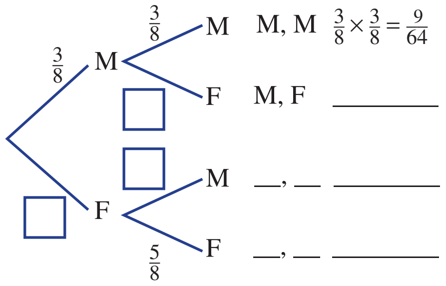
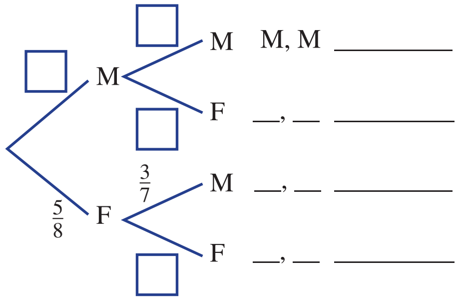
3 Two prizes are awarded to a group of 3 male (M) and 5 female (F) candidates.

Copy and complete each tree diagram. Include the missing branch probabilities and outcome probabilities.

a with replacement



b without replacement



For `without replacement´ the second selection is out of 7, not 8.

Example 10 Constructing a tree diagram for multistage events

Boxes A and B contain 4 counters each. Box A contains 2 red and 2 green counters and box B contains 1 red and 3 green counters. A box is chosen at random and then a single counter is selected.

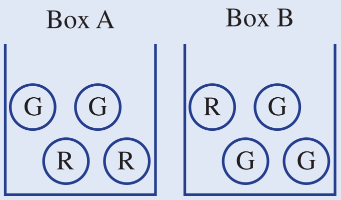
a What is the probability of selecting a red counter from box A?

b What is the probability of selecting a red counter from box B?

c Represent the options available as a tree diagram that shows all possible outcomes and related probabilities.

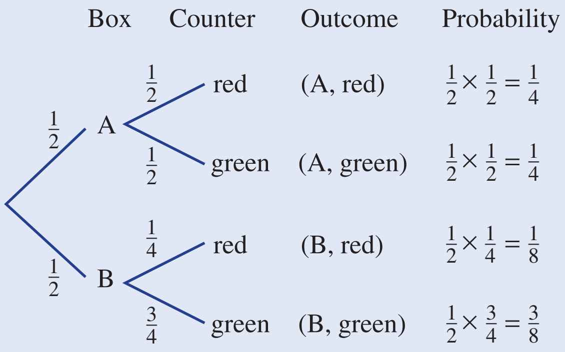
d What is the probability of selecting box B and a red counter?

e What is the probability of selecting a red counter?



SOLUTION	EXPLANATION
a $P(\text{red from box A}) = \frac{2}{4} = \frac{1}{2}$	Two of the 4 counters in box A are red.
b $P(\text{red from box B}) = \frac{1}{4}$	One of the 4 counters in box B is red.

c



First selection is a box followed by a counter.

Multiply each of the probabilities along the branch pathways to find the probability of each outcome.

d $P(\text{B, red}) = \frac{1}{2} \times \frac{1}{4}$

$= \frac{1}{8}$

The probability of choosing box B is $\frac{1}{2}$ and a red counter from box B is $\frac{1}{4}$, so multiply the probabilities for these two outcomes together.

e $P(1 \text{ red}) = \frac{1}{2} \times \frac{1}{2} + \frac{1}{2} \times \frac{1}{4}$

$= \frac{1}{4} + \frac{1}{8}$

$= \frac{3}{8}$

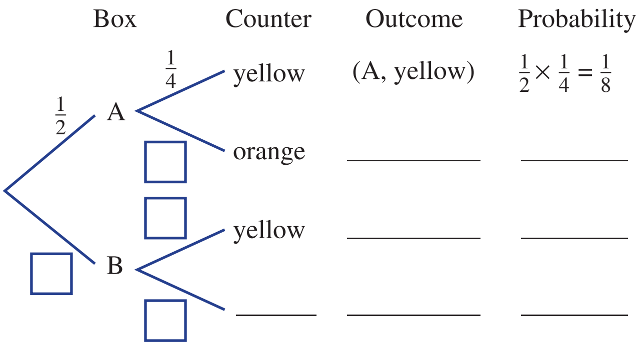
The outcomes (A, red) and (B, red) both contain 1 red counter, so add the probabilities for these two outcomes together.

4 Boxes A and B contain 4 counters each. Box A contains 1 yellow and 3 orange counters and box B contains 3 yellow and 1 orange counter. A box is chosen at random and then a single counter is selected.

a If box A is chosen, what is the probability of selecting a yellow counter?

b If box B is chosen, what is the probability of selecting a yellow counter?

c Represent the options available by completing this tree diagram.



For part **e**, add the probabilities for both outcomes that have a yellow counter.

d What is the probability of selecting box B and a yellow counter?

e What is the probability of selecting 1 yellow counter?

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Example 11 Using a tree diagram without replacement

A bag contains 5 blue (B) and 3 white (W) marbles and two marbles are selected without replacement.

a Draw a tree diagram showing all outcomes and probabilities.

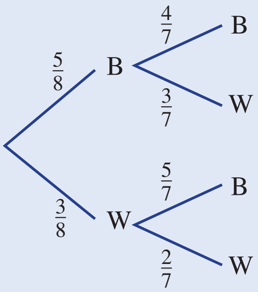
b Find the probability of selecting:

- **i** a blue marble followed by a white marble (B, W)
- **ii** 2 blue marbles
- **iii** exactly one blue marble

c If the experiment was repeated with replacement, find the answers to each question in part **b**.

SOLUTION

a



Selection 1	Selection 2	Outcome	Probability
		(B, B)	$\frac{5}{8}\times\frac{4}{7}=\frac{5}{14}$
		(B, W)	$\frac{5}{8}\times\frac{3}{7}=\frac{15}{56}$
		(W, B)	$\frac{3}{8}\times\frac{5}{7}=\frac{15}{56}$
		(W, W)	$\frac{3}{8}\times\frac{2}{7}=\frac{3}{28}$

After one blue marble is selected there are 7 marbles remaining: 4 blue and 3 white.
After one white marble is selected there are 7 marbles remaining: 5 blue and 2 white.

b **i** $P(\text{B, W})=\frac{5}{8}\times\frac{3}{7}$

$=\frac{15}{56}$

Multiply the probabilities on the (B, W) pathway.

ii $P(\text{B, B})=\frac{5}{\cancel{8}_2}\times\frac{\cancel{4}^1}{7}$

$=\frac{5}{14}$

Only 4 blue marbles remain after the first selection. Multiply the probabilities on the (B, B) pathway.

iii $P(1\text{ blue})=\frac{5}{8}\times\frac{3}{7}+\frac{3}{8}\times\frac{5}{7}$

$=\frac{30}{56}$

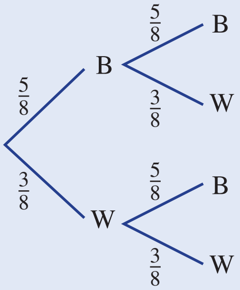
$=\frac{15}{28}$

The outcomes (B, W) and (W, B) both have one blue marble. Multiply probabilities to find individual probabilities, then sum for the final result.

c **i** $P(\text{B, W})=\frac{5}{8}\times\frac{3}{8}$

$=\frac{15}{64}$

When selecting objects with replacement, remember that the number of marbles in the bag remains the same for each selection.



ii $P(\text{B, B})=\frac{5}{8}\times\frac{5}{8}$

$=\frac{25}{64}$

iii $P(1\text{ blue})=\frac{5}{8}\times\frac{3}{8}+\frac{3}{8}\times\frac{5}{8}$

$=\frac{30}{64}=\frac{15}{32}$

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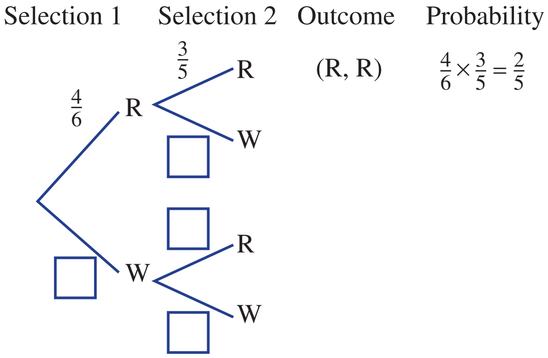
5 A bag contains 4 red (R) and 2 white (W) marbles, and two marbles are selected without replacement.



a Complete this tree diagram showing all outcomes and probabilities.

b Find the probability of selecting:

  i a red marble and then a white marble (R, W)

  ii 2 red marbles

  iii exactly 1 red marble

c If the experiment is repeated with replacement, find the answers to each question in part **b**. You may need to redraw the tree diagram.

6 Two students are selected from a group of 3 males (M) and 4 females (F), without replacement.

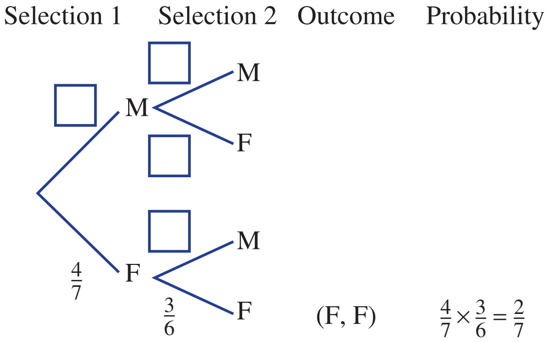
a Complete this tree diagram to help find the probability of selecting:

  i 2 males

  ii 2 females

  iii 1 male and 1 female

  iv 2 people, either both male or both female



b If the experiment is repeated with replacement, find the answers to each question in part **a**.

PROBLEM-SOLVING AND REASONING	7, 8	8, 9

7 A 4-sided die is rolled twice and the pair of numbers is recorded.

a Complete this tree diagram to list the outcomes.

b State the total number of outcomes.

c Find the probability of obtaining:

  i a 4 then a 1; i.e. the outcome (4, 1)

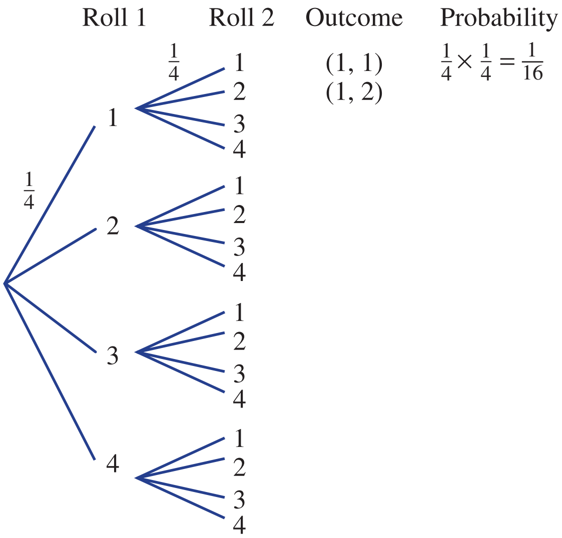
  ii a double

d Find the probability of obtaining a sum described by the following.

  i equal to 2

  ii equal to 5

  iii less than or equal to 5



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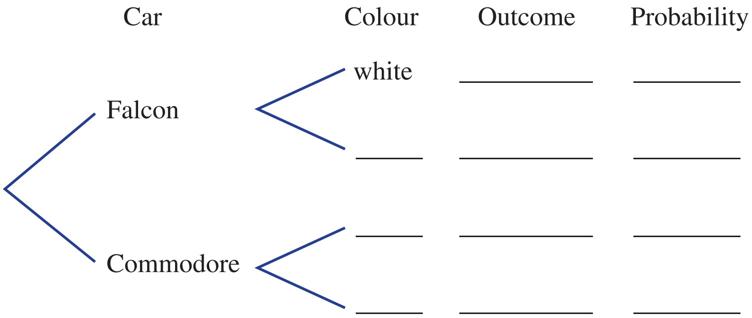
8 As part of a salary package, a person can select either a Falcon or a Commodore. There are 3 white Falcons and 1 silver Falcon and 2 white Commodores and 1 red Commodore to choose from.

a Complete a tree diagram showing a random selection of a car type, then a colour.



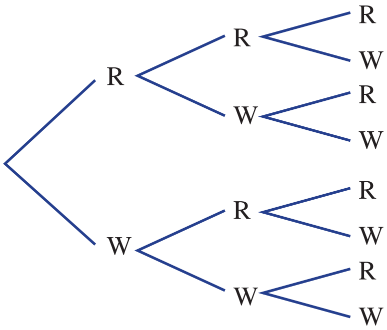
There is an equal chance of choosing a Falcon or a Commodore.

b Find the probability that the person chooses:

- **i** a white Falcon
- **ii** a red Commodore
- **iii** a white car
- **iv** a car that is not white
- **v** a silver car or a white car
- **vi** a car that is not a Falcon nor red

9 A box contains 3 red balls and 3 white balls. Three balls are chosen, without replacement. What is the probability that:

- **a** all 3 balls are red?
- **b** exactly 2 balls are red?
- **c** at least 1 ball is red?



ENRICHMENT – 10

Rainy days

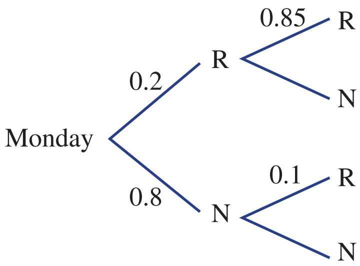
10 Imagine that the probability of rain next Monday is 0.2. The probability of rain on a day after a rainy day is 0.85, and the probability of rain on a day after a non-rainy day is 0.1.

a For next Monday and Tuesday, find the probability of having:

- **i** two rainy days
- **ii** exactly one rainy day
- **iii** at least one dry day

b For next Monday, Tuesday and Wednesday, find the probability of having:

- **i** three rainy days
- **ii** exactly one dry day
- **iii** at most two rainy days



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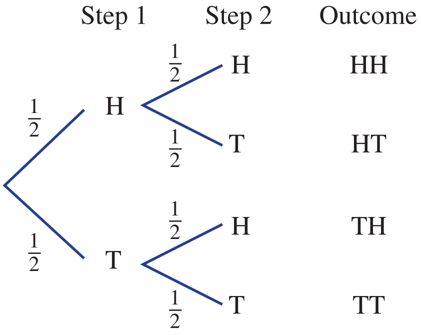
4G Dependent events and independent events

In some two-step experiments, the result in the first step is independent of the result in the second step. This means that the result of the first step has no effect on the probability or outcome of the second step.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Are they independent?

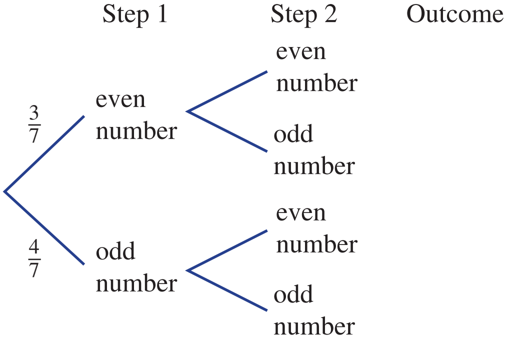
Rachel is tossing a fair coin repeatedly.



Every time she tosses the coin, the probabilities are the same.

- What is the probability of heads on Rachel's first toss?
- What is the probability of heads on Rachel's second toss?
- Is the probability of a head on the second toss affected by the result of the first toss?
- Do you think this means that 'heads on first toss' and 'heads on second toss' are independent events?

Sophie places 7 balls, which are numbered from 1 to 7, into a box and then selects one randomly. She does not replace it before she chooses another.



For each selection the probabilities change.

- What is the probability that the second ball is even if the first ball was:
  - **a** even?
  - **b** odd?
- Are your answers to **a** and **b** different?
- Do you think that the events 'even number on first ball' and 'even number on second ball' are dependent or independent? Why?

Key ideas

- Two events are **independent** if the outcome of the first step does not change the probability of obtaining the other event in the second step.
- For multistage events where selection is made *with* replacement, successive events are independent.
- For multistage events where selection is made *without* replacement, successive events are not independent.
- If a fair coin is tossed many times, the result is always independent of the previous results.

Independent events Two or more events that do not influence or affect each other

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Exercise 4G

UNDERSTANDING AND FLUENCY 1–3, 6 3–6

1 Would these experiments contain independent events? Answer yes or no.

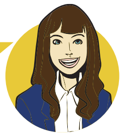
- **a** Rolling a die 3 times
- **b** Choosing 10 jellybeans from a jar, one at a time, and eating them.
- **c** Choosing 5 cards from a standard deck and removing them
- **d** Tossing a coin 3 times
- **e** Tossing a coin and rolling a die

Is the probability the same each time?

2 Complete each sentence.

- **a** For multistage events, successive events are independent if selections are made _____________ replacement.
- **b** For multistage events, successive events are not independent if selections are made _____________ replacement.

Choose from 'with' or 'without'.



Example 12 Deciding whether events are independent

Decide whether the following events A and B are independent.

- **a** A die is rolled twice. Let A be the event 'rolling a 6 on the first roll' and let B be the event 'rolling a 3 on the second roll'.
- **b** Two playing cards are randomly selected from a standard deck, without replacement. Let A be the event 'the first card is a heart' and let B be the event 'the second card is a heart'.

SOLUTION	EXPLANATION
a Yes, events A and B are independent.	The outcome of the first roll of the die does not affect the outcome of the second roll.
b No, events A and B are not independent.	The type of card selected first affects the probability of selecting a heart when choosing the second card.

3 A coin is tossed twice. Let A be the event 'the first toss gives a tail'. Let B be the event 'the second toss gives a tail'.
Are A and B independent events?

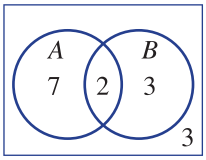
4 **a** Kathryn tossed a fair coin and it showed heads. What is the probability that the coin shows heads on the next toss?

b Felix tossed heads six times in a row. What is the probability that the next toss shows heads?

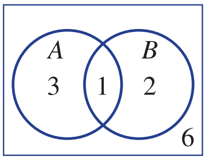
If $P(A) = P(A|B)$ then event B has no effect on event A, so A and B are independent.

5 For each Venn diagram below, find $P(A)$ and $P(A|B)$ and use your results to determine whether or not events A and B are independent.

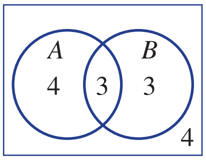
a



b



c



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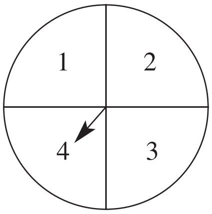
6 **a** What is the probability of tossing heads three times in a row?

b On the spinner shown, what is the probability of spinning a 4 three times in a row?



Looking at the relevant part of a tree diagram may help.

c What is the probability of rolling the number 2 on a die three times in a row?

PROBLEM-SOLVING AND REASONING	7	7, 8

7 The company that manufactures a popular ice-cream is running a promotion. The company claims that 1 in 6 of its ice-creams contains a stick that gives the owner a free ice-cream.

a Tilly says: “I am going to buy 6 ice-creams. One of them will definitely be a winner.” Discuss the validity of Tilly’s statement.

b Cody says: “I bought 5 ice-creams last week and none of them were winners, so there is a really high chance that the next one will be a winner.” Is he correct?

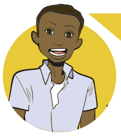
c Lucy says: “I bought 6 ice-creams last week and all of them were winners.” Is this possible?

8 A coin is tossed 5 times. Find the probability of obtaining:

a 5 heads

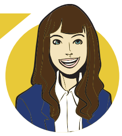
b at least one tail

c at least one head



Coin tosses are independent. From two coins, the probability of two heads is $\frac{1}{2} \times \frac{1}{2}$.

‘At least one tail’ includes all cases except 5 heads.



ENRICHMENT	–	9

Roll a 6, then stop rolling

9 In some games, you must roll a 6 before you can start moving on the board. Try rolling a die and count how many rolls you need to roll a 6. What is the probability that:

a it happens on the first roll?

b you need 2 rolls?

c you need 1, 2, 3 or 4 rolls?

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Puzzles and challenges

1 'I have nothing in common.' Match the answers to the letters in parts **a** and **b** to to uncover the code.

$\frac{5}{14}$	5	2	5	7	10	10	$\frac{7}{11}$

$\frac{5}{11}$	$\frac{3}{14}$	$\frac{1}{2}$	10	5	$\frac{10}{11}$	$\frac{1}{7}$	3	$\frac{5}{11}$

a These questions relate to the Venn diagram at right.

$\boxed{\text{T}}$ How many elements are in *A* and *B*?

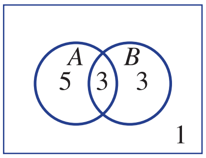
$\boxed{\text{L}}$ How many elements are in *A* or *B*?

$\boxed{\text{V}}$ How many elements are in *B* only?

$\boxed{\text{Y}}$ Find $P(A)$.

$\boxed{\text{S}}$ Find $P(A \text{ or } B)$.

$\boxed{\text{E}}$ Find $P(A \text{ only})$.



b These questions relate to the two-way table at right.

$\boxed{\text{U}}$ What number should be in place of the letter U?

$\boxed{\text{A}}$ What number should be in place of the letter A?

$\boxed{\text{M}}$ Find $P(\text{P and Q})$.

$\boxed{\text{C}}$ Find $P(\text{not P})$.

$\boxed{\text{X}}$ Find $P(\text{neither P nor Q})$.

$\boxed{\text{I}}$ Find $P(\text{P only})$.

	P	**not *P***	**Total**
Q	U	4	9
not *Q*	2		
Total		A	14

2 What is the chance of rolling a sum of at least 10 from rolling two 6-sided dice?

3 *Game* for *two people*: You will need a bag or pocket and coloured counters.

- One person places 8 counters of 3 different colours in a bag or pocket. The second person must not look!
- The second person then selects a counter from the bag. The colour is noted, then the counter is returned to the bag. This is repeated 100 times.
- Complete this table.

Colour	**Tally**	**Frequency**	**Guess**
Total:	100	100	

- Using the experimental results, the second person now tries to guess how many counters of each colour are in the bag.

4 Two digits are chosen without replacement from the set $\{1, 2, 3, 4\}$, to form a two-digit number. Find the probability that the two-digit number is:

a 32

b even

c less than 40

d at least 22

5 Two leadership positions are to be filled from a group of two girls and three boys. What is the probability that the positions will be filled by one girl and one boy?

6 The letters of the word DOOR are jumbled randomly. What is the probability that the final arrangement will spell DOOR?

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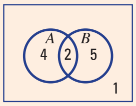
Chapter summary

Probability

Review

- Sample space is the list of all possible outcomes
- $P(\text{event}) = \frac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$

Venn diagram

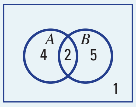


Two-way table

	A	not A	Total
B	2	5	7
not B	4	1	5
Total	6	6	12

Conditional probability

$$P(A \mid B) = \frac{\text{number in } A \text{ and } B}{\text{number in } B}$$



$$P(A \mid B) = \frac{2}{7}$$

$$P(B \mid A) = \frac{2}{6} = \frac{1}{3}$$

Independent events

Multistage events are independent if the result of the first step does not change the probabilities of the steps that follow. For experiments *with replacement*, successive events are independent. For experiments *without replacement*, successive events are not independent.

Arrays

With replacement

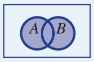
	A	B	C
A	(A, A)	(B, A)	(C, A)
B	(A, B)	(B, B)	(C, B)
C	(A, C)	(B, C)	(C, C)

Without replacement

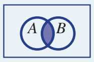
	A	B	C
A	×	(B, A)	(C, A)
B	(A, B)	×	(C, B)
C	(A, C)	(B, C)	×

Notation

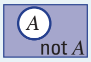
- A or B



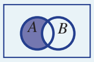
- A and B



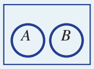
- Complement of A is not A.



- A only



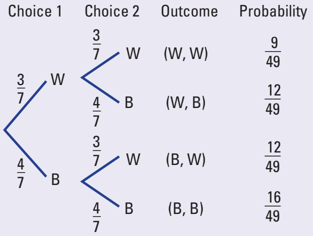
- Mutually exclusive events



Tree diagrams

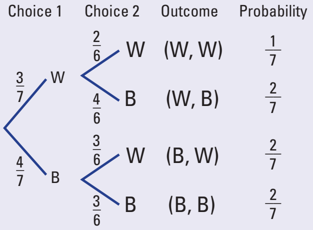
3 white
4 black

With replacement



$$P(\text{W, B}) = \frac{3}{7} \times \frac{4}{7}$$
$$= \frac{12}{49}$$

Without replacement



$$P(\text{one white}) = \frac{2}{7} + \frac{2}{7}$$
$$= \frac{4}{7}$$

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Multiple-choice questions

1 A letter is chosen from the word SUCCESS. The probability that the letter is not a C is:

A $\frac{2}{7}$ **B** $\frac{3}{5}$ **C** $\frac{5}{7}$ **D** $\frac{4}{7}$ **E** $\frac{3}{7}$

2 The number of manufacturing errors spotted in a car plant on 20 days is given by this table.

Number of errors	0	1	2	3	Total
Frequency	11	6	2	1	20

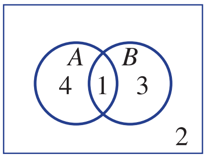
An estimate of the probability that on the next day no errors will be observed is:

A $\frac{3}{10}$ **B** $\frac{9}{20}$ **C** $\frac{11}{20}$ **D** $\frac{17}{20}$ **E** $\frac{3}{20}$

3 For this Venn diagram, $P(A \text{ or } B)$ is equal to:

A $\frac{4}{5}$ **B** $\frac{1}{2}$ **C** $\frac{5}{8}$

D $\frac{1}{4}$ **E** $\frac{1}{10}$



4 15 people like apples or bananas. Of those 15 people, 10 like apples and 3 like both apples and bananas. How many like only apples?

A 5 **B** 3 **C** 13 **D** 7 **E** 10

5 A letter is chosen from each of the words CAN and TOO.
The probability that the pair of letters will not have an O is:

A $\frac{2}{3}$ **B** $\frac{1}{2}$ **C** $\frac{1}{3}$

D $\frac{1}{9}$ **E** $\frac{5}{9}$

	C	A	N
T	(C, T)	(A, T)	(N, T)
O	(C, O)	(A, O)	(N, O)
O	(C, O)	(A, O)	(N, O)

6 The sets A and B are known to be mutually exclusive. Which of the following is therefore true?

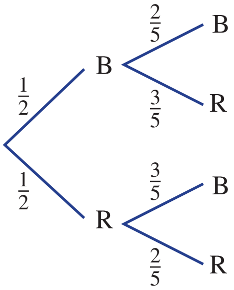
A $P(A) = P(B)$ **B** $P(A \text{ and } B) = 0$ **C** $P(A) = 0$

D $P(A \text{ and } B) = 1$ **E** $P(A \text{ or } B) = 0$

7 For this tree diagram, what is the probability of the outcome (B, R)?

A $\frac{1}{5}$ **B** $\frac{3}{10}$ **C** $\frac{3}{7}$

D $\frac{1}{10}$ **E** $\frac{6}{11}$



8 For this two-way table, $P(A \text{ and } B)$ is:

A $\frac{2}{3}$ **B** $\frac{1}{4}$ **C** $\frac{1}{7}$

D $\frac{1}{3}$ **E** $\frac{2}{7}$

	A	not *A*	Total
B		1	3
not *B*			4
Total		4	

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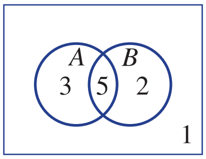
9 For this Venn diagram, $P(A|B)$ is:



A $\frac{5}{7}$ **B** $\frac{5}{2}$ **C** $\frac{5}{8}$ **D** $\frac{5}{3}$ **E** $\frac{3}{11}$

Short-answer questions

1 A 6-sided die is rolled once. Find:

a $P(4)$

b $P(\text{even})$

c $P(\text{at least } 3)$

2 A letter is chosen from the word INTEREST. Find the probability that the letter will be:

a I

b E

c a vowel

d not a vowel

e E or T

3 An engineer inspects 20 houses in a street for cracks. The results are summarised in this table.

Number of cracks	0	1	2	3	4
Frequency	8	5	4	2	1

a From these results, estimate the probability that the next house inspected in the street will have the following number of cracks:

i 0 **ii** 1 **iii** 2 **iv** 3 **v** 4

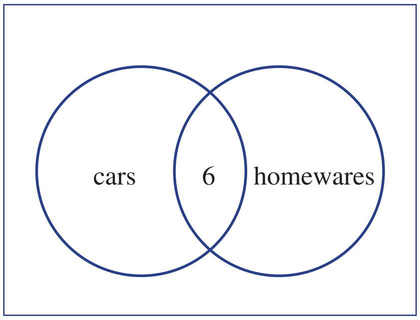
b Estimate the probability that the next house will have:

i at least 1 crack

ii no more than 2 cracks

4 Of 36 people, 18 have an interest in cars (C), 11 have an interest in homewares (H) and 6 have an interest in both cars and homewares.

a Complete this Venn diagram.



b Complete this two-way table.

	C	**not C**	**Total**
H	6		
not H			
Total			

c State the number of people who do not have an interest in either cars or homewares.

d If a person is chosen at random from the group, find the probability that the person will:

i have an interest in cars and homewares

ii have an interest in homewares only

iii not have any interest in cars

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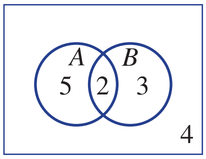
5 All 26 birds in a bird cage have clipped wings and/or a tag. In total, 18 birds have tags, 14 have clipped wings and 6 have both clipped wings and a tag.

a Find the number of birds that have only clipped wings.

b Find the probability that a bird chosen at random will have a tag only.

6 For these probability diagrams, find $P(A|B)$.

a



b

	A	not A	Total
B	1	4	5
not B	2	2	4
Total	3	6	9

7 A letter is chosen at random from the word HAPPY and a second letter is chosen from the word HEY.

a List the sample space by completing this table.

b State the total number of outcomes.

c Find the probability that the two letters chosen will be:

- **i** H then E
- **ii** the same
- **iii** not the same

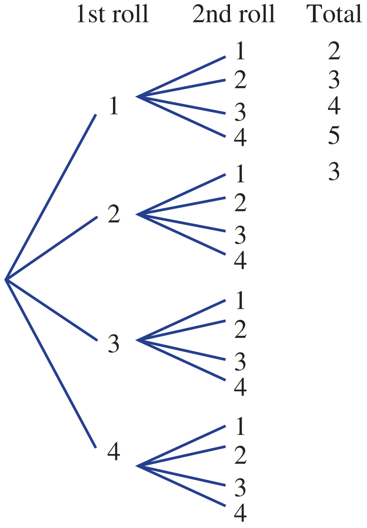
	H	A	P	P	Y
H	(H, H)	(A, H)	(P, H)		
E					
Y					

8 A 4-sided die is rolled twice and the total is noted.

a Complete this tree diagram to list the sample space.

b Find these probabilities.

- **i** $P(2)$
- **ii** $P(5)$
- **iii** $P(1)$
- **iv** $P(\text{not } 1)$



9 Two people are selected from a group of 2 females and 3 males without replacement. Use a tree diagram to find the probability of selecting:

a a female on the first selection

b a male on the second selection given that a female was chosen on the first selection

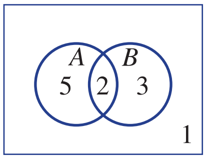
c 2 males

d 1 male

e at least 1 female

10 For each diagram, find $P(A)$ and $P(A|B)$, then decide if events A and B are independent.

a

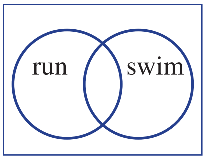


b

	A	not A	Total
B	3		6
not B			
Total	5		10

Extended-response questions

1 Of 15 people surveyed to find out if they run or swim for exercise, 6 said they run, 4 said they swim and 3 said they both run and swim.



- **a** How many people neither run nor swim?
- **b** One of the 15 people is selected at random. Find the probability that they:
  - **i** run or swim
  - **ii** only swim
- **c** Represent the information in a two-way table.
- **d** Find the probability that:
  - **i** a survey participant swims, given that they run
  - **ii** a survey participant runs, given that they swim

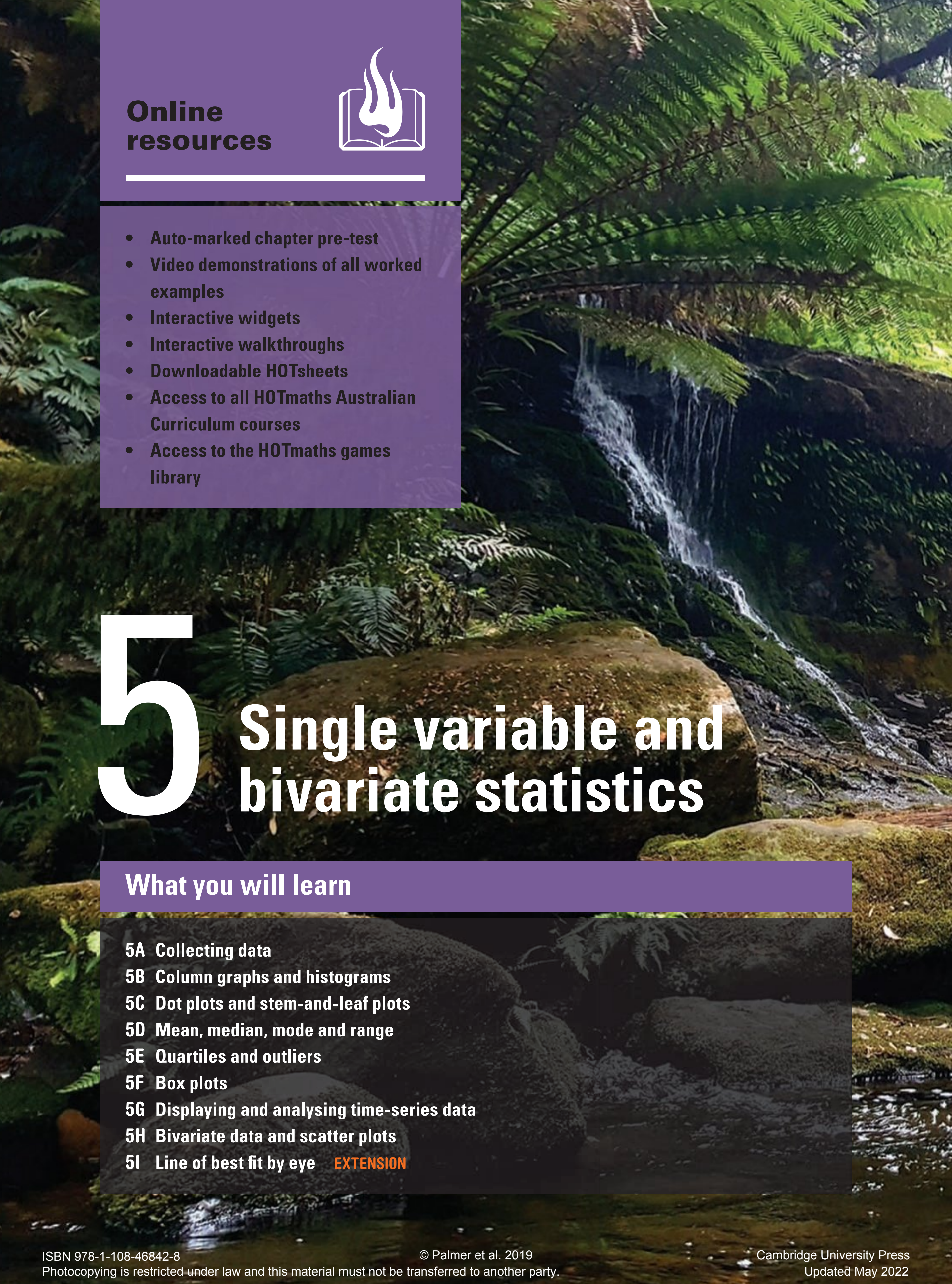
2 A bakery sells three types of bread: raisin (R) at \$2 each, sourdough (S) at \$3 each, and white (W) at \$1.50 each. Judy is in a hurry. She randomly selects 2 loaves and quickly takes them to the counter. (Assume an unlimited loaf supply.)

		1st		
		R	S	W
2nd	R	(R, R)	(S, R)	(W, R)
	S			
	W			

- **a** Complete this table showing the possible combination of loaves that Judy could have selected.
- **b** Find the probability that Judy selects:
  - **i** 2 raisin loaves
  - **ii** 2 loaves that are the same
  - **iii** at least 1 white loaf
  - **iv** not a sourdough loaf

Judy has only \$4 in her purse.

- **c** How many different combinations of bread will Judy be able to afford?
- **d** Find the probability that Judy will not be able to afford her two chosen loaves.



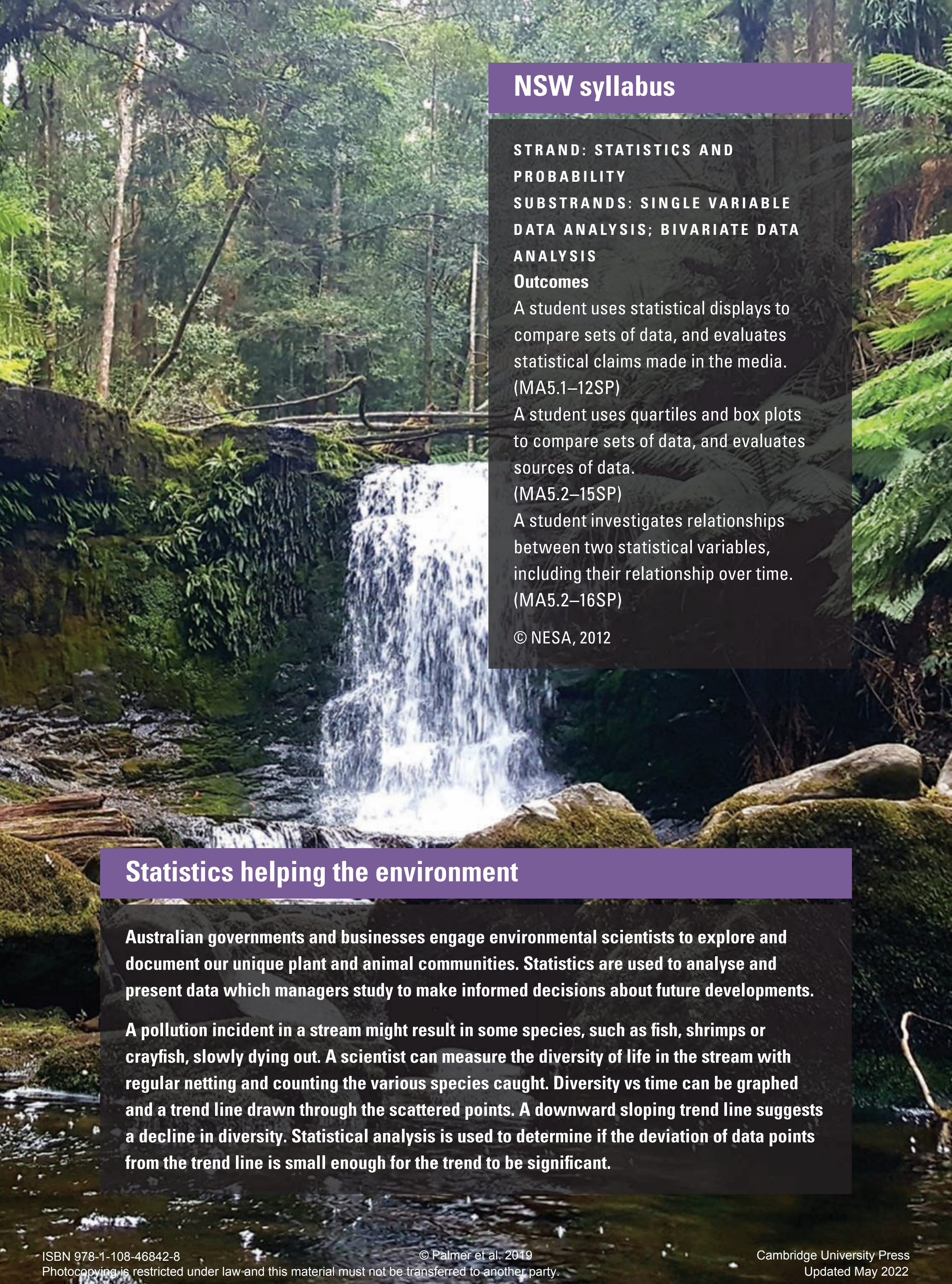
Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

5

Single variable and bivariate statistics

What you will learn



NSW syllabus

STRAND: STATISTICS AND PROBABILITY

SUBSTRANDS: SINGLE VARIABLE DATA ANALYSIS; BIVARIATE DATA ANALYSIS

Outcomes

A student uses statistical displays to compare sets of data, and evaluates statistical claims made in the media.
(MA5.1–12SP)

A student uses quartiles and box plots to compare sets of data, and evaluates sources of data.
(MA5.2–15SP)

A student investigates relationships between two statistical variables, including their relationship over time.
(MA5.2–16SP)

Statistics helping the environment

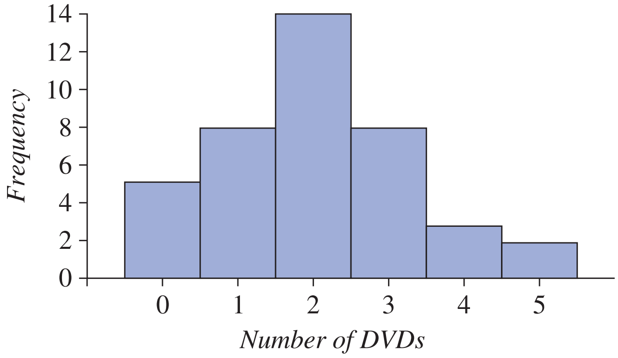
Australian governments and businesses engage environmental scientists to explore and document our unique plant and animal communities. Statistics are used to analyse and present data which managers study to make informed decisions about future developments.

A pollution incident in a stream might result in some species, such as fish, shrimps or crayfish, slowly dying out. A scientist can measure the diversity of life in the stream with regular netting and counting the various species caught. Diversity vs time can be graphed and a trend line drawn through the scattered points. A downward sloping trend line suggests a decline in diversity. Statistical analysis is used to determine if the deviation of data points from the trend line is small enough for the trend to be significant.

1 Below is a list of statistical tools and a list of diagrams. Match each tool (**a**–**r**) with the most appropriate diagram (**A**–**R**).

a frequency distribution table
b dot plot
c stem-and-leaf plot
d sector graph (pie chart)
e divided bar graph
f column graph
g histogram
h box plot
i time-series graph
j mean
k median
l mode
m lower quartile and upper quartile
n minimum and maximum
o range
p interquartile range
q symmetrical data
r bimodal data

A



B $\dfrac{\text{sum of all data values}}{\text{number of data values}}$

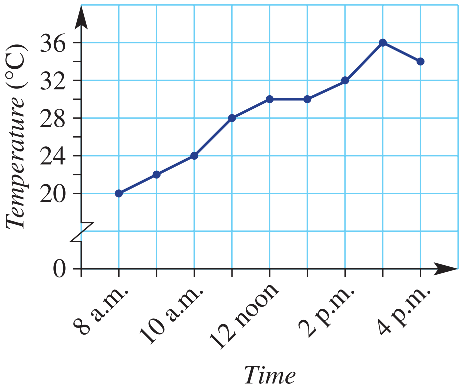
C 1, 1, 2, 2, 3, 3, ④, 4, 4, 5, 6, 7, 18

D $\boxed{5}$ 8 10 15 20 12 10 $\boxed{50}$

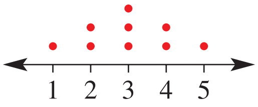
E $\boxed{5}$ 8 10 15 20 12 10 $\boxed{50}$

$50 - 5 = 45$

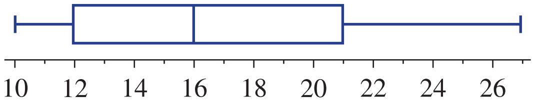
F



G



H



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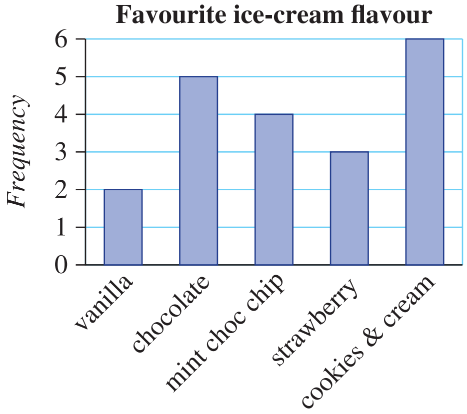
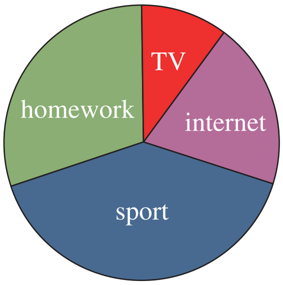
I



J

Interval	Frequency	Percentage frequency
0–4	3	15
5–9	7	35
10–14	6	30
15–19	4	20
Total	20	100

K



L

M 4 5 $\boxed{3}$ 6 4 $\boxed{3}$ $\boxed{3}$

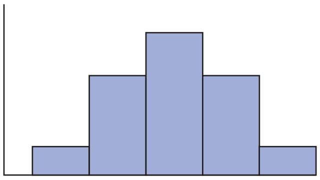
N 3, $\boxed{15}$, $\boxed{12}$, 9, $\boxed{12}$, $\boxed{15}$, 6, 8

O $10 \quad 11 \quad \textcircled{12} \quad 14 \quad \underbrace{15 \mid 17} \quad 18 \quad \textcircled{21} \quad 26 \quad 27$

P $10 \quad 11 \quad \textcircled{12} \quad 14 \quad \underbrace{15 \mid 17} \quad 18 \quad \textcircled{21} \quad 26 \quad 27$

$21 - 12 = 9$

Q

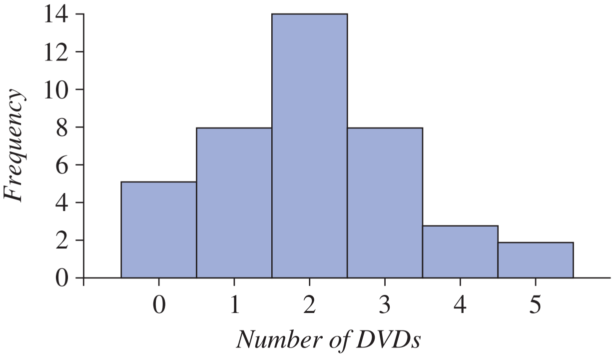


R

Stem	Leaf
9	8
10	2 6
11	1 1 4 9
12	3 6
13	8 9 9
14	0 2 5

2 The number of DVDs rented per person at a store is shown in this graph.

- **a** How many customers rented three DVDs?
- **b** How many customers were surveyed?
- **c** How many DVDs were rented during the survey?
- **d** How many customers rented fewer than two DVDs?



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3 This table shows the frequency of scores in a test.

Score	Frequency
0–19	2
20–39	3
40–59	6
60–79	12
80–100	7

a How many scores were in the 40 to less than 60 range?

b How many scores were:

  i at least 60?

  ii less than 80?

c How many scores were there in total?

d What percentage of scores were in the 20 to less than 40 range?

4 Calculate:

a $\frac{6+10}{2}$

b $\frac{8+9}{2}$

c $\frac{2+4+5+9}{4}$

d $\frac{3+5+8+10+14}{5}$

5 For each of these data sets, find:

  i the mean (i.e. by dividing the sum by the number of scores)

  ii the mode (most frequent)

  iii the median (middle value of ordered data)

  iv the range (difference between highest and lowest)

a 38, 41, 41, 47, 58

b 2, 2, 2, 4, 6, 6, 7, 9, 10, 12

6 This stem-and-leaf plot shows the weight, in grams, of some small calculators.

a How many calculators are represented in the plot?

b What is the mode (most frequent)?

c What is the minimum calculator weight and maximum weight?

d Find the range (i.e. maximum value – minimum value).

Stem	Leaf
9	8
10	2 6
11	1 1 4 9
12	3 6
13	8 9 9
14	0 2 5

13 | 6 means 136 grams

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5A Collecting data

Interactive
Widgets
HOTsheets
Walkthrough

A statistician is a person who is employed to design surveys. They also collect, analyse and interpret data. They assist the government, companies and other organisations to make decisions and plan for the future.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Statisticians:

- **Formulate** and **refine** questions for a survey.
- Choose some **subjects** (i.e. people) to complete the survey.
- **Collect** the data.
- **Organise and display** the data using the most appropriate graphs and tables.
- **Analyse** the data.
- **Interpret the data** and draw conclusions.

There are many reports in the media that begin with the words 'A recent study has found that…'. These are usually the result of a survey or investigation that a researcher has conducted to collect information about an important issue, such as unemployment, crime or obesity.

Let's start: Critiquing survey questions

Here is a short survey. It is not very well constructed.

Question 1: How old are you?

Question 2: How much time did you spend sitting in front of the television or a computer yesterday?

Question 3: Some people say that teenagers like you are lazy and spend too much time sitting around when you should be outside exercising. What do you think of that comment?

Have a class discussion about the following.

- What will the answers to Question 1 look like? How could they be displayed?
- What will the answers to Question 2 look like? How could they be displayed?
- Is Question 2 going to give a realistic picture of your normal daily activity?
- How could Question 2 be improved?
- What will the answers to Question 3 look like? How could they be displayed?
- How could Question 3 be improved?

Key ideas

- Surveys are used to collect statistical data.
- Survey questions need to be constructed carefully so that the person knows exactly what sort of answer to give. They should use simple language and should not be ambiguous.
- Survey questions should not be worded so that they deliberately try to provoke a certain kind of response.
- Surveys should respect the privacy of the people being surveyed.

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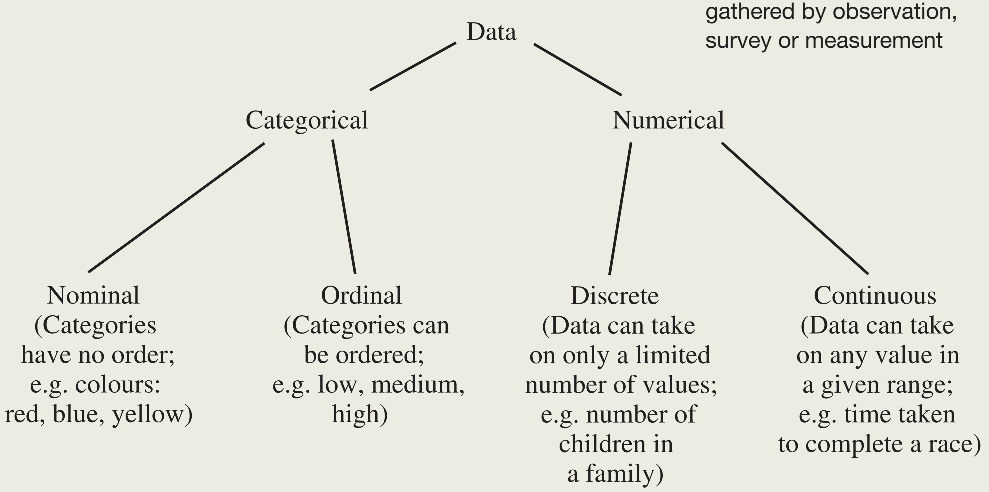
Key ideas

- If the question contains an option to be chosen from a list, the number of options should be an odd number, so that there is a ‘neutral’ choice. For example, the options could be:

strongly disagree	disagree	unsure	agree	strongly agree

- A *population* is a group of people, animals or objects with something in common. Some examples of populations are:
  - all the people in Australia on Census night
  - all the students in your school
  - all the boys in your Maths class
  - all the tigers in the wild in Sumatra
  - all the cars in Sydney
  - all the wheat farms in NSW
- A *sample* is a group that has been chosen from a population. Sometimes information from a sample is used to describe the whole population, so it is important to choose the sample carefully.
- If information is collected from a sample of a population so that some members are less likely to be included, then the sample is thought to be biased.
- **Statistical data** can be categorised as follows.

Statistical data Information gathered by observation, survey or measurement



Exercise 5A

UNDERSTANDING AND FLUENCY		1–6	2–7

1 A popular Australian ‘current affairs’ television show recently investigated the issue of spelling. They suspected that people in their twenties are not as good at spelling as people in their fifties, so they decided to conduct a statistical investigation. They chose a sample of 12 people aged 50–59 years and 12 people aged 20–29 years.

Answer the following questions on paper, then discuss in a small group or as a whole class.

a Do you think that the number of people surveyed is enough?

b How many people do you think there are in Australia aged 20–29 years?

c How many people do you think there are in Australia aged 50–59 years?
d Use the website of the Australian Bureau of Statistics to look up the answers to parts **b** and **c**.
e Do you think it is fair and reasonable to compare the spelling ability of these two groups of people?
f How would you go about comparing the spelling ability of these two groups of people?
g Would you give the two groups the same set of words to spell?
h How could you give the younger people an unfair advantage?
i What sorts of words would you include in a spelling test for the survey?
j How and where would you choose the people to do the spelling test?

2 Match each word (**a**–**h**) with its definition (**A**–**H**).

a population
b census
c sample
d survey
e data
f variable
g statistics
h confidentiality

A a group chosen from a population
B a tool used to collect statistical data
C the state of being secret
D an element or feature that can vary
E all the people or objects in question
F statistics collected from an entire population
G the practise of collecting and analysing data
H the factual information collected from a survey or other source

3 Match each word (**a**–**f**) with its definition (**A**–**F**).

a numerical
b continuous
c discrete
d categorical
e ordinal
f nominal

A categorical data that has no order
B data that are numbers
C numerical data that take on a limited number of values
D data that can be divided into categories
E numerical data that take any value in a given range
F categorical data that can be ordered

Example 1 Describing types of data

What type of data would the following survey questions generate?
a How many televisions do you have in your home?
b To what type of music do you most like to listen?

SOLUTION	EXPLANATION
a numerical and discrete	The answer to the question is a number with a limited number of values; in this case, a whole number.
b categorical and nominal	The answer is a type of music and these categories have no order.

4 Which one of the following survey questions would generate numerical data?
A What is your favourite colour?
B What type of car does your family own?
C How long does it take for you to travel to school?
D What type of dog do you own?

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5 Which one of the following survey questions would generate categorical data?

A How many times do you eat at your favourite fast-food place in a typical week?

B How much do you usually spend buying your favourite fast food?

C How many items did you buy last time you went to your favourite fast-food place?

D Which is your favourite fast food?

6 Year 10 students were asked the following questions in a survey. Describe what type of data each question generates.

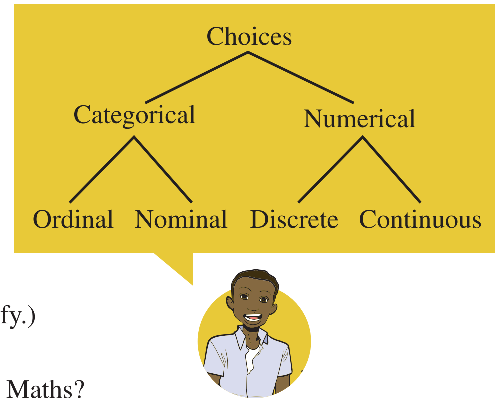
a How many people under the age of 18 years are there in your immediate family?

b How many letters are there in your first name?

c Which company is the carrier of your mobile telephone calls?
Optus/Telstra/Vodafone/3/Virgin/Other (Please specify.)

d What is your height?

e How would you describe your level of application in Maths? (Choose from very high, high, medium or low.)



7 Every student in Years 7 to 12 votes in the prefect elections. The election process is an example of:

A a population.

B continuous data.

C a representative sample.

D a census.

PROBLEM-SOLVING AND REASONING	8, 9	9–11

8 TV ‘ratings’ are used to determine the shows that are the most popular. Every week some households are chosen at random and a device is attached to their television. The device keeps track of the shows the households are watching during the week.

The company that chooses the households should always attempt to find:
A a census.
B continuous data.
C a representative sample.
D ungrouped data.

9 The principal decides to survey Year 10 students to determine their opinion of Mathematics. In order to increase the chance of choosing a representative sample, the principal should:
A give a survey form to the first 30 Year 10 students who arrive at school.
B give a survey form to all the students studying the most advanced maths subject.
C give a survey form to five students in every Maths class.
D give a survey form to 20% of the students in every class.

10 Discuss some of the problems with the selection of a survey sample for each given topic.
a A survey at the train station of how Australians get to work.
b An email survey on people’s use of computers.
c Phoning people on the electoral roll to determine Australia’s favourite sport.

11 Choose a topic in which you are especially interested, such as football, cricket, movies, music, cooking, food, computer games or social media.

Make up a survey about your topic that you could give to the students in your class. It must have *four* questions.

Question 1 must produce data that are categorical and ordinal.
Question 2 must produce data that are categorical and nominal.
Question 3 must produce data that are numerical and discrete.
Question 4 must produce data that are numerical and continuous.

ENRICHMENT	–	12

The 2016 Australian Census

12 Research the 2016 Australian Census on the website of the Australian Bureau of Statistics. Find out something interesting from the results of the 2016 Australian Census.

Write a short news report or record a 3-minute news report on your computer.

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5B Column graphs and histograms

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Data can be collected in a number of ways, including surveys, experiments, recording the performance of a sportsperson or just counting. As a simple list, data can be difficult to interpret. Sorting the data into a frequency table allows us to make sense of it and draw conclusions from it.

Statistical graphs are an essential part of the analysis and representation of data. By looking at statistical graphs, we can draw conclusions about the numbers or categories in the data set.

Let's start: A packet of Smarties

Smarties are sold in small packets.

- How many Smarties would you expect to find in one packet?
- Would you expect every packet to contain the same number of Smarties?
- How many different colours would you expect to find in your packet?

Consider these photos of the Smarties found in one packet.

- Which of the following tools could be used to display and analyse the data produced by the question: What are the colours of the Smarties in your packet?
  A frequency distribution table
  B dot plot
  C stem-and-leaf plot
  D sector graph (pie chart)
  E divided bar graph
  F column graph
  G histogram
  H mean
  I median
  J mode
  K range
- Open a small packet of Smarties and use some of the tools listed above to analyse its contents. Compare your results with your initial expectations.

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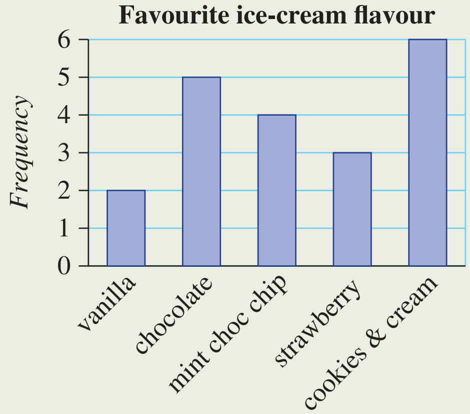
- A **frequency table** displays data by showing the number of values within a set of categories or class intervals. It may include a tally column to help count the data.

Favourite ice-cream flavour	Tally	Frequency
vanilla	||	2
chocolate	卌	5
mint choc chip	||||	4
strawberry	|||	3
cookies and cream	卌 |	6

Frequency table A table showing all possible scores in one column and the frequency of each score in another column

- A **column graph** can be used for a single set of categorical or discrete data.



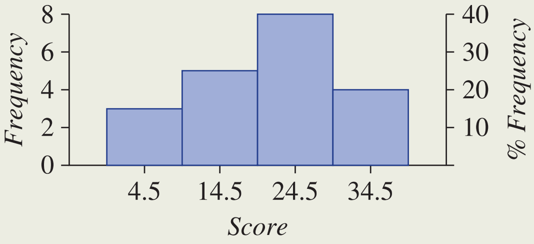
Column graph A graphical representation of a single set of categorical or discrete data, where columns are used to show the frequency of scores

- **Histograms** can be used for grouped discrete or continuous numerical data. The frequency of particular class intervals is recorded.
  - In the following tables, the interval 10 – 19 includes all numbers from 10 (including 10) to less than 20.
  - The percentage frequency is calculated as

$$\% \text{Frequency} = \frac{\text{frequency}}{\text{total}} \times 100\%.$$

Histogram A special type of column graph with no gaps between the columns; it can represent class intervals

Class interval	Frequency	Percentage frequency
1–9	3	$\frac{3}{20} \times 100 = 15\%$
10–19	5	$\frac{5}{20} \times 100 = 25\%$
20–29	8	40%
30–39	4	20%
Total	20	100%



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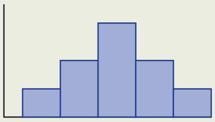
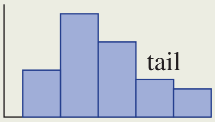
Key ideas

- Data can be symmetrical or skewed.

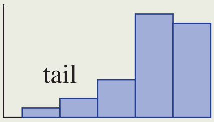
Symmetrical



Positively skewed



Negatively skewed



Exercise 5B

UNDERSTANDING AND FLUENCY

1–4 3–6

1 Classify each set of data as categorical or numerical.

- **a** 4.7, 3.8, 1.6, 9.2, 4.8
- **b** red, blue, yellow, green, blue, red
- **c** low, medium, high, low, low, medium
- **d** 3 g, 7 g, 8 g, 7 g, 4 g, 1 g, 10 g

2 Complete these frequency tables.

a

Car colour	Tally	Frequency
red	|||	
white	卌	
green	||	
silver	||	
Total		

In this tally, 卌 is 5.

b

Class interval	Frequency	Percentage frequency
80–84	8	$\frac{8}{50} \times 100 = 16\%$
85–89	23	
90–94	13	
95–100		
Total	**50**	

Example 2 Constructing a frequency table and column graph

Twenty people checking out of a hotel were surveyed on the level of service provided by the hotel staff. The results were:

poor	first class	poor	average	good
good	average	good	first class	first class
good	good	first class	good	average
average	good	poor	first class	good

- **a** Construct a frequency table to record the data, with headings Category, Tally and Frequency.
- **b** Construct a column graph for the data.

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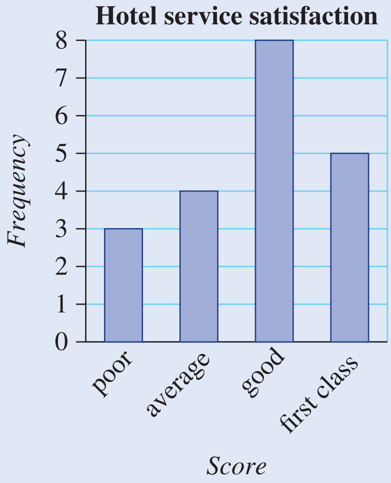
SOLUTION

a

Category	Tally	Frequency
Poor	|||	3
Average	||||	4
Good	𝍸 |||	8
First class	𝍸	5
Total	20	20

b



EXPLANATION

Construct a table with the headings Category, Tally, Frequency.

Fill in each category shown in the data. Work through the data in order, recording a tally mark (|) next to the category. It is a good idea to tick the data as you go, to keep track.

On the 5th occurrence of a category, place a diagonal line through the tally marks (𝍸). Then start again on the 6th. Do this every five values, as it makes the tally marks easy to count up.

Once all data are recorded, count the tally marks for the frequency.

Check that the frequency total adds up to the number of people surveyed (in this case 20).

Draw a set of axes with frequency going up to 8.

For each category, draw a column with height up to its frequency value.

Leave gaps between each column.

Give your graph an appropriate heading.

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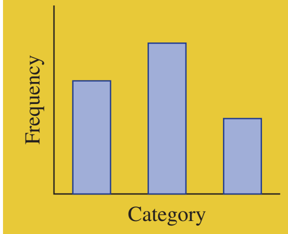
3 Complete the following for the data below obtained from surveys.

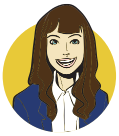
i Copy and complete this frequency table.

Category	Tally	Frequency
⋮	⋮	⋮

ii Construct a column graph for the data and include a heading.

In the column graph, leave spaces between each column.





a The results from 10 subjects on a student's school report are:

good
very low
low

low
good
good

good
good
excellent
low

b The favourite sports of a class of students are:

football
netball
basketball
football
tennis

football
tennis
basketball
basketball
tennis

netball
football
tennis
football
football

netball
football
basketball
football
tennis

Example 3 Constructing and analysing a histogram

Twenty people were surveyed to find out how many times they use the internet in a week. The raw data are listed.

21, 19, 5, 10, 15, 18, 31, 40, 32, 25
11, 28, 31, 29, 16, 2, 13, 33, 14, 24

a Organise the data into a frequency table using class intervals of 10. Include a percentage frequency column.

b Construct a histogram for the data, showing both the frequency and percentage frequency on the one graph.

c Which interval is the most frequent?

d What percentage of people used the internet 20 times or more?

SOLUTION

a

Class interval	Tally	Frequency	Percentage frequency
0–9	||	2	10%
10–19	卌 |||	8	40%
20–29	卌	5	25%
30–39	||||	4	20%
40–49	|	1	5%
Total	20	20	100%

EXPLANATION

Work through the data and place a tally mark in the correct interval each time.

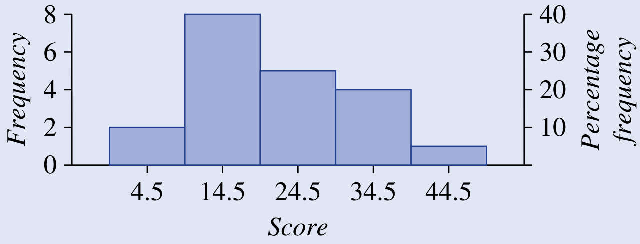
The interval 10–19 includes all numbers from 10 (including 10) to less than 20, so 10 is in this interval but 20 is not.

Count the tally marks to record the frequency.

Add the frequency column to ensure all 20 values have been recorded.

Calculate each percentage frequency by dividing the frequency by the total (i.e. 20) and multiplying by 100; i.e. $\frac{2}{20} \times 100 = 10$.

b **Number of times the internet is accessed**



In a histogram there are no gaps between the columns. When data is grouped into classes, the class centre is sometimes displayed in the middle of the base of the column. For instance, in the 40–49 class interval, the class centre is $\frac{(49 + 40)}{2} = 44.5$.

c The 10–19 interval is the most frequent.

The frequency (8) is highest for this interval. It is the highest bar on the histogram.

d 50% of those surveyed used the internet 20 or more times.

Sum the percentages for the class intervals from 20–49 and above.

$25 + 20 + 5 = 50$

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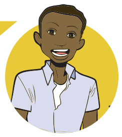
4 The Maths test results of a class of 25 students were recorded as:

74	65	54	77	85	68	93
59	71	82	57	98	73	66
88	76	92	70	77	65	68
81	79	80	75			

Construct a frequency table like this

Class interval	Tally	Frequency	Percentage frequency
50–59	|||	3	$\frac{\text{freq.}}{\text{total}} \times 100\%$
60–69			
70–79			
80–89			
90–99			
Total			



a Organise the data into a frequency table using class intervals of 10. Include a percentage frequency column.

b Construct a histogram for the data, showing both the frequency and percentage frequency on the one graph.

c Which interval is the most frequent?

d If an A is awarded for a score of 80 or more, what percentage of the class received an A?

5 The number of wins scored this season is given for 20 hockey teams. Here are the raw data.

4, 8, 5, 12, 15, 9, 9, 7, 3, 7
10, 11, 1, 9, 13, 0, 6, 4, 12, 5

a Organise the data into a frequency table using class intervals of 5, starting with 0–4, then 5–9 etc. and include a percentage frequency column.

b Construct a histogram for the data, showing both the frequency and percentage frequency on the one graph.

c Which interval is the most frequent?

d What percentage of teams scored 5 or more wins?

6 This frequency table displays the way in which 40 people travel to and from work.

Percentage frequency $= \frac{\text{frequency}}{\text{total}} \times 100$

Type of transport	Frequency	Percentage frequency
Car	16	
Train	6	
Ferry	8	
Walking	5	
Bicycle	2	
Bus	3	
Total	**40**	

a Copy and complete the table.

b Use the table to find:

- **i** the frequency of people who travel by train
- **ii** the most popular form of transport
- **iii** the percentage of people who travel by car
- **iv** the percentage of people who walk or cycle to work
- **v** the percentage of people who travel by public transport, including trains, buses and ferries.

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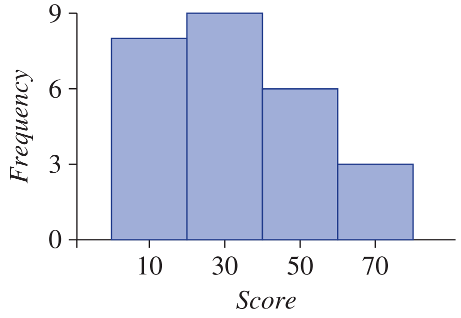
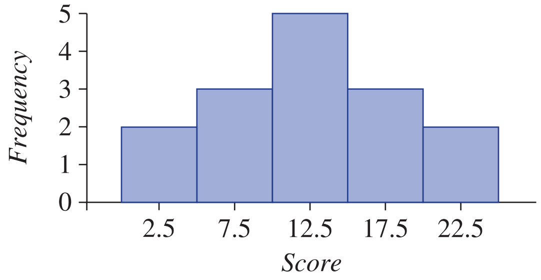
PROBLEM-SOLVING AND REASONING 7, 8 7, 9, 10

7 Which of these histograms shows a symmetrical data set and which one shows a skewed data set?

a



b



8 This tally records the number of mice that were weighed and categorised into particular mass intervals for a scientific experiment.

Mass (grams)	Tally
10–14	III
15–19	𝍸 I
20–24	𝍸 𝍸 𝍸 I
25–29	𝍸 𝍸 𝍸 𝍸 I
30–34	IIII

a Construct a table using these column headings: Mass, Frequency and Percentage frequency.

b Find the total number of mice weighed in the experiment.

c State the percentage of mice that were in the 20–24 gram interval.

d Which was the most common weight interval?

e What percentage of mice were in the most common mass interval?

f What percentage of mice had a mass of 15 grams or more?

9 A school orchestra contains four musical sections: string, woodwind, brass and percussion. The number of students playing in each section is summarised in this tally.

Section	Tally
String	𝍸 𝍸 𝍸 𝍸 I
Woodwind	𝍸 III
Brass	𝍸 II
Percussion	IIII

a Construct and complete a percentage frequency table for the data.

b What is the total number of students in the school orchestra?

c What percentage of students play in the string section?

d What percentage of students do not play in the string section?

e If the number of students in the string section increased by three, what would be the percentage of students who play in the percussion section? Round your answer to 1 decimal place.

10 Describe the information that is lost when displaying data using a histogram.

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ENRICHMENT – 11, 12

Interpreting further graphical displays

11 The graph shown compares the life expectancy of males and females in 10 different countries. Use the graph to answer the questions that follow.

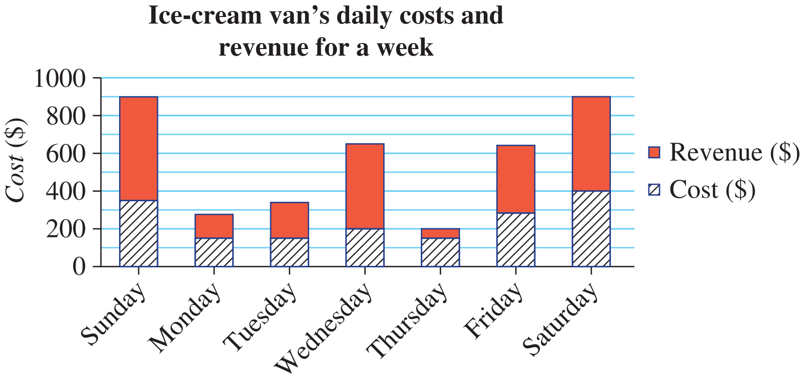
a Which country has the biggest difference in life expectancy for males and females? Approximately how many years is this difference?

b Which country appears to have the smallest difference in life expectancy between males and females?

c From the information in the graph, write a statement comparing the life expectancy of males and females.

d South Africa is clearly below the other countries. Provide some reasons why you think this may be the case.

12 This graph shows the amount, in dollars, spent (Cost) on the purchase and storage of ice-cream each day by an ice-cream vendor, and the amount of money made from the daily sales of ice-cream (Revenue) over the course of a week.



a On which particular days was the cost highest for the purchase and storage of ice-cream? Why do you think the vendor chose these days to spend the most?

b Wednesday earned the greatest revenue for any weekday. What factors may have led to this?

c Daily profit is determined by the difference in revenue and cost. Identify:

  i on which day the largest profit was made and the amount of profit (in dollars)

  ii on which day the vendor suffered the biggest financial loss

d Describe some problems associated with this type of graph.

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5C Dot plots and stem-and-leaf plots

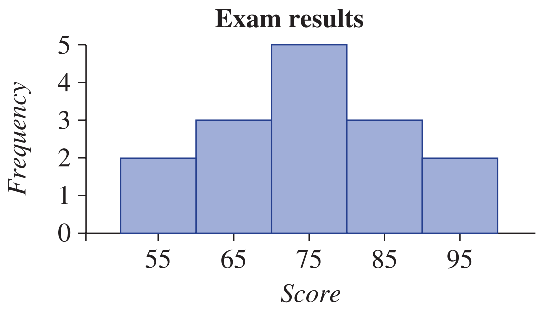
Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

In addition to column graphs, dot plots and stem-and-leaf plots can be used to display categorical or discrete data. They can also display two related sets for comparison. Like a histogram, they help to show how the data are distributed. A stem-and-leaf plot has the advantage of still displaying all the individual data items.

Let's start: Alternate representations

The histogram and stem-and-leaf plot below represent the same set of data. They show the exam scores achieved by a class.



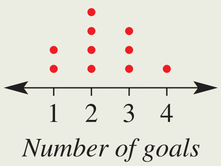
Stem	Leaf
5	1 3
6	5 7 8 8
7	1 2 4 4 6
8	3 4 7
9	6

6 | 8 means 68

- Describe the similarities in what the two graphs display.
- What information does the stem-and-leaf provide that the histogram does not? What is the advantage of this?
- Which graph do you prefer?
- Discuss any other types of graphs that could be used to present the data.

Key ideas

- A **dot plot** records the frequency of each category or discrete value in a data set.
  - Each occurence of the value is marked with a dot.



Dot plot A graph in which each dot represents one score

- A **stem-and-leaf plot** displays each value in the data set using a stem number and a leaf number.
  - The data are displayed in two parts: a stem and a leaf.
  - The 'key' tells you how to interpret the stem and leaf parts.
  - The graph is similar to a histogram with class intervals, but the original data values are not lost.
  - The stem-and-leaf plot is ordered to allow for further statistical calculations.

Stem	Leaf
1	0 1 1 5
2	3 7
3	4 4 6
4	2 9

2 | 3 means 23

key

Stem-and-leaf plot A table that lists numbers in order, grouped in rows

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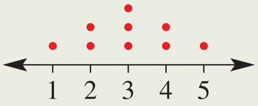
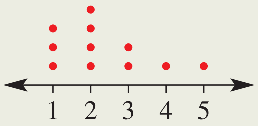
Key ideas

- The shape of each of these graphs gives information about the distribution of the data.
  - A graph that is even either side of the centre is symmetrical.



  - A graph that is bunched to one side of the centre is skewed.

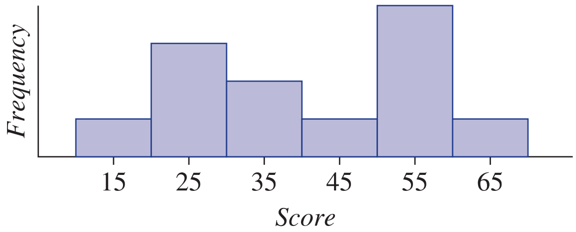


Exercise 5C

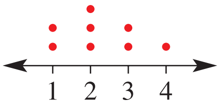
UNDERSTANDING AND FLUENCY 1–5, 7 4–8

1 Name each of these types of graphs.

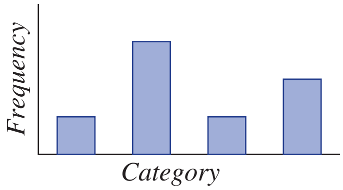
a



b



c



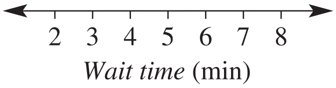
d

Stem	Leaf
0	1 1 3
1	2 4 7
2	0 2 2 5 8
3	1 3

2 | 5 means 25

2 A student records the following wait times, in minutes, for his school bus over 4 school weeks.

5	4	2	8	4	2	7	5	3	3
5	4	2	5	4	5	8	7	2	6



Copy and complete this dot plot of the data.

3 List the data shown in these stem-and-leaf plots.

a

Stem	Leaf
3	2 5
4	1 3 7
5	4 4 6
6	0 2
7	1 1

4 | 1 means 41

b

Stem	Leaf
0	2 3 7
1	4 4 8 9
2	3 6 6
3	0 5

2 | 3 means 2.3

Look at the key '4 | 1 means 41' to see how the stems and leaves go together.

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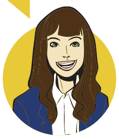
4 Order this stem-and-leaf plot.

Stem	Leaf
12	7 2 3
10	1 4 8 1
13	9 0 2
11	3 0 3 6

12 | 2 means 122

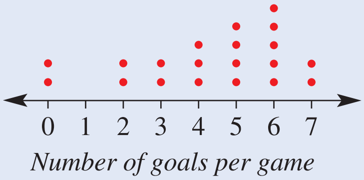
Stems and leaves need to be placed in numerical order.



Example 4 Interpreting a dot plot

This dot plot shows the number of goals per game scored by a team during the soccer season.

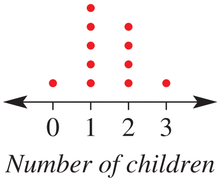
a How many games were played?
b What was the most common number of goals per game?
c How many goals were scored for the season?
d Describe the data in the dot plot.



SOLUTION	EXPLANATION
a There were 20 matches played.	Each dot represents a match. Count the number of dots.
b 6 goals in a game occured most often.	The most common number of goals has the most dots.
c $2 \times 0 + 2 \times 2 + 2 \times 3 + 3 \times 4 + 4 \times 5 + 5 \times 6 + 2 \times 7$ $= 0 + 4 + 6 + 12 + 20 + 30 + 14$ $= 86$ goals	Count the number of games (i.e. dots) for each number of goals and multiply by the number of goals. Add these together.
d Two games resulted in no goals but the data were generally skewed towards a higher number of goals.	Consider the shape of the graph; it is bunched towards the 6 end of the goal scale.

5 A number of families were surveyed to find the number of children in each. The results are shown in this dot plot.

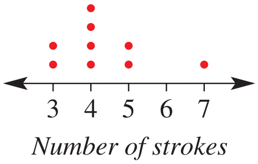
a How many families were surveyed?
b What was the most common number of children in a family?
c How many children were there in total?
d Describe the data in the dot plot.



4 families had 2 children (4 dots), so that represents 8 children from these families

6 This dot plot shows the number of strokes a golfer played, each hole, in his round of golf.

a How many holes did he play?
b How many strokes did he play in the round?
c Describe his round of golf.



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Example 5 Constructing a stem-and-leaf plot

For the following set of data:

22 62 53 44 35 47 51 64 72
32 43 57 64 70 33 51 68 59

a Organise the data into an ordered stem-and-leaf plot.

b Describe the distribution of the data as symmetrical or skewed.

SOLUTION

a

Stem	Leaf
2	2
3	2 3 5
4	3 4 7
5	1 1 3 7 9
6	2 4 4 8
7	0 2

5 | 1 means 51

EXPLANATION

For two-digit numbers, select the tens value as the stem and the units as the leaves.

The data ranges from 22 to 72, so the graph will need stems 2 to 7.

Work through the data and record the leaves in the order of the data.

Stem	Leaf
2	2
3	5 2 3
4	4 7 3
5	3 1 7 1 9
6	2 4 4 8
7	2 0

51 occurs twice, so the leaf 1 is recorded twice in the 5 stem row.

Once data are recorded, redraw and order the leaves from smallest to largest.

Include a key to explain how the stem and leaf go together; i.e. 5 | 1 means 51.

b The distribution of the data is symmetrical.

The shape of the graph is close to being symmetrical (evenly spread) either side of the centre.

7 Complete for the following sets of data.

i Organise the data into an ordered stem-and-leaf plot.

ii Describe the distribution of the data as symmetrical or skewed.

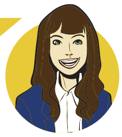
a 46 22 37 15 26 38 52 24
31 20 15 37 21 25 26

b 35 16 23 55 38 44 12 48 21 42
53 36 35 25 40 51 27 31 40 36 32

c 153 121 124 117 125 118 135 137 162
145 147 119 127 149 116 133 160 158

d 4.9 3.7 4.5 5.8 3.8 4.3 5.2 7.0 4.7
4.4 5.5 6.5 6.1 3.3 5.4 2.0 6.3 4.8

Remember to include a key such as '4 | 6 means 46'

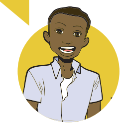


Symmetrical

Stem	Leaf
1	1 2
2	1 2 3
3	1 2 3 4
4	1 2 7
5	3

Skewed

Stem	Leaf
1	2 5 7 8
2	3 4 6 6
3	1 2
4	5



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Example 6 Constructing back-to-back stem-and-leaf plots

Two television sales employees sell the following number of televisions each week over a 15-week period.

Employee 1

23 38 35 21 45 27 43 36
19 35 49 20 39 58 18

Employee 2

28 32 37 20 30 45 48 17
32 37 29 17 49 40 46

a Construct an ordered back-to-back stem-and-leaf plot.

b Describe the distribution of each employee's sales.

SOLUTION

a

Employee 1		Employee 2
Leaf	Stem	Leaf
9 8	1	7 7
7 3 1 0	2	0 8 9
9 8 6 5 5	3	0 2 2 7 7
9 5 3	4	0 5 6 8 9
8	5	

3 | 7 means 37

b Employee 1's sales are symmetrical, whereas employee 2's sales are skewed.

EXPLANATION

Construct an ordered stem-and-leaf plot with employee 1's sales on the left-hand side and employee 2's sales on the right-hand side. Include a key.

Observe the shape of each employee's graph. If appropriate, use the words symmetrical (spread evenly around the centre) or skewed (bunched to one side of the centre).

8 Complete for the following sets of data.

- **i** Draw a back-to-back stem-and-leaf plot.
- **ii** Comment on the distribution of the two data sets.

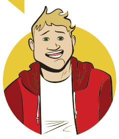
a Set 1: 61 38 40 53 48 57 64
39 42 59 46 42 53 43

Set 2: 41 55 64 47 35 63 61
52 60 52 56 47 67 32

b Set 1: 176 164 180 168 185 187 195 166 201
199 171 188 175 192 181 172 187 208

Set 2: 190 174 160 170 186 163 182 171
167 187 171 165 194 182 163 178

Using a key for part **b** may help.
Recall that 17 | 6 means 176.
Stems will be 16, 17 etc.



PROBLEM-SOLVING AND REASONING 9, 10 10–12

9 Two football players, Nick and Jack, compare their personal tallies of the number of goals scored for their team over a 12-match season. Their tallies are as follows.

Game	1	2	3	4	5	6	7	8	9	10	11	12
Nick	0	2	2	0	3	1	2	1	2	3	0	1
Jack	0	0	4	1	0	5	0	3	1	0	4	0

a Draw a dot plot to display Nick's goal-scoring achievement.
b Draw a dot plot to display Jack's goal-scoring achievement.
c How would you describe Nick's scoring habits?
d How would you describe Jack's scoring habits?

10 This stem-and-leaf plot shows the times, in minutes, that Chris has achieved in the past 14 fun runs he competed in.

a What is the difference between his slowest and fastest times?
b Just by looking at the stem-and-leaf plot, what would you estimate to be Chris's average time?
c If Chris records another time of 24.9 minutes, how would this affect your answer to part **b**?

Stem	**Leaf**
20	5 7
21	1 2 6
22	2 4 6 8
23	4 5 6
24	3 6

22 | 4 means 22.4 min

11 The data below show the distances travelled (in km) by students at an inner-city and an outer-suburb school.

Inner city: 3 10 9 14 21 6
1 12 24 1 19 4

Outer suburb: 12 21 18 9 34 19
24 3 23 41 18 4

a Draw a back-to-back stem-and-leaf plot for the data.
b Comment on the distribution of distances travelled by students for each school.
c Give a practical reason for the distribution of the data.

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12 Determine the possible values of the pronumerals in the following ordered stem-and-leaf plots.

a

Stem	Leaf
1	2 4
2	3 6 9 b
a	1 4
4	7 c 8

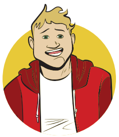
2 | 3 means 2.3

b

Stem	Leaf
20	a 1 4
21	2 2 9
22	0 b 5 7
23	1 4

22 | 7 means 227

The stems and leaves are ordered from smallest to largest. A leaf can appear more than once.



ENRICHMENT – 13

Splitting stems

13 The back-to-back stem-and-leaf plot below shows the maximum daily temperature for two cities over a 2-week period.

a Describe the difference between the stems 1 and 1*.

b To which stem would these numbers be allocated?

i 12°C **ii** 5°C

c Why might you use this process of splitting stems, like that used for 1 and 1*?

d Compare and comment on the differences in temperatures between the two cities.

e What might be a reason for these different temperatures?

Maximum temperature

City A leaf	Stem	City B leaf
	0	
9 8 8	0*	
4 3 3 1 1 1	1	
8 8 6 6 5	1*	7 9
	2	0 2 2 3 4 4
	2*	5 6 7 7 8
	3	1

1 | 4 means 14
1* | 5 means 15

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5D Mean, median, mode and range

In the previous sections you have seen how to summarise data in the form of a frequency table and to display data using graphs. Key summary statistics also allow us to describe the data using a single numerical value. The mean, for example, may be used to describe a student's performance over a series of tests. The median (middle value when data are ordered smallest to largest) is often used when describing the house prices in a suburb. These are termed *measures of centre*. Providing information about the spread of the data is the range, which measures the difference between the maximum and minimum values.

Average house prices in a suburb are often described using the median price.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Mean, median or mode?

The following data represent the number of goals scored by Ellie in each game of a 9-game netball season.

24 18 25 16 3 23 27 19 25

It is known that the figures below represent, in some order, the mean, median and mode.

25 20 23

- Without doing any calculations, can you suggest which statistic is which? Explain.
- From the data, what gives an indication that the mean will be less than the median (middle value)?
- Describe how you would calculate the mean, median and mode from the data values.

Key ideas

- Statisticians use **summary statistics** to highlight important aspects of a data set. These are summarised below.
- Some summary statistics are called **measures of location.**
  - The two most commonly used measures of location are the **mean** and the **median**. These are also called '**measures of centre**' or '**measures of central tendency**'. Mean and median can only be applied to numerical data.
  - The **mean** is sometimes called the '**arithmetic mean**' or the '**average**'. The formula used for calculating the mean, $\bar{x}$, is:

$$\bar{x} = \frac{\text{sum of data values}}{\text{number of data values}}$$

For example: In the following data set

5	7	2	5	1

the mean is $\frac{5 + 7 + 2 + 5 + 1}{5} = 20 \div 5 = 4$

Mean A value calculated by dividing the total of a set of numbers by the number of values

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Key ideas

- The **median** divides an ordered data set into two sets, each of which contain the same number of data values. It is often called the 'middle value'. The median is found by firstly ensuring the data values are in ascending order, then selecting the 'middle' value.

  If the number of values is odd, simply choose the one in the middle.

  2 2 3 **4** 6 9 9

  Median = 4

  If the number of values is even, find the average of the two in the middle.

  2 2 3 **4** **7** 9 9 9

  Median = (4 + 7) ÷ 2 = 5.5

Median The middle score when all the numbers in a set are arranged in order

- The **mode** of a data set is the most frequently occurring data value. There can be more than one mode. When there are two modes, the data is said to be **bimodal**. The mode can be very useful for categorical data. It can also be used for numerical data, but it may not be an accurate measure of centre. For example, in the data set below the mode is 10, but it is the largest data value.

1	2	3	10	10

Mode The score that appears most often in a set of numbers

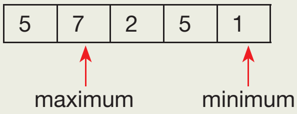
Bimodal When a set of data has two modes

- An **outlier** is a data value which is significantly greater than or less than the other data values in the data set. The inclusion of an outlier in a data set can inflate or deflate the mean and give a false impression of the 'average'. For example:
  In the data set 1, 2, 3, 4, 5, the mean is 3 and median is 3.
  If the data value 5 is changed to 20, it is now an outlier.
  In the data set 1, 2, 3, 4, 20, the median is still 3, but the mean is now 6, which is greater than four of the five data values. In this case, the median is a better measure of centre than the mean.

■ Some summary statistics are called **measures of spread**

- The **range** is a measure of spread.
- The range of a data set is given by the formula:
  range = maximum data value – minimum data value
  For example: In the data set below the range is 7 − 1 = 6
- In the future you will encounter some other measures of spread such as interquartile range and standard deviation.

Range The difference between the highest and lowest numbers in a set



Exercise 5D

UNDERSTANDING AND FLUENCY 1–4, 5–6(½) 4, 5–6(½), 7

1 Use the words from the list below to fill in the missing word in these sentences.
mean, median, mode, bimodal, range
a The _________ is the most frequently occurring value in a data set.
b Dividing the sum of all the data values by the total number of values gives the ________.
c The middle value of a data set ordered from smallest to largest is the __________.
d A data set with two most common values is _________.
e A data set has a maximum value of 7 and a minimum value of 2. The ________ is 5.

2 Calculate the following.

a $\dfrac{1 + 4 + 5 + 8 + 2}{5}$ **b** $\dfrac{3 + 7 + 6 + 2}{4}$ **c** $\dfrac{3.1 + 2.3 + 6.4 + 1.7 + 2.5}{5}$

3 Circle the middle value(s) of these ordered data sets.

a 2 4 6 7 8 10 11

b 6 9 10 14 17 20

Recall that an even number of data values will have two middle values.

4 Sebastian drinks the following number of cups of coffee each day in a week.

4 5 3 6 4 3 3

a How many cups of coffee does he drink in the week (sum of the data values)?

b How many days are in the week (total number of data values)?

c What is the mean number of cups of coffee Sebastian drinks each day (i.e. part **a** ÷ part **b**)?

Example 7 Finding the mean, mode and range

For the following data sets, find:

i the mean **ii** the mode **iii** the range

a 2, 4, 5, 8, 8 **b** 3, 15, 12, 9, 12, 15, 6, 8

SOLUTION	EXPLANATION
a **i** Mean $= \dfrac{2 + 4 + 5 + 8 + 8}{5}$ $= \dfrac{27}{5}$ $= 5.4$	Mean $= \dfrac{\text{sum of all data values}}{\text{number of data values}}$ Add all the data and divide by the number of values (in this case, 5).
ii The mode is 8.	The mode is the most common value in the data.
iii Range $= 8 - 2$ $= 6$	Range = maximum value − minimum value
b **i** Mean $= \dfrac{3 + 15 + 12 + 9 + 12 + 15 + 6 + 8}{8}$ $= \dfrac{80}{8}$ $= 10$	Mean $= \dfrac{\text{sum of all data values}}{\text{number of data values}}$ Add all the data and divide by the number of values (8).
ii There are two modes, 12 and 15.	The data set is bimodal: 12 and 15 are the most common data values.
iii Range $= 15 - 3$ $= 12$	Range = maximum value − minimum value

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5 For each of the following data sets, find:

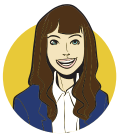
- **i** the mean
- **ii** the mode
- **iii** the range

a 2 4 5 8 8
b 5 8 10 15 20 12 10 50
c 55 70 75 50 90 85 50 65 90
d 27 30 28 29 24 12
e 2.0 1.9 2.7 2.9 2.6 1.9 2.7 1.9
f 1.7 1.2 1.4 1.6 2.4 1.3

$\text{Mean} = \dfrac{\text{sum of data values}}{\text{number of data values}}$

Mode is the most common value.

Range = maximum − minimum



Example 8 Finding the median

Find the median of each data set.

a 4, 7, 12, 2, 9, 15, 1 **b** 16, 20, 8, 5, 21, 14

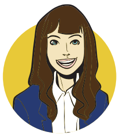
SOLUTION	EXPLANATION
a 1 2 4 ⑦ 9 12 15 Median = 7	The data must first be ordered from smallest to largest. The median is the middle value. For an odd number of data values, there will be one middle value.
b 5 8 $\underbrace{14 \quad 16}$ 20 21 $\text{Median} = \dfrac{14 + 16}{2}$ $= 15$	Order the data from smallest to largest. For an even number of data values, there will be two middle values. The median is the average of these two values (i.e. the value halfway between the two middle numbers).

6 Find the median of each data set.

a 1 4 7 8 12
b 1 2 2 4 4 7 9
c 11 13 6 10 14 13 11
d 62 77 56 78 64 73 79 75 77
e 2 4 4 5 6 8 8 10 12 22
f 1 2 2 3 7 12 12 18
g 30 36 31 38 27 40
h 2.4 2.0 3.2 2.8 3.5 3.1 3.7 3.9

First, make sure that the data are in order.

For two middle values, find their average.



7 Nine people watch the following number of hours of television on a weekend.

4 4 6 6 6 8 9 9 11

a Find the mean number of hours of television watched.
b Find the median number of hours of television watched.
c Find the range of the television hours watched.
d What is the mode number of hours of television watched?

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PROBLEM-SOLVING AND REASONING 8, 9(½), 10 9(½), 10–13

8 Eight students compare the amount of pocket money they receive. The data are as follows.

$12 $15 $12 $24 $20 $8 $50 $25

a Find the range of pocket money received.

b Find the median amount of pocket money.

c Find the mean amount of pocket money.

d Why is the mean larger than the median?

Example 9 Calculating summary statistics from a stem-and-leaf plot

For the data in this stem-and-leaf plot, find:

a the range

b the mode

c the mean

d the median

Stem	Leaf
2	5 8
3	1 2 2 2 6
4	0 3 3
5	2 6

5 | 2 means 52

SOLUTION	EXPLANATION
a Minimum value = 25 Maximum value = 56	In an ordered stem-and-leaf plot the first data item is the minimum and the last is the maximum. Use the key '5 | 2 means 52' to see how to put the stem and leaf together.
Range = 56 − 25 = 31	Range = maximum value − minimum value
b Mode = 32	The mode is the most common value. The leaf 2 appears three times with the stem 3.
c Mean $= \frac{25 + 28 + 31 + 32 + 32 + 32 + 36 + 40 + 43 + 43 + 52 + 56}{12}$ $= \frac{450}{12}$ $= 37.5$	Form each data value from the graph and add them all together. Then divide by the number of data values in the stem-and-leaf plot.
d Median $= \frac{32 + 36}{2}$ $= 34$	There is an even number of data values: 12. The median will be the average of the middle two values (i.e. the 6th and 7th data values).

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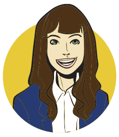
9 For the data in these stem-and-leaf plots, find:

- **i** the range
- **ii** the mode
- **iii** the mean (rounded to 1 decimal place)
- **iv** the median



Use the key to see how the stem and leaf go together.

a

Stem	Leaf
2	1 3 7
3	2 8 9 9
4	4 6

3 | 2 means 32

b

Stem	Leaf
0	4 4
1	0 2 5 9
2	1 7 8
3	2

2 | 7 means 27

c

Stem	Leaf
10	1 2 4
11	2 6
12	5

11 | 6 means 116

d

Stem	Leaf
3	0 0 5
4	2 7
5	1 3 3
6	0 2

3 | 2 means 3.2

10 This back-to-back stem-and-leaf plot shows the results achieved by two students, Hugh and Mark, on their end-of-year examination in each subject.

a For each student, find:

- **i** the mean
- **ii** the median
- **iii** the range

Hugh leaf	Stem	Mark leaf
8 8 5	6	4
7 3	7	4 7
5 4 2 1 1	8	2 4 6 8
	9	2 4 5

7 | 4 means 74%

b Compare the performance of the two students using your answers to part **a**.

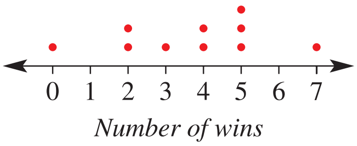
11 A real estate agent recorded the following amounts for the sale of five houses.

$120 000 $210 000 $280 000 $370 000 $1 700 000

The mean is $536 000 and the median is $280 000.

Which is a better measure of the centre of the five house prices: the mean or the median? Give a reason.

12 This dot plot shows the number of wins recorded by a school lacrosse team in the past 10 eight-game seasons.



a What was the median number of wins?

b What was the mean number of wins?

c The following season, the team records 3 wins.

What effect will this have (i.e. increase/decrease/no change) on the:

- **i** median?
- **ii** mean?

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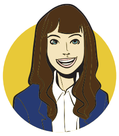
13 Catherine achieves the following scores on her first four Maths tests:

64 70 72 74

a What is her mean mark from the Maths tests?

b In the fifth and final test, Catherine is hoping to raise her mean mark to 73. What mark does she need on the last test to achieve this?

A mean of 73 from 5 tests will need a five-test total of 73 × 5.



ENRICHMENT

– 14

Moving run average

14 A moving average is determined by calculating the average of all data values up to a particular time or place in the data set.

Consider a batsman in cricket with the following runs scored from 10 completed innings.

Innings	1	2	3	4	5	6	7	8	9	10
Score	26	38	5	10	52	103	75	21	33	0
Moving average	26	32								

In the table, 26 is the average after 1 innings and 32 is the average after 2 innings.

a Complete the table by calculating the moving average for innings 3–10. Round to the nearest whole number where required.

b Plot the score and moving averages for the batsman on the same set of axes, with the innings number on the horizontal axis. Join the points to form two line graphs.

c Describe the behaviour of the:

- **i** score graph
- **ii** moving average graph

d Describe the main difference in the behaviour of the two graphs. Give reasons.

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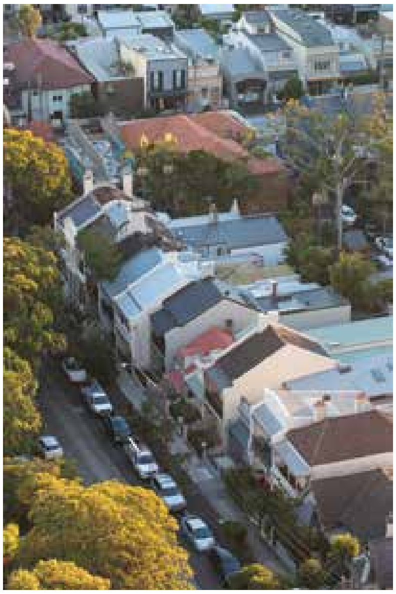
5E Quartiles and outliers

Interactive
Widgets
HOTsheets
Walkthrough

In addition to the median of a single set of data, there are two related statistics called the upper and lower quartiles. If data are placed in order, then the lower quartile is central to the lower half of the data. The upper quartile is central to the upper half of the data. These quartiles are used to calculate the interquartile range, which helps to describe the spread of the data, and show whether or not any data points do not fit the rest of the data (i.e. outliers).



Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: House prices

A real estate agent tells you that the median house price for a suburb in 2013 was $753 000 and the mean was $948 000.

- Is it possible for the median and the mean to differ by so much?
- Under what circumstances could this occur? Discuss.

Key ideas

- The **five-figure summary** uses the following statistical measures.
  - minimum value (Min): the lowest value
  - lower **quartile** (Q_1): the number above 25% of the ordered data
  - median (Q_2): the middle value, above 50% of the ordered data
  - upper quartile (Q_3): the number above 75% of the ordered data
  - maximum value (Max): the highest value

Odd number of data values

$$1\ \underbrace{2\ \ 2}\ 3\ \ )\text{⑤}(\ \ 6\ \underbrace{6\ \ 7}\ 9$$

$$Q_1 = \frac{2+2}{2} = 2 \qquad Q_2 \qquad Q_3 = \frac{6+7}{2} = 6.5$$

Even number of data values

$$3\ \text{③}\ 4\ \underbrace{7\,|\,8}\ 8\ \ 9\ \text{⑨}\ 9$$

$$Q_1 = 3 \quad Q_2 = 7.5 \quad Q_3 = 9$$

- Another measure of the spread of the data is the **interquartile range (IQR)**.

$$\begin{aligned}\text{IQR} &= \text{upper quartile} - \text{lower quartile}\\ &= Q_3 - Q_1\end{aligned}$$

- **Outliers** are data elements outside the vicinity of the rest of the data. A data point is an outlier if it is either:
  - less than $Q_1 - 1.5 \times \text{IQR}$ *or*
  - greater than $Q_3 + 1.5 \times \text{IQR}$

Five-figure summary A set of numbers that summarise a set of data: the minimum score, first quartile, median, third quartile and maximum score

Quartiles The three values that separate the scores when a set of ordered data is divided into four equal parts

Interquartile range A measure of spread giving the difference between the upper and lower quartiles

Outlier Any value that is much larger or much smaller than the rest of the data in a set

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Exercise 5E

UNDERSTANDING AND FLUENCY 1–4, 5–6(½), 7 5–6(½), 7, 8

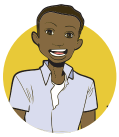
1 **a** State the five values that need to be calculated for a five-figure summary.
b Explain the difference between the range and the interquartile range.
c What is an outlier?

2 Complete the following for calculating outliers.
a Numbers below _____ −1.5 × IQR
b Numbers above Q_3 + ____ × IQR.

3 The following data show, in order, the numbers of cars owned by 10 families surveyed.
0, 1, 1, 1, 1, 2, 2, 2, 3, 3
a Find the median (the middle value).
b By splitting the data in half, determine:
  i the lower quartile, Q_1 (middle of lower half)
  ii the upper quartile, Q_3 (middle of upper half)

4 Complete the following for the data set with $Q_1 = 3$ and $Q_3 = 8$:
a Find IQR = $Q_3 - Q_1$.
b Calculate $Q_1 - 1.5 \times \text{IQR}$ and $Q_3 + 1.5 \times \text{IQR}$.
c Identify the name that would be given to the value 18 in the data set.

Order of operations says to multiply 1.5 × IQR before adding or subtracting.



Example 10 Finding quartiles and IQR for an even number of data values

Consider this data set.
2, 2, 4, 5, 6, 8, 10, 13, 16, 20
a Find the upper quartile (Q_3) and the lower quartile (Q_1).
b Determine the IQR.

SOLUTION

a
$$2 \quad 2 \quad \underset{Q_1}{\underset{\uparrow}{\textcircled{4}}} \quad 5 \quad \underbrace{6 \mid 8} \quad 10 \quad \underset{Q_3}{\underset{\uparrow}{\textcircled{13}}} \quad 16 \quad 20$$
$$Q_2 = \frac{6+8}{2}$$
$$= 7$$
$$Q_1 = 4 \text{ and } Q_3 = 13$$

EXPLANATION

The data are already ordered. Since there is an even number of values, split the data in half to locate the median.
Q_1 is the middle value of the lower half:
$2 \ 2 \ \textcircled{4} \ 5 \ 6$
Q_3 is the middle value of the upper half.

b
$$\text{IQR} = 13 - 4$$
$$= 9$$

IQR = $Q_3 - Q_1$

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5 For these data sets, find:

- **i** the upper quartile (Q_3) and the lower quartile (Q_1)
- **ii** the IQR

a 3, 4, 6, 8, 8, 10

b 10, 10, 11, 14, 14, 15, 16, 18, 20, 21

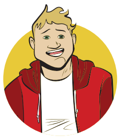
c 41, 49, 53, 58, 59, 62, 62, 65

d 1.2, 1.7, 1.9, 2.2, 2.4, 2.5, 2.9, 3.2

For an even number of data values, split the ordered data in half:

$$\begin{array}{cccccc} 2 & 4 & 7 \,|\, & 8 & 10 & 12 \\ & \uparrow & & & \uparrow & \\ & Q_1 & & & Q_3 & \end{array}$$

$IQR = Q_3 - Q_1$



Example 11 Finding quartiles and IQR for an odd number of data values

Consider this data set.

2.2, 1.6, 3.0, 2.7, 1.8, 3.6, 3.9, 2.8, 3.8

a Find the upper quartile (Q_3) and the lower quartile (Q_1).

b Determine the IQR.

SOLUTION

a

$$\begin{array}{ccc} 1.6 \;\; 1.8 \,|\, 2.2 \;\; 2.7 & 2.8 & 3.0 \;\; 3.6 \,|\, 3.8 \;\; 3.9 \\ & \uparrow & \\ & Q_2 & \end{array}$$

$$Q_1 = \frac{1.8 + 2.2}{2} = \frac{4.0}{2} = 2.0$$

$$Q_3 = \frac{3.6 + 3.8}{2} = \frac{7.4}{2} = 3.7$$

b $IQR = 3.7 - 2.0$
$= 1.7$

EXPLANATION

First order the data and locate the median (Q_2).
Split the data in half; i.e. either side of the median.
Q_1 is the middle value of the lower half; for two middle values, average the two numbers.
Q_3 is the middle value of the upper half.

$IQR = Q_3 - Q_1$

6 For these data sets, find:

- **i** the upper quartile (Q_3) and the lower quartile (Q_1)
- **ii** the IQR

a 1, 2, 4, 8, 10, 11, 14

b 10, 7, 14, 2, 5, 8, 3, 9, 2, 12, 1

c 0.9, 1.3, 1.1, 1.2, 1.7, 1.5, 1.9, 1.1, 0.8

d 21, 7, 15, 9, 18, 16, 24, 33, 4, 12, 13, 18, 24

For an odd number of data values, split ordered data in half, leaving out the middle value.

$$\begin{array}{ccccccc} 0 & \textcircled{2} & 4\,) & 7 & (\,9 & \textcircled{14} & 16 \\ & \uparrow & & & & \uparrow & \\ & Q_1 & & & & Q_3 & \end{array}$$

Example 12 Finding the five-figure summary and outliers

The following data set represents the number of flying geese spotted on each day of a 13-day tour of England.

5, 1, 2, 6, 3, 3, 18, 4, 4, 1, 7, 2, 4

a For the data, find:
  - **i** the minimum and maximum number of geese spotted
  - **ii** the median
  - **iii** the upper and lower quartiles
  - **iv** the IQR

b Find any outliers.

c Can you give a possible reason for why the outlier occurred?

SOLUTION

a **i** Min = 1, max = 18

ii 1, 1, 2, 2, 3, 3, ④, 4, 4, 5, 6, 7, 18

$\therefore$ Median = 4

iii Lower quartile $(Q_1) = \dfrac{2+2}{2}$

$= 2$

Upper quartile $(Q_3) = \dfrac{5+6}{2}$

$= 5.5$

iv IQR = 5.5 − 2

= 3.5

b $Q_1 - 1.5 \times \text{IQR} = 2 - 1.5 \times 3.5$

$= 2 - 5.25$

$= -3.25$

$Q_3 + 1.5 \times \text{IQR} = 5.5 + 1.5 \times 3.5$

$= 5.5 + 5.25$

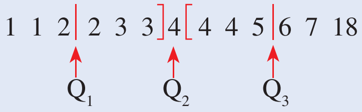
$= 10.75$

$\therefore$ The outlier is 18.

c Perhaps a flock of geese was spotted that day.

EXPLANATION

Look for the largest and smallest numbers and order the data:



Since Q_2 falls on a data value, it is not included in the lower or higher halves when Q_1 and Q_3 are calculated.

$\text{IQR} = Q_3 - Q_1$

A data point is an outlier if it is less than $Q_1 - 1.5 \times \text{IQR}$ or greater than $Q_3 + 1.5 \times \text{IQR}$.

There are no numbers less than −3.25 but 18 is greater than 10.75.

7 The following numbers of cars were counted on each day for 15 days, travelling on a quiet suburban street.

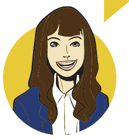
10, 9, 15, 14, 10, 17, 15, 0, 12, 14, 8, 15, 15, 11, 13

a For the given data, find:
  - **i** the minimum and maximum number of cars counted
  - **ii** the median
  - **iii** the lower and upper quartiles (Q_1 and Q_3)
  - **iv** the IQR

b Find any outliers.

c Give a possible reason for the outlier.

Outliers:
more than $Q_3 + 1.5 \times \text{IQR}$
or less than
$Q_1 - 1.5 \times \text{IQR}$.



8 Summarise the data sets below by finding:

- **i** the minimum and maximum values
- **ii** the median (Q_2)
- **iii** the lower and upper quartiles (Q_1 and Q_3)
- **iv** the IQR
- **v** any outliers

a 4, 5, 10, 7, 5, 14, 8, 5, 9, 9

b 24, 21, 23, 18, 25, 29, 31, 16, 26, 25, 27

c 10, 13, 2, 11, 10, 8, 24, 12, 13, 15, 12

d 3, 6, 10, 11, 17, 4, 4, 1, 8, 4, 10, 8

PROBLEM-SOLVING AND REASONING

9, 10 9, 11, 12

9 Twelve different calculators had the following numbers of buttons.
36, 48, 52, 43, 46, 53, 25, 60, 128, 32, 52, 40

a For the given data, find:

- **i** the minimum and maximum number of buttons
- **ii** the median
- **iii** the lower and upper quartiles (Q_1 and Q_3)
- **iv** the IQR
- **v** any outliers
- **vi** the mean

b Which is a better measure of the centre of the data: the mean or the median? Explain.

c Can you give a possible reason why the outlier has occurred?

10 At an airport Adele checks the weight of 20 luggage items. If the weight of a piece of luggage is an outlier, then the contents undergo a further check. The weights, in kilograms, are:

1 4 5 5 6 7 7 7 8 8
10 10 10 13 15 16 17 19 30 31

How many luggage items will undergo a further check?

11 The prices of nine fridges are displayed in a sale catalogue. They are:

\$350 \$1000 \$850 \$900 \$1100
\$1200 \$1100 \$1000 \$1700

How many of the fridge prices could be considered outliers?

12 For the data in this stem-and-leaf plot, find:

a the IQR

b any outliers

c any outliers if the number 32 was added to the list

Stem	Leaf
0	1
1	6 8
2	0 4 6 8
3	0

2|4 means 24

Split the data in half to find Q_2, then find Q_1 and Q_3.

ENRICHMENT

– 13

Some research

13 Use the internet to search for data about a topic that interests you. Try to choose a single set of data that includes between 15 and 50 values.

a Organise the data using:

- **i** a stem-and-leaf plot
- **ii** a frequency table and histogram

b Find the mean and the median.

c Find the range and the interquartile range.

d Write a brief report describing the centre and spread of the data, referring to parts **a**–**c** above.

e Present your findings to your class or a partner.

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5F Box plots

Interactive
Widgets
HOTsheets
Walkthrough

The five-figure summary (min, Q_1, Q_2, Q_3, max) can be represented in graphical form as a box plot. Box plots are graphs that summarise single data sets. They clearly display the minimum and maximum values, the median, the quartiles and any outliers. Q_1, Q_2 and Q_3 divide the data into quarters. Box plots also give a clear indication of how data are spread, as the IQR (interquartile range) is shown by the width of the central box.

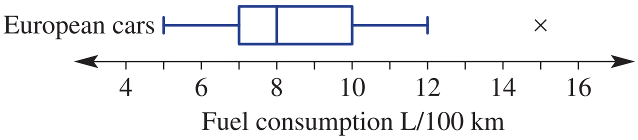
Box plots are used to compare a school's performance against the performance of all the schools in a state.

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Fuel consumption

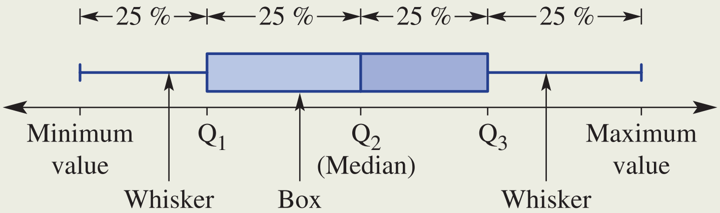
This box plot summarises the average fuel consumption (litres per 100 km) for a group of European-made cars.



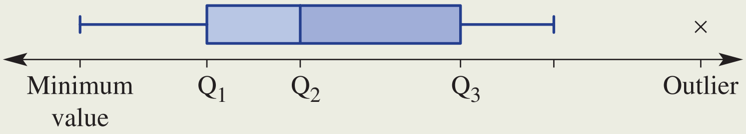
- What does each part of the box plot represent in terms of the five-figure summary?
- What do you think the cross (×) represents?
- Describe how you can use the box plot to find the IQR.
- Above what value would you expect the fuel consumption to be for the top 25% of cars?

Key ideas

- A **box plot** (also called a box-and-whisker plot) can be used to summarise a data set. It displays the five figure summary (min, Q_1, Q_2, Q_3, max), as shown.



- An outlier is marked with a cross (×).
  - An outlier is greater than $Q_3 + 1.5 \times \text{IQR}$ or less than $Q_1 - 1.5 \times \text{IQR}$. $\text{IQR} = Q_3 - Q_1$
  - The whiskers stretch to the lowest and highest data values that are not outliers.



Box plot A diagram using rectangles and ranges to show the spread of a set of data, using five important values

ISBN 978-1-108-46842-8 Cambridge University Press
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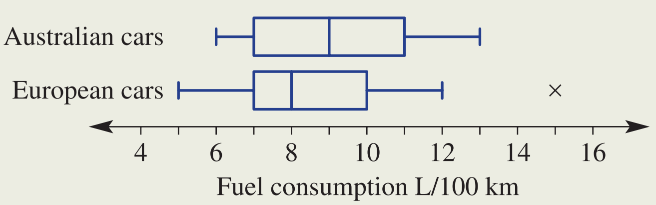
Key ideas

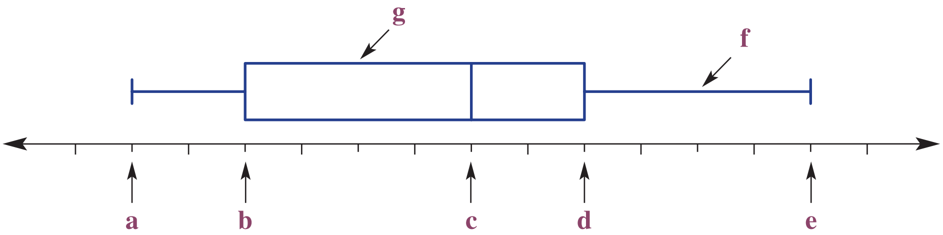
- Parallel box plots are box plots drawn on the same scale. They are used to compare data sets within the same context.



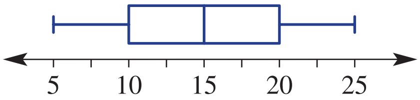
Exercise 5F

UNDERSTANDING AND FLUENCY 1–4, 5–6(½) 4, 5–6(½)

1 Label the parts of the box plot below.



2 For this simple box plot, find:

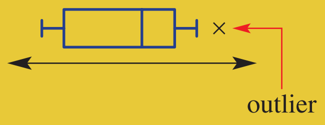


a the median (Q_2)
b the minimum
c the maximum
d the range
e the lower quartile (Q_1)
f the upper quartile (Q_3)
g the interquartile range (IQR)

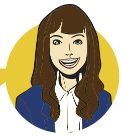
3 Construct a box plot showing these features.

a min = 1, $Q_1 = 3$, $Q_2 = 4$, $Q_3 = 7$, max = 8
b outlier = 5, minimum above outlier = 10, $Q_1 = 12$, $Q_2 = 14$, $Q_3 = 15$, max = 17

Box plot shape:



Include an even scale.



4 Select from the list below to fill in the blanks.

minimum,Q_1, Q_2, Q_3, *maximum*

a The top 25% of data are above ________.
b The middle 50% of data are between _____ and _____.
c The lowest or first 25% of data are between the _____ and _____.
d The highest or last 25% of data are between _____ and the _____.

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Example 13 Constructing box plots with no outliers

Consider the given data set.

12 26 14 11 15 10 18 17 21 27

a Find the five-figure summary (the minimum, lower quartile (Q_1), median (Q_2), upper quartile (Q_3) and the maximum).

b Draw a box plot to summarise the data.

SOLUTION

a 10 11 12 14 15 | 17 18 21 26 27

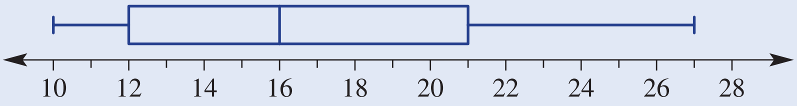
min Q_1 $Q_2 = \frac{15 + 17}{2}$ $= 16$ Q_3 max

Minimum = 10

$Q_1 = 12$, $Q_2 = 16$, $Q_3 = 21$

Maximum = 27

b



EXPLANATION

a Order the data from smallest to largest.

Locate the median (Q_2) first. For 10 data values there are two middle values, 15 and 17. Average these to find Q_2.

Split the data in half at the median. Q_1 is the middle value of the lower half. Q_3 is the middle value of the upper half. The minimum is the smallest value and the maximum is the largest value.

b Draw an even scale covering the minimum and maximum values.

Mark the minimum (10), Q_1(12), Q_2(16), Q_3(21) and the maximum (27) to draw the box plot.

5 Complete the following for the given data sets.

- **i** Find the five-figure summary (minimum, Q_1, Q_2, Q_3, maximum).
- **ii** Draw a box plot to summarise the data.

a 11, 15, 18, 17, 1, 2, 8, 12, 19, 15

b 0, 1, 5, 4, 4, 4, 2, 3, 3, 1, 4, 3

c 124, 118, 119, 117, 120, 120, 121, 118, 122

d 62, 85, 20, 34, 40, 66, 47, 82, 25, 32, 28, 49, 41, 30, 22

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Example 14 Constructing box plots with outliers

Consider the given data set.

5, 9, 4, 3, 5, 6, 6, 5, 7, 12, 2, 3, 5

a Determine the quartiles Q_1, Q_2 and Q_3.

b Determine whether any outliers exist.

c Draw a box plot to summarise the data, marking outliers if they exist.

SOLUTION

a $\boxed{2\ 3\ \underbrace{3\ 4}_{\substack{\uparrow\\ Q_1}}\ 5\ 5}\ \underset{\substack{\uparrow\\ Q_2}}{\textcircled{5}}\ \boxed{5\ 6\ \underbrace{6\ 7}_{\substack{\uparrow\\ Q_3}}\ 9\ 12}$

$$Q_1 = \frac{3+4}{2} = 3.5 \qquad Q_3 = \frac{6+7}{2} = 6.5$$

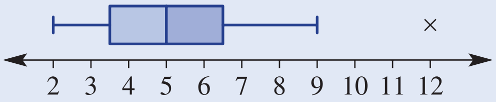
b $\text{IQR} = 6.5 - 3.5 = 3$

$Q_1 - 1.5 \times \text{IQR} = 3.5 - 1.5 \times 3 = -1$

$Q_3 + 1.5 \times \text{IQR} = 6.5 + 1.5 \times 3 = 11$

$\therefore$ 12 is an outlier.

c



EXPLANATION

Order the data to help find the quartiles.

Locate the median Q_2 (the middle value), then split the data in half above and below this value.

Q_1 is the middle value of the lower half and Q_3 is the middle value of the upper half. Average the two middle values to find the median.

Determine $\text{IQR} = Q_3 - Q_1$.

Check for any outliers; i.e. numbers below $Q_1 - 1.5 \times \text{IQR}$ or above $Q_3 + 1.5 \times \text{IQR}$.

There are no data below -1 but $12 > 11$.

Draw a line and mark in a uniform scale reaching from 2 to 12. Sketch the box plot by marking the minimum 2 and the outlier 12, and Q_1, Q_2 and Q_3. The end of the five-point summary is the nearest value below 11; i.e. 9.

6 Complete the following for the data sets below.

- **i** Determine the quartiles Q_1, Q_2 and Q_3.
- **ii** Determine whether any outliers exist.
- **iii** Draw a box plot to summarise the data, marking outliers if they exist.

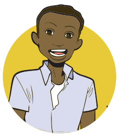
a 4, 6, 5, 2, 3, 4, 4, 13, 8, 7, 6

b 1.8, 1.7, 1.8, 1.9, 1.6, 1.8, 2.0, 1.1, 1.4, 1.9, 2.2

c 21, 23, 18, 11, 16, 19, 24, 21, 23, 22, 20, 31, 26, 22

d 37, 48, 52, 51, 51, 42, 48, 47, 39, 41, 65

Outliers:
more than $Q_3 + 1.5 \times \text{IQR}$
or
less than $Q_1 - 1.5 \times \text{IQR}$
Mark with a cross.
The next value above or below an outlier is used as the new end of the whisker.



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PROBLEM-SOLVING AND REASONING

7, 9 8–10

7 A butcher records the weight (in kilograms) of a dozen parcels of sausages sold on one morning.

1.6 1.9 2.0 2.0 2.1 2.2
2.2 2.4 2.5 2.7 3.8 3.9

a Write down the value of:

i minimum **ii** Q_1 **iii** Q_2
iv Q_3 **v** maximum **vi** IQR

b Find any outliers.

c Draw a box plot for the weight of the parcels of sausages.

8 Phillip the gardener records the number of days that it takes for 11 special bulbs to germinate. The results are:

8 14 15 15 16 16 16 17 19 19 24

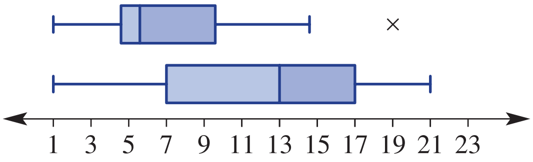
a Write down the value of:

i minimum **ii** Q_1 **iii** Q_2
iv Q_3 **v** maximum **vi** IQR

b Are there any outliers? If so, what are they?

c Draw a box plot for the number of days it takes for the bulbs to germinate.

9 Consider these parallel box plots, A and B.



Parallel box plots are two box plots that can be compared using the same scale.

Compare the box plots at each point of the five-figure summary.

a What statistical measure do these box plots have in common?

b Which data set (A or B) has a wider range of values?

c Find the IQR for:

i data set A **ii** data set B

d How would you describe the main difference between the two sets of data from which the parallel box plots have been drawn?

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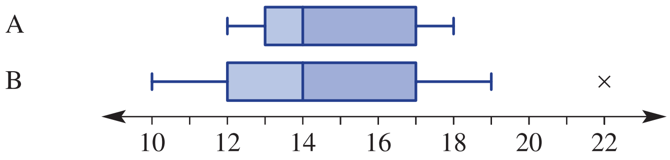
10 Two data sets can be compared using parallel box plots on the same scale, as shown below.



a What statistical measures do these box plots have in common?

b Which data set (A or B) has a wider range of values?

c Find the IQR for:

  i data set A **ii** data set B

d How would you describe the main difference between the two sets of data from which the parallel box plots have been drawn?

ENRICHMENT – 11

Creating parallel box plots

11 Fifteen essays were marked for spelling errors by a particular examiner and the following numbers of spelling errors were counted.

3, 2, 4, 6, 8, 4, 6, 7, 6, 1, 7, 12, 7, 3, 8

The same 15 essays were marked for spelling errors by a second examiner and the following numbers of spelling errors were counted.

12, 7, 9, 11, 15, 5, 14, 16, 9, 11, 8, 13, 14, 15, 13

a Draw parallel box plots for the data.

b Do you believe there was a major difference in the way the essays were marked by the two examiners? If yes, describe this difference.

5G Displaying and analysing time-series data

Interactive

Widgets

HOTsheets

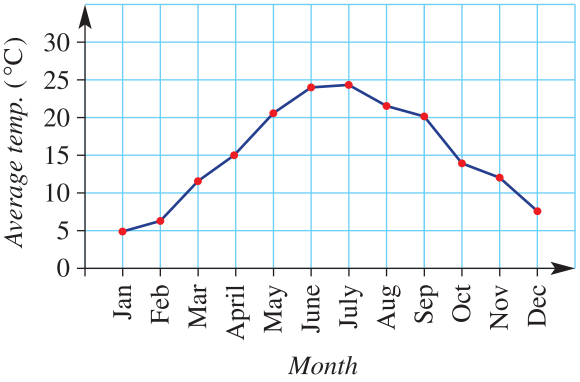
Walkthrough

A time series is a sequence of data values that are recorded at regular time intervals. Examples include temperature recorded on the hour, speed recorded every second, population recorded every year and profit recorded every month. A line graph can be used to represent time-series data. This can help to analyse the data, describe trends and make predictions about the future.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Changing temperatures

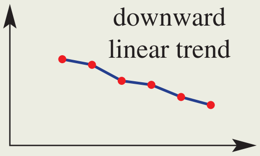
The average monthly maximum temperature for a city is illustrated by this graph.

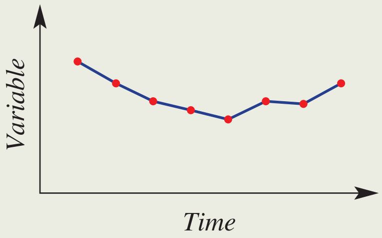


- Describe the trend in the data at different times of the year.
- Explain why the average maximum temperature for December is close to the average maximum temperature for January.
- Do you think this graph is for an Australian city? Explain.
- If another year of temperatures was included on this graph, what would you expect the shape of the graph to look like?
- Do you think this city is in the Northern Hemisphere or the Southern Hemisphere? Give a reason.

Key ideas

- **Time-series data** are recorded at regular time intervals.
- The graph or plot of a time series uses:
  - time on the horizontal axis
  - line segments connecting points on the graph.
- If the time-series plot results in points being on or near a straight line, then we say that the trend is linear.





Time-series data A set of data collected in sequence over a period of time

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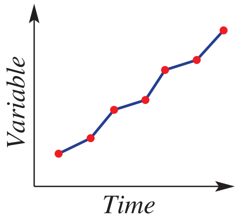
Exercise 5G

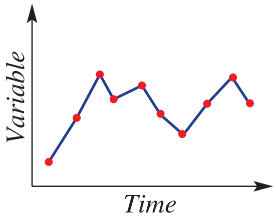
UNDERSTANDING AND FLUENCY	1–4	2, 3, 5

1 Describe the following time-series plots as having a linear (straight line) trend, non-linear trend (a curve) or no trend.

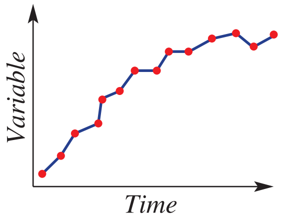
a



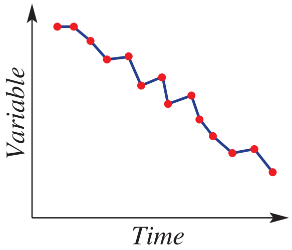
b



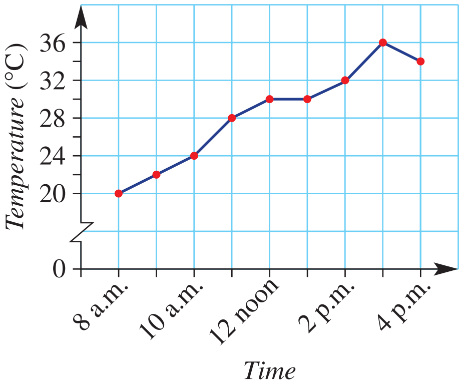
c



d



2 This time-series graph shows the temperature over the course of 8 hours of a day.



a State the temperature at:
  - **i** 8 a.m.
  - **ii** 12 noon
  - **iii** 1 p.m.
  - **iv** 4 p.m.

b What was the maximum temperature?

c During what times did the temperature:
  - **i** stay the same?
  - **ii** decrease?

d Describe the general trend in the temperature for the 8 hours.

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Example 15 Plotting and interpreting a time-series plot

The approximate population of a small town was recorded from 2000 to 2015.

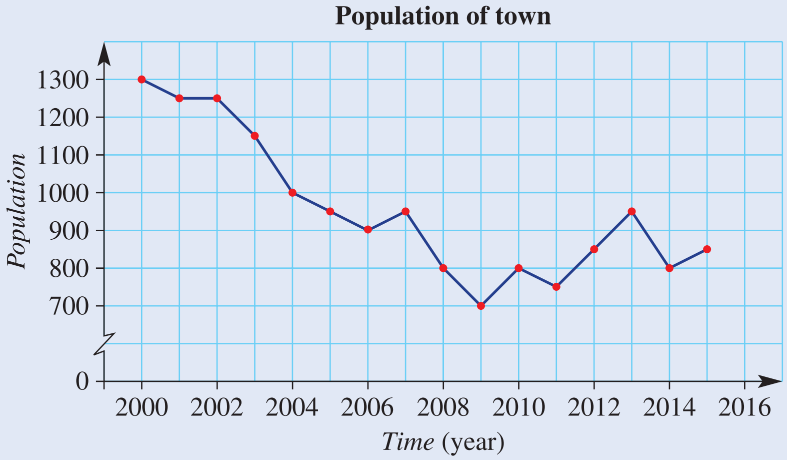
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Population	1300	1250	1250	1150	1000	950	900	950	800	700	800	750	850	950	800	850

a Plot the time series.

b Describe the trend in the data over the 16 years.

SOLUTION

a



b The population declines steadily for the first 10 years. The population rises and falls in the last 6 years, resulting in a slight upwards trend.

EXPLANATION

Use time on the horizontal axis.

Break the *y*-axis so as to not include 0–700. Label an even scale on each axis.

Join points with line segments.

Interpret the overall rise and fall of the lines on the graph.

3 The approximate population of a small town is recorded from 2005 to 2015.

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Population	550	500	550	600	700	650	750	750	850	950	900

a Plot the time-series graph. Break the *y*-axis so it does not include 0–500.

b Describe the general trend in the data over the 11 years.

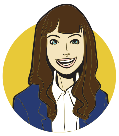
c For the 11 years, what was the:

  i minimum population?

  ii maximum population?

The year will be on the horizontal axis. Place population on the vertical axis.

The vertical axis will need to range from 500 to 950. A scale going up in 100s would suit.



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4 A company's share price over 12 months is recorded in this table.

Month	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Price ($)	1.30	1.32	1.35	1.34	1.40	1.43	1.40	1.38	1.30	1.25	1.22	1.23

a Plot the time-series graph. Break the y-axis to exclude values from \$0 to \$1.20.

b Describe the way in which the share price has changed over the 12 months.

c What is the difference between the maximum and minimum share price in the 12 months?

The scale on the vertical axis will need to include from \$1.20 to \$1.43. Choose an appropriate scale.

5 The pass rate (%) over 10 years for a particular examination is given in a table.

Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Pass rate (%)	74	71	73	79	85	84	87	81	84	83

a Plot the time-series graph for the 10 years.

b Describe the way in which the pass rate for the examination has changed in the given time period.

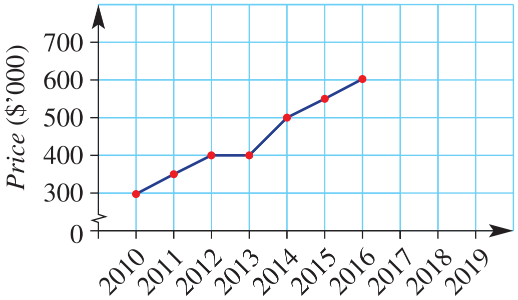
c In what year was the pass rate the maximum?

d By how much had the pass rate improved from 2006 to 2010?

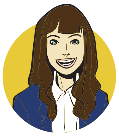
PROBLEM-SOLVING AND REASONING

	6, 7	6, 8, 9

6 This time-series plot shows the upwards trend of house prices in an Adelaide suburb over 7 years from 2010 to 2016.



Recall that a linear trend has the points on or near a straight line.



a Would you say that the general trend in house prices is linear or non-linear?

b Assuming that the trend in house prices continues for this suburb, what would you expect the house price to be in:

i 2017? **ii** 2019?

7 The following data show the monthly sales of strawberries (\$'000s) for a particular year.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sales ($'000s)	22	14	9	11	12	9	7	9	8	10	18	25

a Plot the time-series graph for the year.

b Describe any trends in the data over the year.

c Give a reason why you think the trends you observed may have occurred.

\$'000s means 22 represents \$22 000.

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8 The two top-selling book stores for a company list their sales figures for the first 6 months of the financial year. Sales amounts are in thousands of dollars.

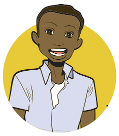
	July	August	September	October	November	December
City Central ($'000)	12	13	12	10	11	13
Chatswood ($'000)	17	19	16	12	13	9

a What was the difference in the sales figure for:
i August? **ii** December?

b In how many months did the City Central store sell more books than the Chatswood store?

c Construct a time-series plot for both stores on the same set of axes.

Use different colours for the two line graphs.



d Describe the trend of sales for the 6 months for:
i City Central **ii** Chatswood

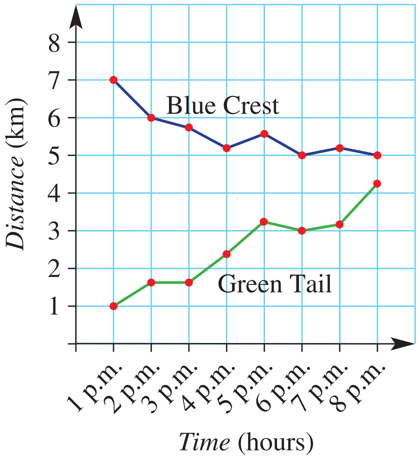
e Based on the trend for the sales for the Chatswood store, what would you expect the approximate sales figure to be in January?

9 Two pigeons (Green Tail and Blue Crest) each have a beacon that communicates with a recording machine. The distance of each pigeon from the machine is recorded every hour for 8 hours.

a State the distance from the machine at 3 p.m. of the:
i Blue Crest **ii** Green Tail

b Describe the trend in the distance from the recording machine for the:
i Blue Crest **ii** Green Tail

c Assuming that the given trends continue, predict the time when the pigeons will be the same distance from the recording machine.



ENRICHMENT – 10

Same data, different interpretations

10 The table shows the number of people in employment during a period in which the same government is in power.

Year in government	Number employed (millions)
1	1.01
2	1.18
3	1.58
4	1.72
5	1.94
6	2.34
7	2.50
8	2.32
9	2.33
10	2.41

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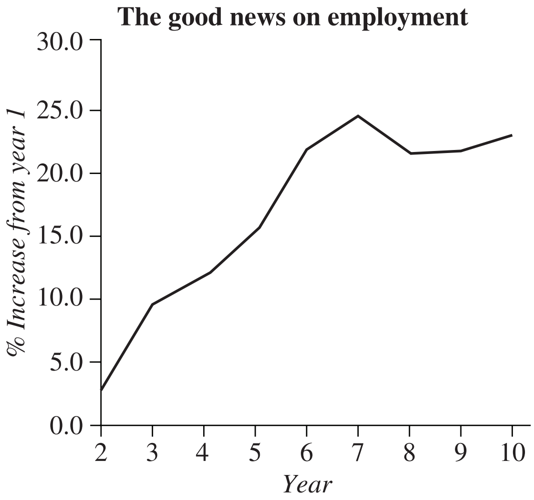
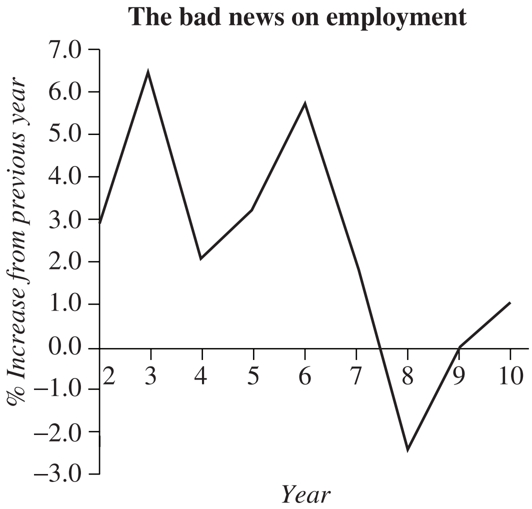
The government and the opposition interpreted these figures in quite different ways in the lead up to the election. They produced graphs in their advertising material with the headings shown below.

- **i** the government



- **ii** the opposition



a Explain what general impression each graph has been intended to give.

b By considering the vertical axis and what each graph is showing, explain how each effect has been achieved.

c Which graph do you believe reflects the situation more accurately? Explain your choice.

d Look for a graph in a magazine or newspaper where you think the data have been distorted to portray a particular belief.

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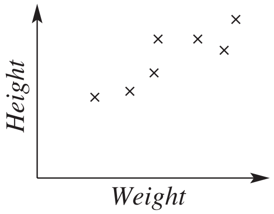
5H Bivariate data and scatter plots

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

When we collect information about two variables in a given context we are collecting bivariate data. As there are two variables involved in bivariate data, we use a number plane to graph the data. These graphs are called scatter plots and are used to show a relationship that may exist between the variables. Scatter plots make it very easy to see the strength of the relationship between the two variables.



Let's start: A relationship or not?

Consider the two variables in each part below.

- Would you expect there to be some relationship between the two variables in each of these cases?
- If you feel that a relationship exists, would you expect the second-listed variable to increase or to decrease as the first variable increases?
  - **a** Height of person and Weight of person
  - **b** Temperature and Life of milk
  - **c** Length of hair and IQ
  - **d** Depth of topsoil and Brand of motorcycle
  - **e** Years of education and Income
  - **f** Spring rainfall and Crop yield
  - **g** Size of ship and Cargo capacity
  - **h** Fuel economy and CD track number
  - **i** Amount of traffic and Travel time
  - **j** Cost of 2 litres of milk and Ability to swim
  - **k** Background noise and Amount of work completed

Key ideas

- **Bivariate data** are data that involves two variables.
  - The two variables are usually related; for example, height and weight.
- A **scatter plot** is a graph on a number plane in which the axes variables correspond to the two variables from the bivariate data. Points are marked with a cross.
- The words *relationship*, *correlation* and *association* are used to describe the way in which the variables are related.

Bivariate data Data that involves two variables

Scatter plot A diagram that uses coordinates to display values for two variables for a set of data

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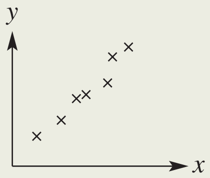
Key ideas

- Types of correlation:
  - The correlation is positive if the y variable generally increases as the x variable increases.
  - The correlation is negative if the y variable generally decreases as the x variable increases.

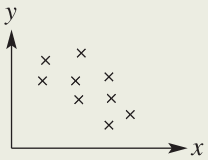
  Examples:

Strong positive correlation



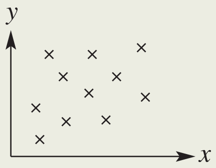
As x increases, y clearly increases.

Weak negative correlation



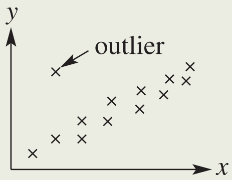
As x increases, y generally decreases.

No correlation



As x increases, there is no particular effect on y.

- An outlier can clearly be identified as a data point that is isolated from the rest of the data.



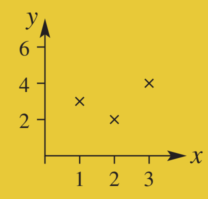
Exercise 5H

UNDERSTANDING AND FLUENCY 1–5 3, 4, 6

1 Decide whether it is likely or unlikely that there will be a strong relationship between these pairs of variables.

a height of door and width of door
b weight of car and fuel consumption
c temperature and length of phone calls
d colour of flower and strength of perfume
e amount of rain and size of vegetables in the vegetable garden

On a scatter plot, mark each point of the plot with a cross.



2 Complete the following for each of the following sets of bivariate data with variables x and y.

i Draw a scatter plot by hand.
ii Decide whether y generally increases or decreases as x increases.

a

x	1	2	3	4	5	6	7	8	9	10
y	3	2	4	4	5	8	7	9	11	12

b

x	0.1	0.3	0.5	0.9	1.0	1.1	1.2	1.6	1.8	2.0	2.5
y	10	8	8	6	7	7	7	6	4	3	1

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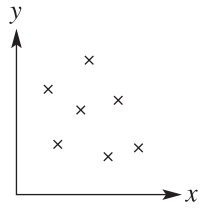
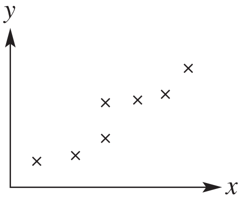
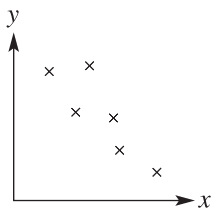
3 For these scatter plots, choose two words from those listed below to best describe the correlation between the two variables.

strong *weak* *positive* *negative*

a


b


c


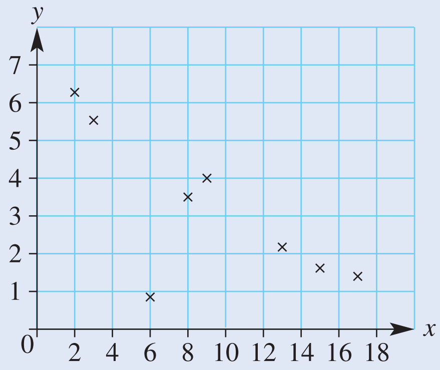
Example 16 Constructing and interpreting scatter plots

Consider this simple bivariate data set.

x	13	9	2	17	3	6	8	15
y	2.1	4.0	6.2	1.3	5.5	0.9	3.5	1.6

a Draw a scatter plot for the data.
b Describe the correlation between x and y as positive or negative.
c Describe the correlation between x and y as strong or weak.
d Identify any outliers.

SOLUTION	EXPLANATION
a (see scatter plot below)	Draw an appropriate scale on each axis by looking at the data: • x is up to 17 • y is up to 6.2 The scale must be spread evenly on each axis. Plot each point, using a cross symbol, on graph paper.
b negative correlation	Looking at the scatter plot, as x increases y decreases.
c strong correlation	The downwards trend in the data is clearly defined.
d The outlier is (6, 0.9).	This point defies the trend.

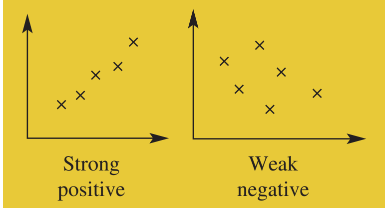


4 Consider this simple bivariate data set.

x	1	2	3	4	5	6	7	8
y	1.0	1.1	1.3	1.3	1.4	1.6	1.8	1.0

a Draw a scatter plot for the data.
b Describe the correlation between x and y as positive or negative.
c Describe the correlation between x and y as strong or weak.
d Identify any outliers.

Correlation



5 Consider this simple bivariate data set.

x	14	8	7	10	11	15	6	9	10
y	4	2.5	2.5	1.5	1.5	0.5	3	2	2

a Draw a scatter plot for the data.
b Describe the correlation between x and y as positive or negative.
c Describe the correlation between x and y as strong or weak.
d Identify any outliers.

6 By completing scatter plots for each of the following data sets, describe the correlation between x and y as positive, negative or none.

a

x	1.1	1.8	1.2	1.3	1.7	1.9	1.6	1.6	1.4	1.0	1.5
y	22	12	19	15	10	9	14	13	16	23	16

b

x	4	3	1	7	8	10	6	9	5	5
y	115	105	105	135	145	145	125	140	120	130

c

x	28	32	16	19	21	24	27	25	30	18
y	13	25	22	21	16	9	19	25	15	12

PROBLEM-SOLVING AND REASONING

7, 8 8–10

7 A tomato grower experiments with a new organic fertiliser and sets up five separate garden beds: A, B, C, D and E. The grower applies different amounts of fertiliser to each bed and records the diameter of each tomato picked.

The average diameter of a tomato from each garden bed and the corresponding amount of fertiliser are recorded below.

Bed	**A**	**B**	**C**	**D**	**E**
Fertiliser (grams per week)	20	25	30	35	40
Average diameter (cm)	6.8	7.4	7.6	6.2	8.5

a Draw a scatter plot for the data with ‘Average diameter’ on the vertical axis and ‘Fertiliser’ on the horizontal axis. Label the points A, B, C, D and E.
b Which garden bed appears to go against the trend?
c According to the given results, would you be confident in saying that the amount of fertiliser fed to tomato plants effects the size of the tomato produced?

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8 For common motor vehicles, consider the two variables *Engine size* (cylinder volume) and *Fuel economy* (number of kilometres travelled for every litre of petrol).

a Do you expect there to be some relationship between these two variables?

b As the engine size increases, would you expect the fuel economy to increase or decrease?

c The following data were collected for 10 vehicles.

Car	A	B	C	D	E	F	G	H	I	J
Engine size	1.1	1.2	1.2	1.5	1.5	1.8	2.4	3.3	4.2	5.0
Fuel economy	21	18	19	18	17	16	15	20	14	11

i Do the data generally support your answers to parts **a** and **b** above?

ii Which car gives a fuel economy reading that does not support the general trend?

9 On 14 consecutive days a local council measures the volume of sound (in decibels) heard from a freeway at various points in a local suburb. The volume (V) of sound is recorded against the distance (d m) between the freeway and the point in the suburb.

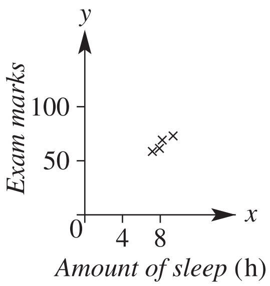
Distance (d)	200	350	500	150	1000	850	200	450	750	250	300	1500	700	1250
Volume (V)	4.3	3.7	2.9	4.5	2.1	2.3	4.4	3.3	2.8	4.1	3.6	1.7	3.0	2.2

a Draw a scatter plot of V against d, plotting V on the vertical axis and d on the horizontal axis.

b Describe the correlation between d and V as positive, negative or none.

c Generally, as d increases, does V increase or decrease?

10 A person presents you with this scatter plot and suggests to you that there is a strong correlation between the amount of sleep and exam marks achieved. What do you suggest is the problem with the person's graph and conclusions?



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ENRICHMENT – 11

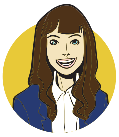
Crime rates and police

11 A government department is interested in convincing the electorate that a large number of police on patrol leads to lower crime rates. Two separate surveys are completed over a one-week period and the results are listed in this table.

	Area	A	B	C	D	E	F	G
Survey 1	Number of police	15	21	8	14	19	31	17
	Incidence of crime	28	16	36	24	24	19	21
Survey 2	Number of police	12	18	9	12	14	26	21
	Incidence of crime	26	25	20	24	22	23	19

a Using scatter plots, determine whether or not there is a relationship between the number of police on patrol and the incidence of crime, using the data in:
  i survey 1
  ii survey 2

Number of police will be on the horizontal axis.



b Which survey results do you think the government will use to make its point? Why?

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5I Line of best fit by eye EXTENSION

Interactive

Widgets

HOTsheets

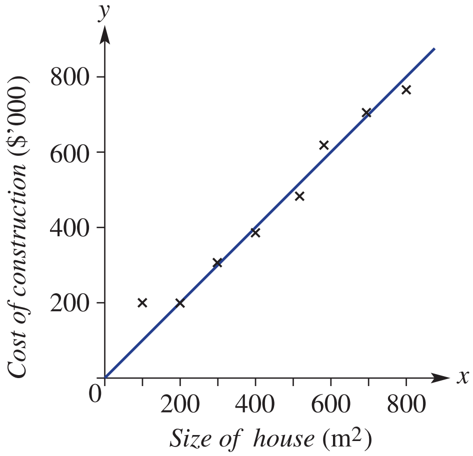
Walkthrough

When bivariate data have a strong linear correlation, we can model the data with a straight line. This line is called a trend line or line of best fit. When we fit the line ‘by eye’, we try to balance the number of data points above the line with the number of points below the line. This trend line can then be used to construct other data points inside and outside the existing data points.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let’s start: Size versus cost

This scatter plot shows the estimated cost of building a house of a given size by a building company. A trend line has been added to the scatter plot.

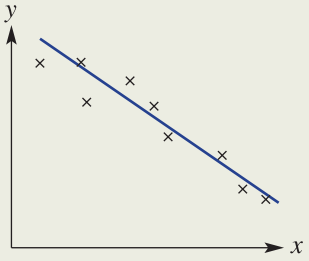


- Why is it appropriate to fit a trend line to the data?
- Do you think the trend line is a good fit to the points on the scatter plot? Why?
- How can you predict the cost of a house of 1000 m^2 with this building company?

Key ideas

- For bivariate data showing a clearly defined positive or negative correlation, a straight line can be fitted by eye.
- A **line of best fit** (or trend line) is positioned by eye by balancing the number of points above the line with the number of points below the line.
  - The distance of each point from the trend line also needs to be taken into account.
  - Outliers should be ignored.
- The line of best fit can be used for:
  - interpolation: finding unknown points within the given data range
  - extrapolation: finding points outside the given data range.

Line of best fit A line that has the closest fit to a set of data points displayed in a scatter plot



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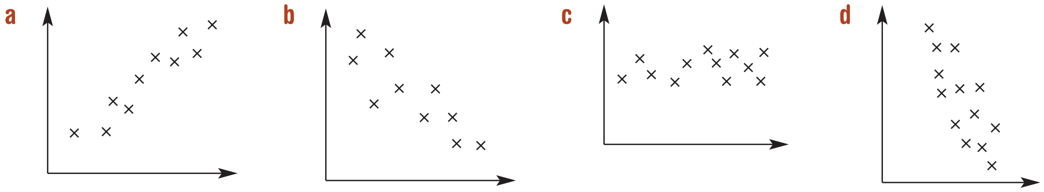
Exercise 5I EXTENSION

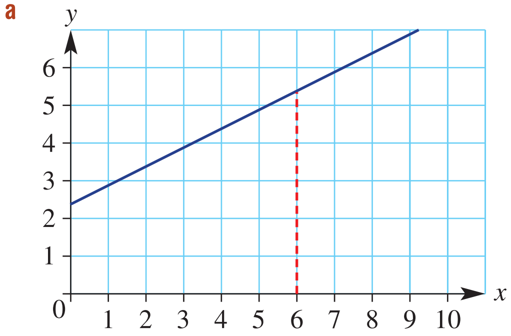
UNDERSTANDING AND FLUENCY 1–5, 7 4, 6–8

1 **a** When is it suitable to add a line of best fit to a scatter plot?
b Describe the general guideline for placing a line of best fit.

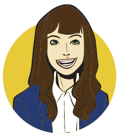
2 Practise fitting a line of best fit onto these scatter plots by trying to balance the number of points above the line with the number of points below the line. (Using a pencil might help.)

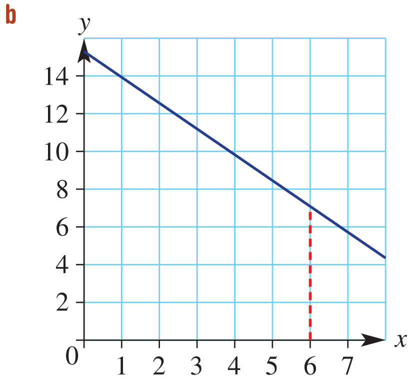


3 For each graph, use the line of best fit shown to estimate the y value when $x = 6$.

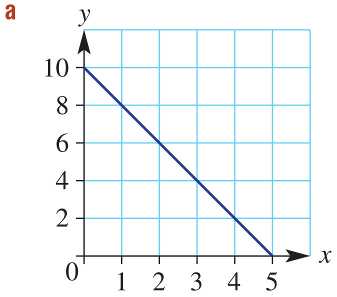


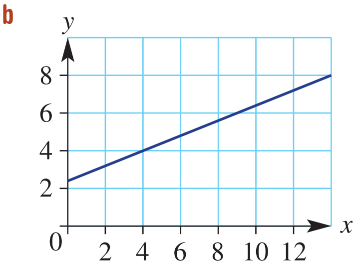
Continue a horizontal line to the y-axis from where the vertical dashed line touches the line of best fit.





4 For each graph, use the line of best fit shown to find the x value when $y = 7$.





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Example 17 Fitting a line of best fit

Consider the variables x and y and the corresponding bivariate data.

x	1	2	3	4	5	6	7
y	1	2	2	3	4	4	5

a Draw a scatter plot for the data.

b Is there positive, negative or no correlation between x and y?

c Fit a line of best fit by eye to the data on the scatter plot.

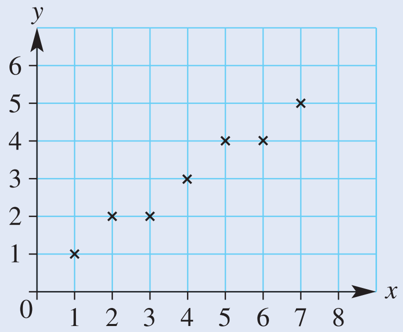
d Use your line of best fit to estimate:

- **i** y when $x = 3.5$
- **ii** y when $x = 0$
- **iii** x when $y = 1.5$
- **iv** x when $y = 5.5$

SOLUTION

EXPLANATION

a

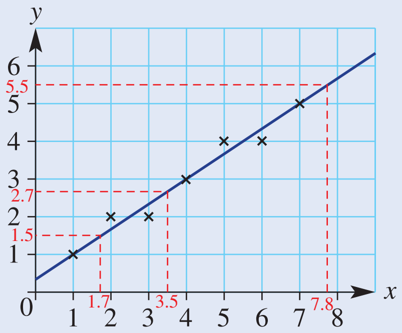


Plot the points on graph paper.

b positive correlation

As x increases, y increases.

c



Since a relationship exists, draw a line on the plot, keeping the same number of points above as below the line (there are no outliers in this case).

d **i** $y \approx 2.7$

ii $y \approx 0.4$

iii $x \approx 1.7$

iv $x \approx 7.8$

Start at $x = 3.5$. Draw a vertical line to the line of best fit, then draw a horizontal line to the y-axis and read off your solution.

Extend vertical and horizontal lines from the values given and read off your solution.

As they are approximations, we use the ≈ sign and not the = sign.

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5 Consider the variables x and y and the corresponding bivariate data.

x	1	2	3	4	5	6	7
y	2	2	3	4	4	5	5

a Draw a scatter plot for the data.

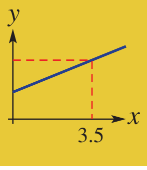
b Is there positive, negative or no correlation between x and y?

c Fit a line of best fit by eye to the data on the scatter plot.

d Use your line of best fit to estimate:

- **i** y when $x = 3.5$
- **ii** y when $x = 0$
- **iii** x when $y = 2$
- **iv** x when $y = 5.5$

Locate $x = 3.5$ and read off the y value.



6 Consider the variables x and y and the corresponding data below.

x	1	2	4	5	7	8	10	12
y	20	16	17	16	14	13	9	10

a Draw a scatter plot for the data.

b Is there positive, negative or no correlation between x and y?

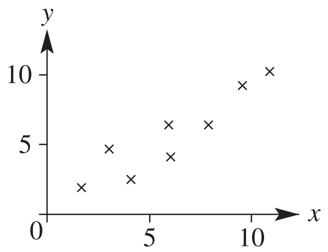
c Fit a line of best fit by eye to the data on the scatter plot.

d Use your line of best fit to estimate:

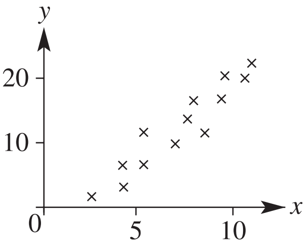
- **i** y when $x = 7.5$
- **ii** y when $x = 0$
- **iii** x when $y = 12$
- **iv** x when $y = 15$

7 For the following scatter plots, pencil in a line of best fit by eye, and then use your line to estimate the value of y when $x = 5$.

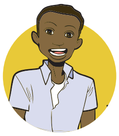
a



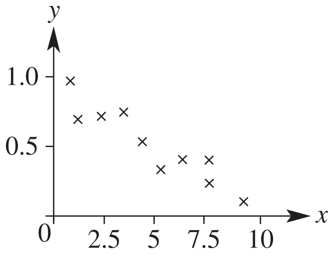
b



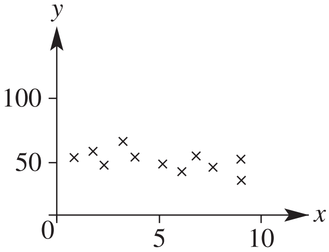
Aim to balance the number of points above and below the line.



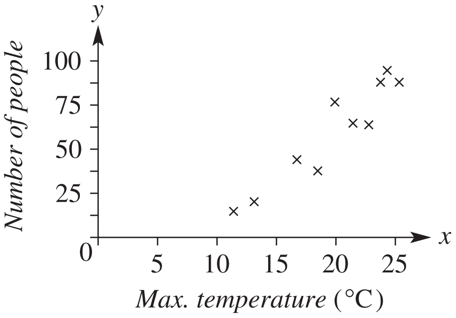
c



d



8 The following chart shows data for the *Number of people* entering a suburban park and the corresponding *Maximum temperature* for 10 spring days.



a Generally, as the maximum daily temperature increases, does the number of people who enter the park increase or decrease?

b Draw a line of best fit by eye on the given chart.

c Use your line of best fit to estimate:

i the number of people expected to enter the park if the maximum daily temperature is 20°C

ii the maximum daily temperature when the total number of people who visit the park on a particular day is 25.

PROBLEM-SOLVING AND REASONING

9, 10 10, 11

9 A small book shop records its profit and number of customers for the past 8 days.

Number of customers	6	12	15	9	8	5	8
Profit ($)	200	450	550	300	350	250	300

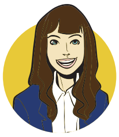
a Draw a scatter plot for the data, using profit on the vertical axis.

b Fit a line of best fit by eye.

c Use your line of best fit to predict the profit for 17 customers.

d Use your line of best fit to predict the number of customers for a $100 profit.

For 17 customers, you will need to extend your line beyond the data. This is called extrapolation.



10 Over eight consecutive years, a city nursery has measured the growth of an outdoor bamboo species for that year. The annual rainfall in the area where the bamboo is growing was also recorded. The data are listed in the table.

Rainfall (mm)	450	620	560	830	680	650	720	540
Growth (cm)	25	45	25	85	50	55	50	20

a Draw a scatter plot for the data, showing growth on the vertical axis.

b Fit a line of best fit by eye.

c Use your line of best fit to estimate the growth expected for the following rainfall readings.

i 500 mm

ii 900 mm

d Use your line of best fit to estimate the rainfall for a given year if the growth of the bamboo was:

i 30 cm

ii 60 cm

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11 At a suburban sports club, the distance record for the hammer throw has increased over time. The first recorded value was 72.3 m in 1967. The most recent record was 118.2 m in 1996. Further details are presented in this table.

Year	1967	1968	1969	1976	1978	1983	1987	1996
New record (m)	72.3	73.4	82.7	94.2	99.1	101.2	111.6	118.2

- **a** Draw a scatter plot for the data.
- **b** Fit a line of best fit by eye.
- **c** Use your line of best fit to estimate the distance record for the hammer throw for the year:
  - **i** 2000
  - **ii** 2015
- **d** Would you say that it is realistic to use your line of best fit to estimate distance records beyond 2015? Why?

ENRICHMENT – 12

Heart rate and age

12 Two independent scientific experiments confirmed a correlation between *Maximum heart rate* and *Age*. The data for the two experiments are presented in this table.

Experiment 1													
Age (years)	15	18	22	25	30	34	35	40	40	52	60	65	71
Max. heart rate	190	200	195	195	180	185	170	165	165	150	125	128	105
Experiment 2													
Age (years)	20	20	21	26	27	32	35	41	43	49	50	58	82
Max. heart rate	205	195	180	185	175	160	160	145	150	150	135	140	90

- **a** Sketch separate scatter plots for experiment 1 and experiment 2, with age on the horizontal axis.
- **b** By fitting a line of best fit by eye to your scatter plots, estimate the maximum heart rate for a person aged 55 years, using the results from:
  - **i** experiment 1
  - **ii** experiment 2
- **c** Estimate the age of a person who has a maximum heart rate of 190, using the results from:
  - **i** experiment 1
  - **ii** experiment 2
- **d** For a person aged 25 years, which experiment estimates a lower maximum heart rate?
- **e** Research the average maximum heart rate of people according to age and compare your research with the results given above.

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1 The mean mass of six boys is 71 kg. The mean mass of five girls is 60 kg. Find the mean mass of all 11 people put together.

2 Sean has a current four-topic average of 78% for Mathematics. What score does he need in the fifth topic to have an overall average of 80%?

3 I am a data set made up of five whole number values. My mode is 2 and both my mean and median are 5. What is my biggest possible range?

4 A single data set has 3 added to every value. Describe the change in:

a the mean
b the median
c the range

5 Find the interquartile range for a set of data if 75% of the data are above 2.6 and 25% of the data are above 3.7.

6 I am a data set with four whole number values.

- I have a range of 8.
- I have a mode of 3.
- I have a median of 6.

What are my four values?

7 A single-ordered data set includes the following data.

2, 4, 5, 6, 8, 10, x

What is the largest possible value of x if it is not an outlier?

8 Describe what happens to the mean, median and mode of a data set if each value in the set is multiplied by 10.

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Chapter summary

Single variable and bivariate statistics

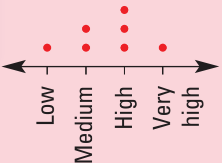
Data

Categorical
- Nominal (e.g. red, blue)
- Ordinal (e.g. low, medium)

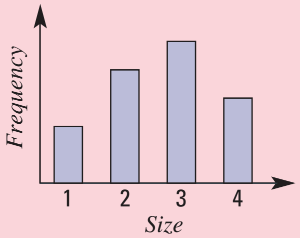
Numerical
- Discrete (e.g. 1, 2, 3)
- Continuous (e.g. 0.31, 0.481)

Graphs for a single set of categorical or discrete data

Dot plot



Column graphs



Stem-and-leaf plot

Stem	Leaf
0	1 6
1	2 7 9
2	3 8
3	4

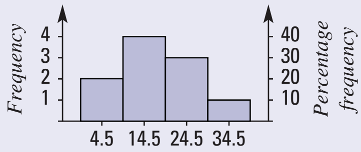
2 | 3 means 23

Frequency tables

Class interval	Frequency	Percentage frequency
0–9	2	20%
10–19	4	40%
20–29	3	30%
30–39	1	10%
Total	10	100%

$$\text{Percentage frequency} = \frac{\text{frequency}}{\text{total}} \times 100$$

Histogram



Measures of centre

- Mean $(\bar{x}) = \frac{\text{sum of all values}}{\text{number of scores}}$
- Median (Q_2) = middle value of ordered data

odd number

$1\ 4\ ⑥\ 9\ 12$

↑

median

even number

$1\ 2\ \underbrace{4\ 6}\ 7\ 11$

$\text{Median} = \frac{4+6}{2}$

$= 5$

- Mode = most common value

Measures of spread

- Range = max − min
- Interquartile range (IQR) $= Q_3 - Q_1$

Quartiles

Q_1: above 25% of the data (middle value of lower half)

Q_3: above 75% of the data (middle value of upper half)

$2\ 3\ 5\ 7\ \underbrace{8\ |\ 9}\ 11\ 12\ 14\ 15$

↑ ↑ ↑

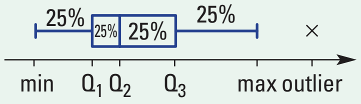
$Q_1 \quad Q_2 = 8.5 \quad Q_3$

$1\ 2\ 3)\ 6\ (7\ 10\ 13$

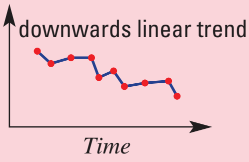
↑ ↑ ↑

$Q_1 = 2 \quad Q_2 \quad Q_3 = 10$

Box plots

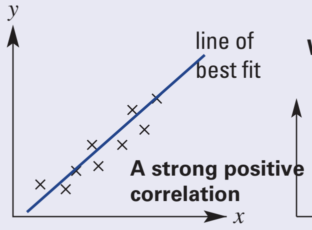


Time-series data



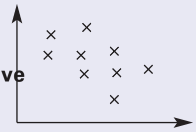
Bivariate data

- Two related variables
- Scatter plot

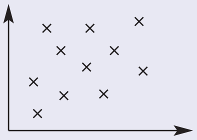


A strong positive correlation

Weak negative correlation



No correlation



Outliers

- Single data set
  - less than $Q_1 - 1.5 \times \text{IQR}$ *or* more than $Q_3 + 1.5 \times \text{IQR}$
- Bivariate
  - not in the vicinity of the rest of the data on the scatter plot

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Multiple-choice questions

1 What type of data is generated by the survey question: ‘what is your favourite sport to play?’

A numerical and discrete

B numerical and continuous

C categorical and continuous

D categorical and nominal

E categorical and ordinal

Questions **2** and **3** refer to the stem-and-leaf plot below.

Stem	Leaf
2	4 9
3	1 1 7 8
4	2 4 6
5	0 4

4 | 2 means 42

2 The minimum score in the data is:

A 4 **B** 0 **C** 24 **D** 38 **E** 54

3 The mode is:

A 3 **B** 31 **C** 4 **D** 38 **E** 30

4 The range and mean of 2, 4, 3, 5, 10 and 6 are:

A range = 8, mean = 5

B range = 4, mean = 5

C range = 8, mean = 4

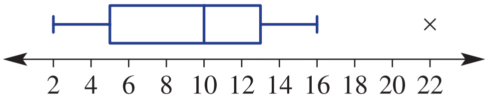
D range = 2 − 10, mean = 6

E range = 8, mean = 6

5 The median of 29, 12, 18, 26, 15 and 22 is:

A 18 **B** 22 **C** 20 **D** 17 **E** 26

Questions **6–8** refer to the box plot below, at right.



6 The interquartile range (IQR) is:

A 8 **B** 5 **C** 3 **D** 20 **E** 14

7 The outlier is:

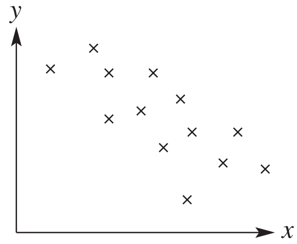
A 2 **B** 0 **C** 20 **D** 16 **E** 22

8 The median is:

A 2 **B** 3 **C** 10 **D** 13 **E** 16

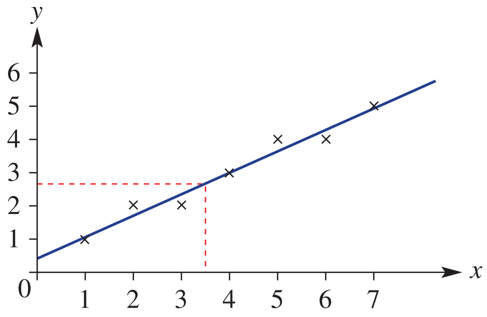
9 The variables x and y in this scatter plot could be described as having:

A no correlation
B strong positive correlation
C strong negative correlation
D weak negative correlation
E weak positive correlation



10 According to this scatter plot, when x is 3.5, y is approximately:

A 4.4 **B** 2.7 **C** 2.5
D 3.5 **E** 5



Short-answer questions

1 A group of 16 people was surveyed to find the number of hours of television they watch in a week. The raw data are listed:

6, 5, 11, 13, 24, 8, 1, 12, 7, 6, 14, 10, 9, 16, 8, 3

a Organise the data into a table with class intervals of 5. Start with 0–4, 5–9 etc. Include a tally, frequency and percentage frequency column.

b Construct a histogram for the data, showing both the frequency and percentage frequency on the graph.

c Would you describe the data as symmetrical or skewed?

2 A basketball team scores the following points per match for a season.

20, 19, 24, 37, 42, 34, 38, 49, 28, 15, 38, 32, 50, 29

a Construct an ordered stem-and-leaf plot for the data.

b Describe the distribution of scores.

3 For the following sets of data, determine:

i the mean **ii** the range **iii** the median

a 2, 7, 4, 8, 3, 6, 5
b 10, 55, 67, 24, 11, 16
c 1.7, 1.2, 1.4, 1.6, 2.4, 1.3

4 Thirteen adults compare their ages at a party. They are:

40, 41, 37, 32, 48, 43, 32, 76, 29, 33, 26, 38, 87

a Find the mean age of the adults, to 1 decimal place.

b Find the median age of the adults.

c Why do you think the mean age is larger than the median age?

5 Determine Q_1, Q_2 and Q_3 for these sets of data.

a 4, 5, 8, 10, 10, 11, 12, 14, 15, 17, 21 **b** 14, 6, 2, 23, 11, 6, 15, 14, 12, 18, 16, 10

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6 For each set of data below, complete the following tasks.

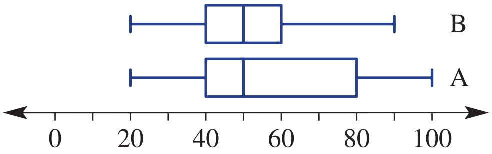
- **i** Find the lower quartile (Q_1) and the upper quartile (Q_3).
- **ii** Find the interquartile range ($IQR = Q_3 - Q_1$).
- **iii** Locate any outliers.
- **iv** Draw a box plot.

a 2, 2, 3, 3, 3, 4, 5, 6, 12

b 11, 12, 15, 15, 17, 18, 20, 21, 24, 27, 28

c 2.4, 0.7, 2.1, 2.8, 2.3, 2.6, 2.6, 1.9, 3.1, 2.2

7 Compare these parallel box plots, A and B, and answer the following as true or false.



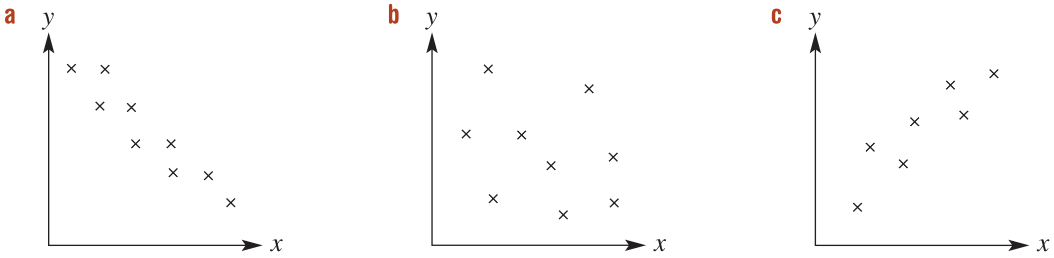
a The range for A is greater than the range for B.

b The median for A is equal to the median for B.

c The interquartile range is smaller for B.

d 75% of the data for A sits below 80.

8 For the scatter plots below, describe the correlation between x and y as positive, negative or none.



9 Consider the simple bivariate data set.

x	1	4	3	2	1	4	3	2	5	5
y	24	15	16	20	22	11	5	17	6	8

a Draw a scatter plot for the data.

b Describe the correlation between x and y as positive or negative.

c Describe the correlation between x and y as strong or weak.

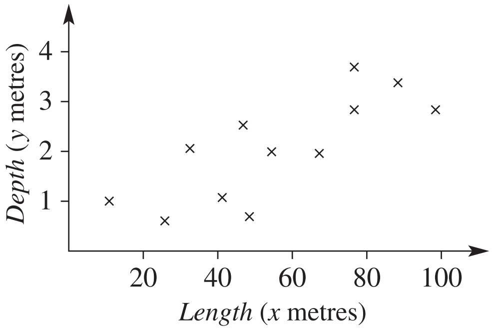
d Identify any outliers.

e Fit a line of best fit by eye.

10 The given scatter plot shows the maximum length (x metres) and depth (y metres) of 11 public pools around town.

a Draw a line of best fit by eye.

b Use your line to estimate the maximum depth of a pool that is 50 m in length.



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Extended-response questions

1 The number of flying foxes taking refuge in a fig tree was recorded over a period of 14 days. The data collected are given here.

Tree	73	50	36	82	15	24	73	57	65	86	51	32	21	39

a Find the IQR.
b Identify any outliers.
c Draw a box plot for the data.

2 A newsagent records the *number of customers* and *profit* for 14 working days.

Number of customers	18	13	15	24	29	12	18	16	15	11	4	32	26	21
Profit ($)	150	70	100	210	240	90	130	110	120	80	30	240	200	190

a Draw a scatter plot for the data and draw a line of best fit by eye. Place *number of customers* on the horizontal axis.
b Use your line of best fit to predict the profit for:
  i 10 customers
  ii 20 customers
  iii 30 customers
c Use your line of best fit to predict the number of customers for a:
  i $50 profit
  ii $105 profit
  iii $220 profit

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Chapter 1: Financial mathematics

Multiple-choice questions

1 Nigel earns $1256 a week. Using 52 weeks in a year, his annual income is:
A $24.15 **B** $32 656 **C** $65 312 **D** $15 072 **E** $12 560

2 Who earns the most?
A Sally: $56 982 p.a.
B Greg: $1986 per fortnight
C Chris: $1095 per week
D Paula: $32.57 per hour, 38-hour weeks for 44 weeks
E Bill: $20 000 p.a.

3 Adriana works 35 hours a week, earning $575.75. Her wage for a 38-hour week would be:
A $16.45 **B** $21 878.50 **C** $625.10 **D** $530.30 **E** $575.75

4 Jake earns a retainer of $420 per week plus a 2% commission on all sales. What is his fortnightly pay when his sales total $56 000 for the fortnight?
A $2240 **B** $840 **C** $1540 **D** $1960 **E** $56 420

5 Danisha earns $4700 gross a month. She has annual deductions of $14 100 in tax and $1664 in health insurance. Her net monthly income is:
A $3386.33 **B** $11 064 **C** $40 636 **D** $72 164 **E** $10 000

Short-answer questions

1 Sean earns $25.76 an hour as a mechanic. Calculate his:
- **a** time and a half rate
- **b** double time rate
- **c** weekly wage for 38 hours at normal rate
- **d** weekly wage for 38 hours at normal rate plus 3 hours at time and a half

2 Wendy earns $25.40 an hour on weekdays and double time on the weekends. Calculate her weekly pay if she works 9 a.m. to 3 p.m. Monday to Friday and 9 a.m. till 11:30 a.m. on Saturday.

3 Cara invests 10% of her net annual salary for one year into an investment account earning 4% p.a. simple interest for 5 years. Calculate the simple interest earned if her annual net salary is $17 560.

4 Marina has a taxable income of $42 600. Calculate her income tax if she falls into the following tax bracket.

$3572 plus 32.5c for
each $1 over $37 000

5 Darren earns $372 per week plus 1% commission on all sales. Find his weekly income if his sales for the week total $22 500.

6 **a** A $120 shirt is discounted by 15%. What is the sale price?
b A $1100 dining table is marked up by 18% of its cost price. What was its cost price, to the nearest dollar?

7 Each fortnight, Raj earns \$1430 gross and pays \$34.94 in superannuation, \$23.40 in union fees and \$493.60 in tax.

a What is Raj's annual gross income?
b How much tax does Raj pay each year?
c What is Raj's net annual income?
d What is Raj's net weekly income?

8 Find the final value of an investment of \$7000 at 6% p.a., compounded annually for 4 years.

Extended-response question

1 A computer, with a recommended retail price of \$749, is offered for sale in three different ways.

Method A	Method B	Method C
5% discount for cash	3% fee for a credit card payment	20% deposit and then \$18.95 per month for 3 years

a Jai pays cash. How much does Jai pay?
b Talia buys a tablet using her mother's credit card. How much more does Talia pay for her tablet compared to Jai?
c Georgia needs to pay for her tablet using method C.
  i Calculate the deposit Georgia needs to pay.
  ii What is the final cost of Georgia purchasing the tablet on terms?
  iii How much interest does Georgia pay on her purchase?
  iv What percentage of the recommended retail price is Georgia's interest? Round your answer to 2 decimal places.

Chapter 2: Measurement

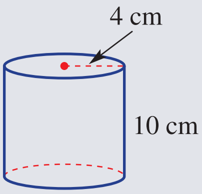
Multiple-choice questions

1 The number of centimetres in 2.8 metres is:
A 0.28 **B** 28 **C** 280 **D** 2.8 **E** 2800

2 A rectangle has length 7 cm and perimeter 22 cm. Its breadth is:
A 7.5 cm **B** 15 cm **C** 14 cm **D** 8 cm **E** 4 cm

3 The area of a circle with diameter 10 cm is given by:
A $\pi(10)^2$ cm^2 **B** $\pi(5)^2$ cm^2 **C** 10π cm^2 **D** $5 \times \pi$ cm^2 **E** 25 cm^2

4 The surface area of this cylinder is closest to:
A 351.9 cm^2 **B** 301.6 cm^2 **C** 175.9 cm^2
D 276.5 cm^2 **E** 183.4 cm^2



5 The area of the triangular cross-section of a prism is 8 mm^2 and the prism's height is 3 mm. The prism's volume is:
A 48 mm^3 **B** 12 mm^3 **C** 24 mm^2
D 24 mm^3 **E** 12 mm^2

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Short-answer questions

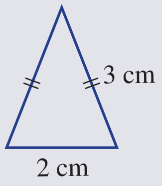
1 Convert these measurements to the units shown in the brackets.

a 0.43 m (cm) **b** 32 000 mm^2 (cm^2) **c** 0.03 m^3 (cm^3) **d** 23 m (mm)

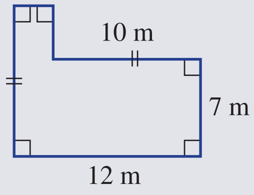
e 8 s (ms) **f** 7.8 s (ns) **g** 8000 t (Mt) **h** 2.3×10^{12} MB (TB)

2 Find the perimeter of each of these shapes.

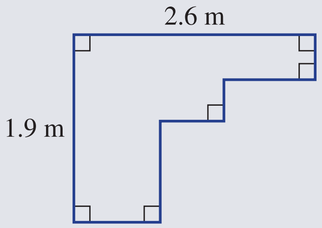
a



b



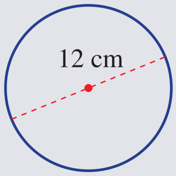
c



3 For these shapes, find, correct to 2 decimal places:

i the perimeter **ii** the area

a



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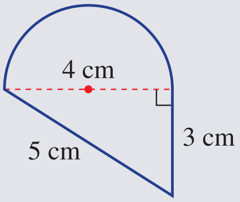

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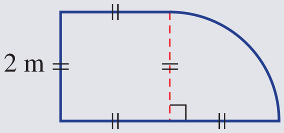
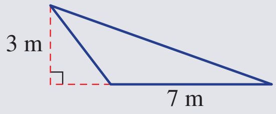
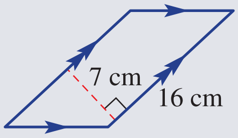


4 Find the area of each of these shapes.

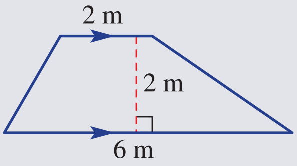
a



b



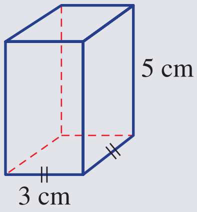
c



5 For these solids, find (correct to 2 decimal places where necessary):

i the volume **ii** the surface area

a



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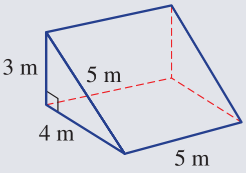
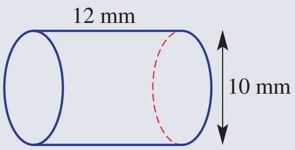
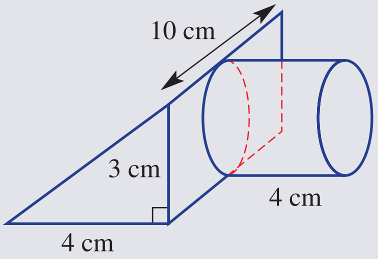


c



6 Find the surface area and volume of this solid, correct to 2 decimal places. You will need Pythagoras' theorem to help find the surface area.



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7 Give the limits of accuracy for each of the following measurements.

a 7 mL **b** 8.99 g

c 700 km (given to three significant figures) **d** 700 km (given to two significant figures)

8 A rectangle has its dimensions given as 4.3 m by 6.8 m.

a Between what two values does the true length lie?

b What are the limits of accuracy for the breadth of this rectangle?

c What are the limits of accuracy for the perimeter and area of this rectangle?

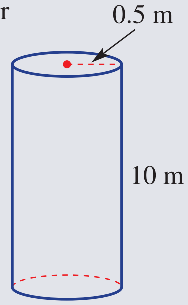
Extended-response question

1 A concrete cylindrical pole has radius 0.5 m and height 10 m. Only the outer curved surface is to be painted. Answer the following to 2 decimal places.

a What volume of concrete is used to make the pole?

b What area is to be painted?

c A litre of paint covers 6 m^2. Paint costs \$12 per litre and there are 18 poles to be painted. What is the cost of paint required? Round to the nearest \$10.



Chapter 3: Algebraic expressions and indices

Multiple-choice questions

1 The expanded and simplified form of $4(2x - 3) - 4$ is:

A $8x - 7$ **B** $6x - 11$ **C** $8x - 16$ **D** $8x - 8$ **E** $6x - 7$

2 The fully factorised form of $4x^2 + 12x$ is:

A $4(x^2 + 3x)$ **B** $4x(x + 12)$ **C** $4(x^2 + 12x)$ **D** $4x(x + 3)$ **E** $2x(x + 6)$

3 $\frac{5(x-2)}{3} \times \frac{12}{x-2}$ simplifies to:

A 20 **B** -6 **C** $\frac{20}{x}$ **D** $16(x - 2)$ **E** $\frac{(x-2)}{6}$

4 Using index laws, $\frac{3x^2y \times 2x^3y^2}{xy^3}$ simplifies to:

A $\frac{5x^5}{y}$ **B** $6x^5$ **C** $\frac{6x^2}{y}$ **D** $6x^4$ **E** $\frac{6x^4}{y}$

5 When expressed with positive indices $(a^3)^4b^{-2}$ is:

A $\frac{a^7}{b^2}$ **B** $\frac{a^{12}}{b^2}$ **C** $\frac{1}{a^7b^2}$ **D** $\frac{a^{12}}{b^{-2}}$ **E** a^7b^2

Short-answer questions

1 Simplify the following.

a $2xy + 7x + 5xy - 3x$ **b** $-3a \times 7b$ **c** $\frac{4a^2b}{8ab}$

2 **a** Expand and simplify the following.

i $-4(x - 3)$ **ii** $3x(5x + 2)$ **iii** $4(2x + 1) + 5(x - 2)$

b Factorise the following.

i $18 - 6b$ **ii** $3x^2 + 6x$ **iii** $-8xy - 12y$

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3 Simplify these algebraic fractions.

a $\frac{6x+18}{6}$ **b** $\frac{3(x-1)}{8x} \div \frac{x-1}{2x}$ **c** $\frac{x}{2}+\frac{2x}{5}$ **d** $\frac{x}{4}-\frac{3}{8}$

4 Use index laws to simplify the following. Express with positive indices.

a $2x^2 \times 5x^4$ **b** $\frac{12x^3y^2}{3xy^5}$ **c** $(2m^4)^3$ **d** $3x^0 + (4x)^0$

e $\left(\frac{3a}{b^4}\right)^2$ **f** $3a^{-5}b^2$ **g** $\frac{4}{t^{-5}}$ **h** $\frac{4x^5y^3 \times 5x^{-2}y}{10x^7y^2}$

5 **a** Write the following as basic numerals.

i 4.73×10^5 **ii** 5.21×10^{-3}

b Convert these to scientific notation, using 3 significant figures.

i 0.000027561 **ii** 8 707 332

Extended-response question

1 Julie invests \$3000 at an interest rate of 6% per year.

a Write a rule for the amount of money, \$$A$, in her account after n years.

b How much will be in her account, correct to 2 decimal places, in:

i 2 years' time? **ii** 6 years' time?

c Use trial and error to determine how long it will take Julie to double her initial investment. Answer to 1 decimal place.

Chapter 4: Probability

Multiple-choice questions

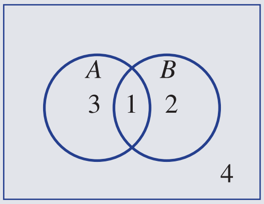
1 A letter is chosen from the word PROBABILITY. What is the probability that it will not be a vowel?

A $\frac{3}{11}$ **B** $\frac{4}{11}$ **C** $\frac{7}{11}$ **D** $\frac{1}{2}$ **E** $\frac{8}{11}$

2 For this Venn diagram, $P(A \text{ or } B)$ is equal to:

A 1 **B** $\frac{1}{6}$ **C** $\frac{1}{10}$

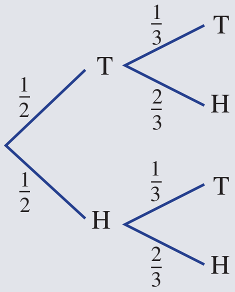
D $\frac{3}{10}$ **E** $\frac{3}{5}$



3 For this tree diagram, what is the probability of the outcome (T, H)?

A $\frac{1}{3}$ **B** $\frac{1}{6}$ **C** $\frac{1}{2}$

D $\frac{1}{4}$ **E** $\frac{2}{3}$



4 When two coins are tossed, what is the probability that at least one of them shows heads?

A $\frac{1}{2}$ **B** $\frac{3}{4}$ **C** $\frac{1}{3}$ **D** $\frac{2}{3}$ **E** $\frac{1}{4}$

5 The number of faults in a computer network over a period of 10 days is recorded in this table.

Number of faults	0	1	2	3
Frequency	1	5	3	1

An estimate for the probability that on the next day there would be at least two errors is:

A $\frac{3}{10}$ **B** $\frac{1}{5}$ **C** $\frac{4}{5}$ **D** $\frac{2}{5}$ **E** $\frac{1}{10}$

Short-answer questions

1 A keen bird-watcher records the number of different species of birds in his backyard over a 20-day period.

Number of species	0	1	2	3	4	5	6
Frequency	0	2	3	8	4	2	1

From these results, estimate the probability that on the next day the bird-watcher will observe the following number of species.

a 3 **b** 2 or 3 **c** fewer than 5 **d** at least 2

2 Of 25 students, 18 are wearing jackets, 14 are wearing hats and 10 are wearing both jackets and hats.

a Represent this information in a Venn diagram.

b Represent this information in a two-way table.

c How many students are wearing neither a hat nor a jacket?

d If a person is chosen randomly from the group, find the probability that the person will be wearing:

i a hat and not a jacket **ii** a hat or a jacket

iii a hat and a jacket **iv** a hat, given that they are wearing a jacket

3 Two fair 6-sided dice are rolled and the total is recorded.

a Complete the table to find the total number of outcomes.

b Find:

i $P(5)$ **ii** $P(7)$

iii $P(\text{at least } 7)$ **iv** $P(\text{at most } 4)$

		Die 2					
		1	**2**	**3**	**4**	**5**	**6**
Die 1	**1**	2	3	4			
	2	3	4				
	3						
	4						
	5						
	6						

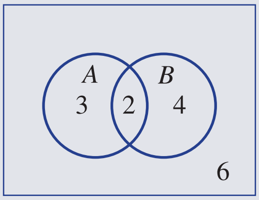
4 Two people are chosen from a group of 2 males and 4 females without replacement. Use a tree diagram to help find the probability of selecting:

a 2 males **b** 1 male and 1 female

c at least 1 female

5 For each diagram, find $P(A)$ and $P(A \text{ given } B)$, and state whether A and B are independent events.

a



b

	A	not A	Total
B	3	2	5
not B	2	1	3
Total	5	3	8

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Extended-response question

1 A hot dog stall produces two types of hot dogs: traditional (T) at \$4 each and Aussie (A) at \$5 each. Leon randomly selects two hot dogs.

	T	**A**
T	(T, T)	
A		

a Complete this table to show the possible selections.

b Find the probability of selecting:

- **i** two Aussie hot dogs
- **ii** at least one Aussie hot dog

c Leon has only \$8. What is the probability that he will be able to afford two hot dogs?

Chapter 5: Single variable and bivariate statistics

Multiple-choice questions

1 The values of a and b in this frequency table are:

A $a = 3, b = 28$
B $a = 4, b = 28$
C $a = 4, b = 19$
D $a = 6, b = 20$
E $a = 3, b = 30$

Colour	Frequency	Percentage frequency (%)
blue	4	16
red	7	b
green	a	12
white	6	24
black	5	20
Total	25	

2 The mean, median and mode of the data set 3, 11, 11, 7, 1, 9 are:

A mean $= 7$, median $= 9$, mode $= 11$
B mean $= 6$, median $= 9$, mode $= 11$
C mean $= 7$, median $= 8$, mode $= 11$
D mean $= 7$, median $= 11$, mode $= 8$
E mean $= 8$, median $= 7$, mode $= 11$

3 For the given stem-and-leaf plot, the range and median, respectively, of the data are:

A 20, 12.5 **B** 7, 12 **C** 27, 12.5
D 29.3 **E** 27, 13

Stem	Leaf
0	2 2 6 7
1	0 1 2 3 5 8
2	3 3 5 7 9

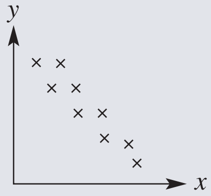
1|5 means 15

4 The interquartile range (IQR) for the data set 2, 3, 3, 7, 8, 8, 10, 13, 15 is:

A 5 **B** 8.5 **C** 7 **D** 13 **E** 8

5 The best description of the correlation between the variables for the scatter plot shown is:

A weak negative **B** strong positive **C** strong negative
D weak positive **E** no correlation



Short-answer questions

1 Twenty people were surveyed to find out how many days in the past completed month they had used public transport. The results were as follows.

7, 16, 22, 23, 28, 12, 18, 4, 0, 5, 8, 19, 20, 22, 14, 9, 21, 24, 11, 10

- **a** Organise the data into a frequency table with class intervals of 0–4, 5–9 etc., and include a percentage frequency column.
- **b** Construct a histogram for the data, showing both the frequency and the percentage frequency on the one graph.
- **c** **i** State the frequency of people who used public transport on 10 or more days.
  - **ii** State the percentage of people who used public transport on fewer than 15 days.
  - **iii** State the most common interval of days for which public transport was used. Can you think of a reason for this?

2 The data shows the number of DVDs owned by students in a school class.

12 24 36 17 8 24 9 4 15 32 41 26 15 18 7

- **a** Display the data using a stem-and-leaf plot.
- **b** Describe the distribution of the data as symmetrical or skewed.

3 For the data set 8, 10, 2, 17, 6, 30, 12, 7, 12, 15, 4:

- **a** Order the data.
- **b** Determine:
  - **i** the minimum and maximum values
  - **ii** the median
  - **iii** the lower quartile (Q_1) and the upper quartile (Q_3)
  - **iv** $\text{IQR}(=Q_3 - Q_1)$
  - **v** any outliers
- **c** Draw a box plot of the data.

4 Farsan's bank balance over 12 months is recorded below.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Balance ($)	1500	2100	2300	2500	2200	1500	1200	1600	2000	2200	1700	2000

- **a** Plot the time series for the 12 months.
- **b** Describe the way in which the bank balance has changed over the 12 months.
- **c** Between which consecutive months did the biggest change in the bank balance occur?
- **d** What is the overall change in the bank balance over the year?

Extended-response question

1 The heights of plants in a group of the same species after a month of watering with a set number of millimetres of water per day are recorded below.

Water (mL)	8	5	10	14	12	15	18
Height (cm)	25	27	34	40	35	38	45

- **a** Draw a scatter plot for the data, using *Water* for the x-axis.
- **b** Describe the correlation between water and height as positive, negative or none.
- **c** Fit a line of best fit by eye to the data on the scatter plot.
- **d** Use your line of best fit to estimate:
  - **i** the height of a plant watered with 16 mL of water per day
  - **ii** the daily amount of water given to a plant of height 50 cm

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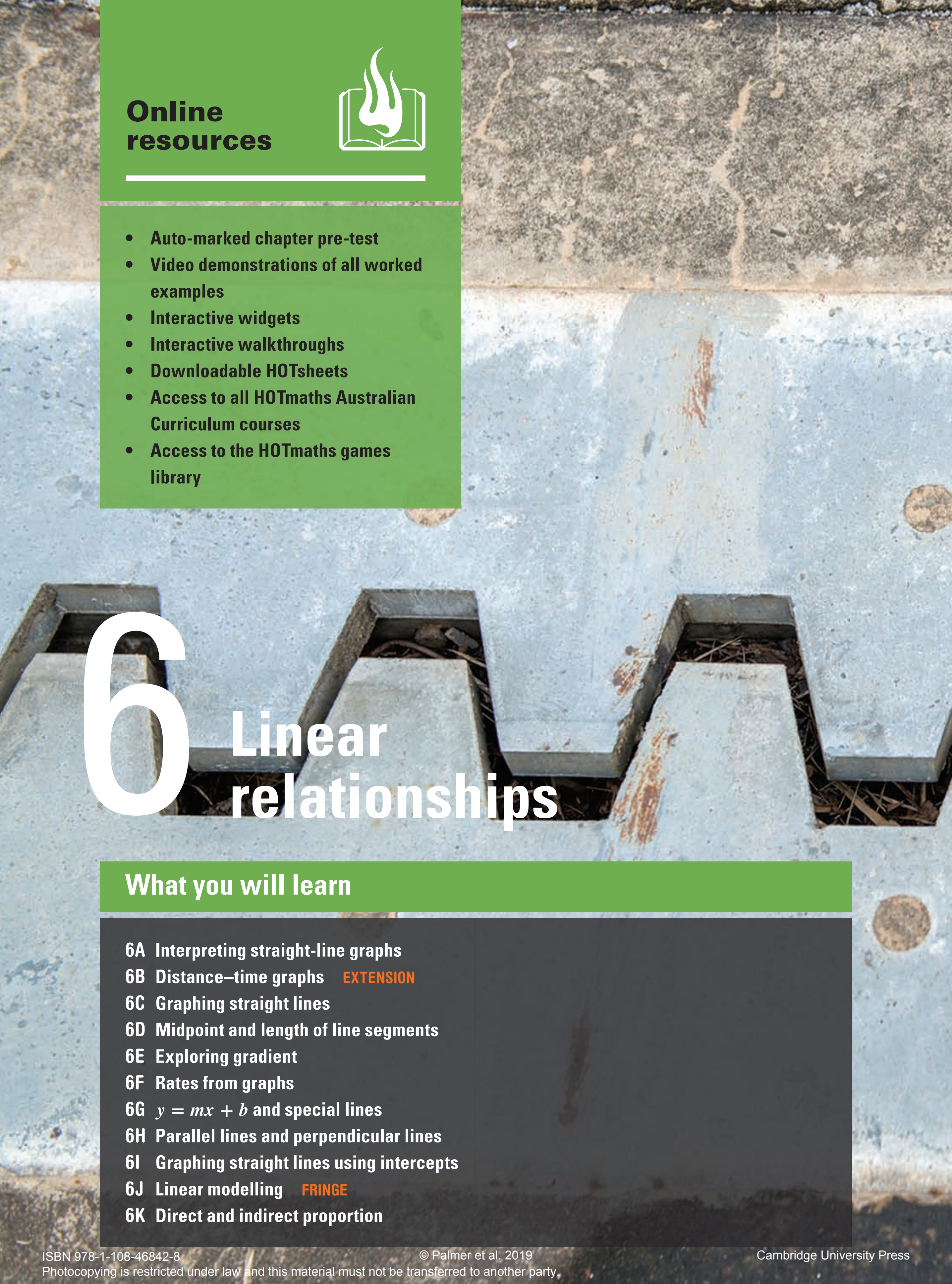

Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

6

Linear relationships

What you will learn

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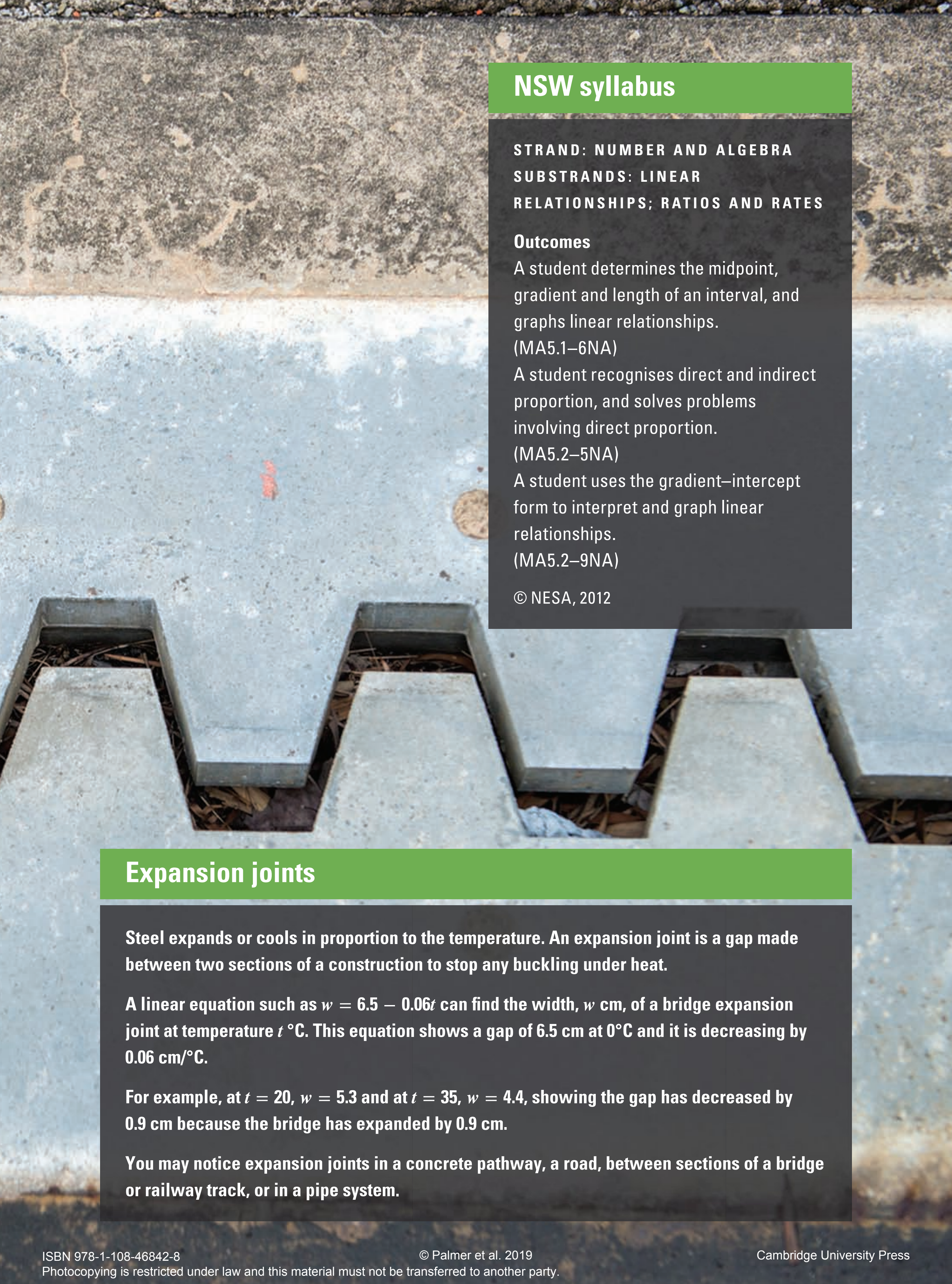

NSW syllabus

STRAND: NUMBER AND ALGEBRA

SUBSTRANDS: LINEAR RELATIONSHIPS; RATIOS AND RATES

Outcomes

A student determines the midpoint, gradient and length of an interval, and graphs linear relationships.
(MA5.1–6NA)

A student recognises direct and indirect proportion, and solves problems involving direct proportion.
(MA5.2–5NA)

A student uses the gradient–intercept form to interpret and graph linear relationships.
(MA5.2–9NA)

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Expansion joints

Steel expands or cools in proportion to the temperature. An expansion joint is a gap made between two sections of a construction to stop any buckling under heat.

A linear equation such as $w = 6.5 - 0.06t$ can find the width, w cm, of a bridge expansion joint at temperature t °C. This equation shows a gap of 6.5 cm at 0°C and it is decreasing by 0.06 cm/°C.

For example, at $t = 20$, $w = 5.3$ and at $t = 35$, $w = 4.4$, showing the gap has decreased by 0.9 cm because the bridge has expanded by 0.9 cm.

You may notice expansion joints in a concrete pathway, a road, between sections of a bridge or railway track, or in a pipe system.

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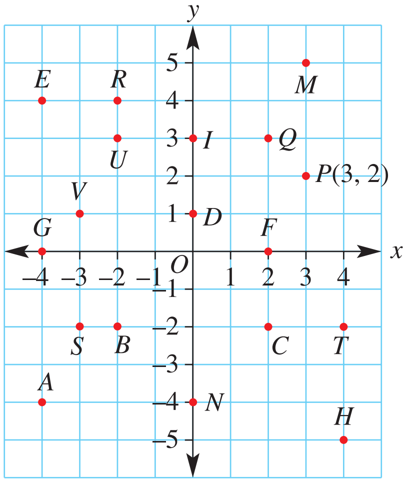
1 The coordinates of P on this number plane are (3, 2). Write down the coordinates of:

- **a** M
- **b** T
- **c** A
- **d** V
- **e** C
- **f** F



2 Name the point with coordinates:

a (−4, 0)	**b** (0, 1)
c (−2, −2)	**d** (−3, −2)
e (0, −4)	**f** (2, 3)

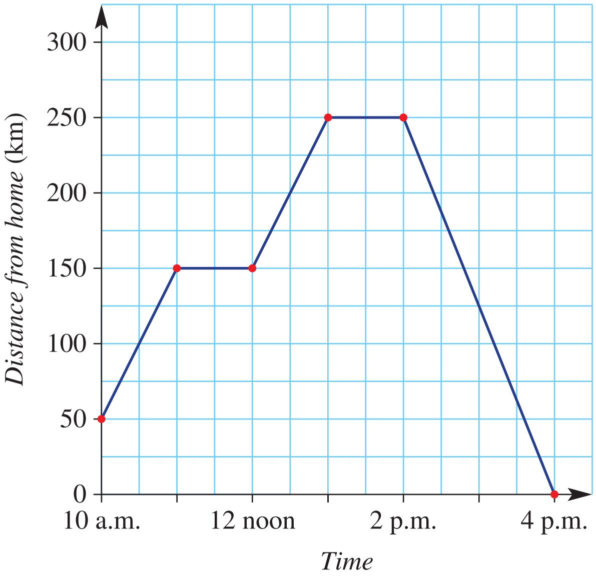
3 Draw up a four-quadrant number plane and plot the following points. What shapes do they form?

- **a** (0, 0), (0, 5), (5, 5), (5, 0)
- **b** (−3, −1), (−3, 1), (4, 0)
- **c** (−2, 3), (−4, 1), (−2, −3), (2, −3), (4, 1), (2, 3)

4 Find the mean of the following pairs.

a 10 and 12	**b** 15 and 23
c 6 and 14	**d** 3 and 4
e −6 and 6	**f** −3 and 1
g 0 and 7	**h** −8 and −10

5 **a** For how many minutes did the Heart family stop on their trip if their journey is shown in this travel graph?



b How far had they travelled by 1 p.m., after starting at 10 a.m.?

c What was their speed in the first hour of travel?

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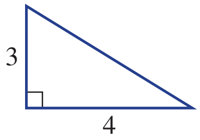
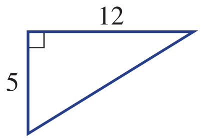
6 Find the length of the hypotenuse in each right-angled triangle. Use $a^2 + b^2 = c^2$. Round to 2 decimal places in parts **e** and **f**.

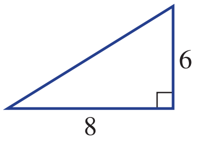
a



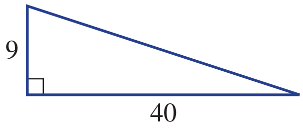
b



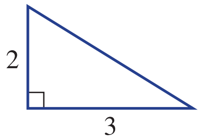
c



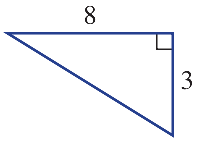
d



e



f



7 Copy and complete the table of values for each rule given.

a $y = x + 3$

x	0	1	2	3
y				

b $y = x - 2$

x	0	1	2	3
y				

c $y = 2x$

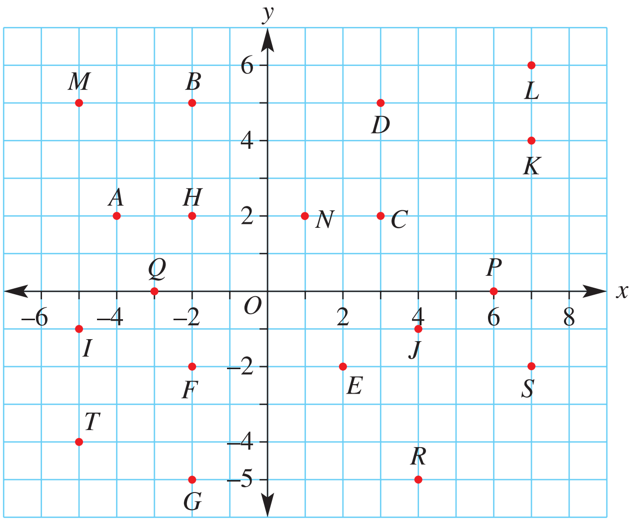
x	0	1	2
y			

d $y = 4 - x$

x	−2	−1	0
y			

8 Use the Cartesian plane to find the following distances.

a OP
b QP
c MB
d FS
e BD
f TM
g AC
h LS
i AH
j RJ
k LK
l BG



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6A Interpreting straight-line graphs

Interactive

Widgets

HOTsheets

Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

When two variables are related, we can use mathematical rules to describe the relationship. The simplest kind of relationship forms a straight line graph and the rule is called a linear equation.

Information can be easily read from within a linear graph – this is called interpolation. A straight line can also be extended to determine information outside of the original data – this is called extrapolation.

For example, if a swimming pool is filled at 1000 L per hour, the relationship between volume and time is linear because the volume is increasing at the constant rate of 1000 L/hr.

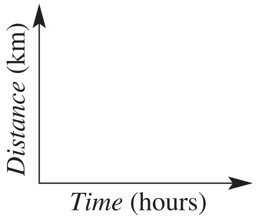
$$\text{Volume} = 1000 \times \text{number of hours}$$

This rule is a linear equation and the graph of volume versus time will be a straight line.

When a pool is filled with water at a constant rate, the graph of volume versus time will be a straight line.

Let's start: Graphing a straight line

Jozef is an athlete who trains by running 24 km in two hours at a constant rate. Draw a straight line graph to show this linear relation.



- Draw axes with time (up to 2 hours) on the horizontal axis and distance (up to 24 km) on the vertical axis.
- Mark the point on the graph that shows the start of Jozef's run.
- Mark the point on the graph that shows the end of Jozef's run.
- Join these two points with a straight line.
- Mark the point on the graph that shows Jozef's position after half an hour. How far had he run?
- Mark the point on the graph that shows Jozef's position after 18 km. For how long had Jozef been running?
- Name the variables shown on the graph.
- Discuss some advantages of showing information on a graph.

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Key ideas

- A **variable** is a pronumeral that can take on many different values.

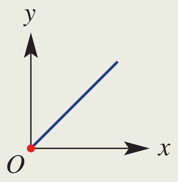
Variable A pronumeral that can take on any value

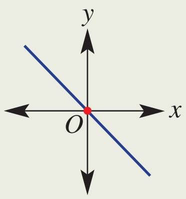
- There are many real-life situations that involve two variables, such as the time spent cycling and the distance travelled.
- A table is often used to show some values that satisfy a relationship. In this example, the values in the top row are increasing by 1 and the numbers in the bottom row are increasing by 5. This is an example of a **linear relationship**.

Linear relationship The relationship between a variable and a constant term

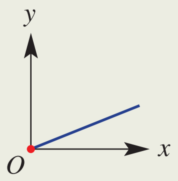
Time	0	1	2	3	4	5
Distance	0	5	10	15	20	25

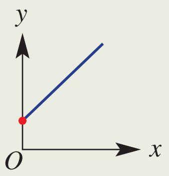
- A graph on the Cartesian plane is used to display all the values that satisfy a relationship between two variables. Linear relationships are always straight-line graphs.
  - Some straight-line graphs pass through the origin (O).



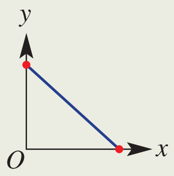


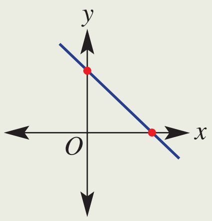
  - Some straight-line graphs indicate that both variables are increasing.



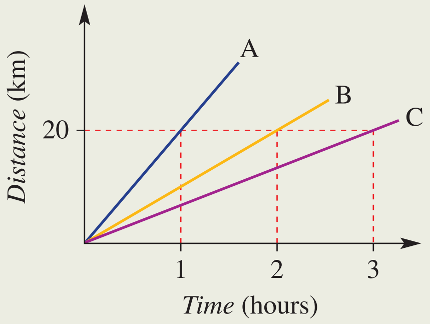


  - Some straight-line graphs indicate that one variable decreases as the other increases.



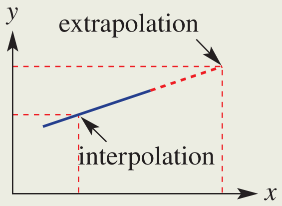


- Information about one of the variables based on information about the other variable is easily determined by reading from the graph:
  - A 20 km in 1 hour
  - B 20 km in 2 hours
  - C 20 km in 3 hours



Key ideas

- Information can be found from:



- reading within a graph (**interpolation**) or
- reading off an extended graph (**extrapolation**).

Interpolation Reading information from within a graph

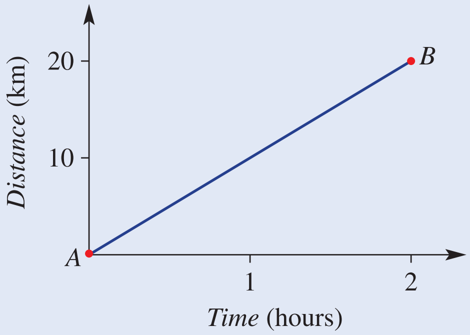
Extrapolation Determining information outside of the original data

Exercise 6A

UNDERSTANDING AND FLUENCY	1–3, 5	2–4, 6

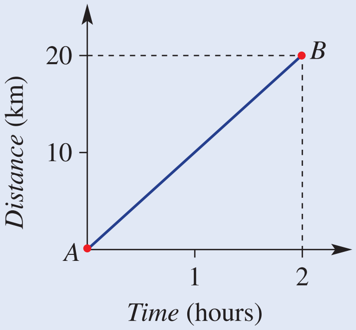
Example 1 Reading information from a graph

The graph shown here shows the journey of a cyclist from one place (A) to another (B).



a How far did the cyclist travel?
b How long did it take the cyclist to complete the journey?
c If the cyclist rode from A to B and then halfway back to A, how far was the journey?

SOLUTION	EXPLANATION
a 20 km	Draw an imaginary line from point B to the vertical axis; i.e. 20 km.
b 2 hours	Draw an imaginary line from point B to the horizontal axis; i.e. 2 hours.
c $20 + 10 = 30$ km	Ride 20 km out and 10 km back.



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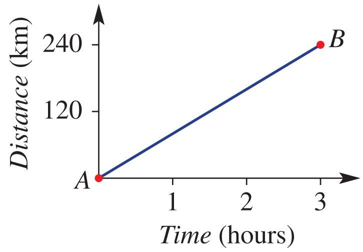
1 This graph shows a car journey from one place (A) to another (B).

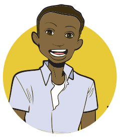
a How far did the car travel?

b How long did it take to complete the journey?

c If the car was driven from A to B, then halfway back to A, how far was the journey?



For distance travelled, draw a horizontal line from B to the distance scale.

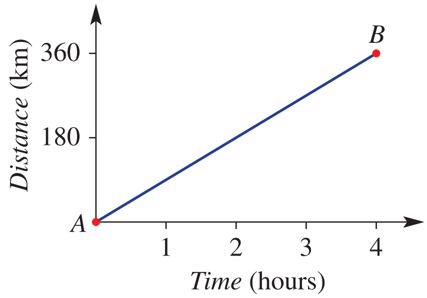


2 This graph shows a motorcycle journey from one place (A) to another (B).

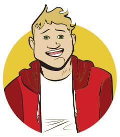
a How far did the motorcycle travel?

b How long did it take to complete the journey?

c If the motorcycle travelled from A to B, then halfway back to A, how far was the journey?



To find the total time taken to go from A to B, look on the time scale that is level with point B on the line.



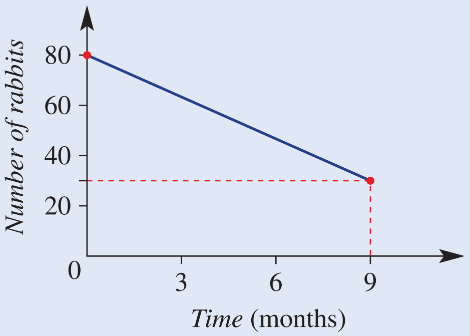
Example 2 Interpreting information from a graph

The number of rabbits in a colony has decreased according to this graph.

a How many rabbits were there in the colony to begin with?

b How many rabbits were there after 9 months?

c How many rabbits disappeared from the colony during the 9-month period?



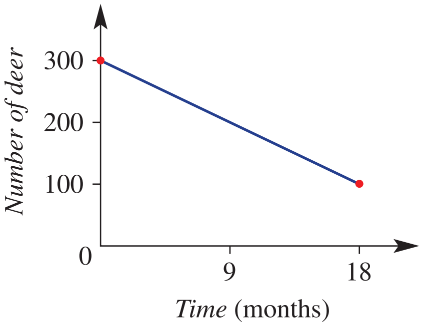
SOLUTION	EXPLANATION
a 80 rabbits	At $t = 0$ there were 80 rabbits.
b 30 rabbits	Read the number of rabbits from the graph at $t = 9$.
c $80 - 30 = 50$ rabbits	There were 80 rabbits at the start and 30 after 9 months.

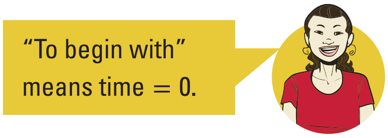
3 The number of deer in a particular forest has decreased over recent months according to the graph shown.

a How many deer were there to begin with?

b How many deer were there after 18 months?

c How many deer disappeared from the colony during the 18-month period?



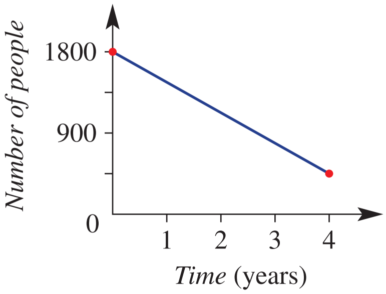


4 The number of people in a small village has decreased over recent years according to the graph shown.

a How many people were there to begin with?

b How many people were there after 4 years?

c How many people disappeared from the village during the 4-year period?



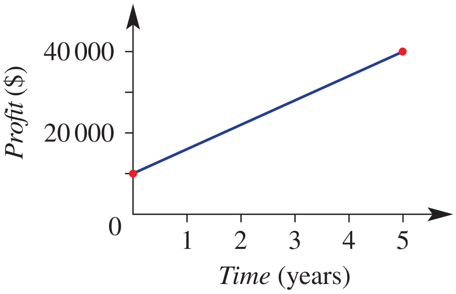
5 This graph shows the profit result for a company over a 5-year period.

a What is the profit of the company at:

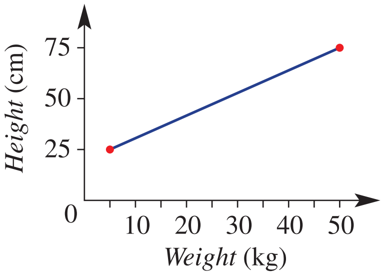
- **i** the beginning of the 5-year period?
- **ii** the end of the 5-year period?

b Has the profit increased or decreased over the 5-year period?

c How much has the profit increased over the 5 years?



6 A height versus weight graph for a golden retriever dog breed is shown.



a From the smallest to the largest dog, use the graph to find the total increase in:

- **i** height
- **ii** weight

b Fill in the missing numbers.

- **i** The largest weight is ____ times the smallest weight.
- **ii** The largest height is ____ times the smallest height.

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PROBLEM-SOLVING AND REASONING 7, 9 7, 8, 10

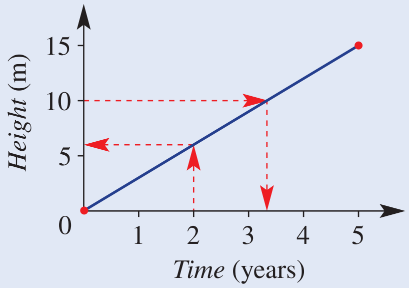
Example 3 Reading within a graph (interpolation)

This graph shows the growth of a tree over 5 years.

a How many metres has the tree grown over the 5 years?

b Use the graph to find how tall the tree is after 2 years.

c Use the graph to find how long it took for the tree to grow to 10 metres.



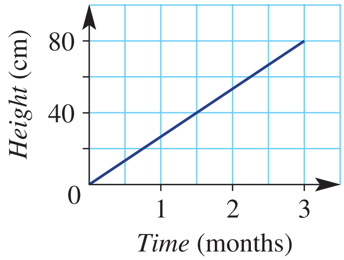
SOLUTION	EXPLANATION
a 15 metres	The end point of the graph is at 15 metres.
b 6 metres	Draw a dotted line at 2 years and read the height.
c 3.3 years	Draw a dotted line at 10 metres and read the time.

7 The graph below shows the height of a tomato plant over 3 months.

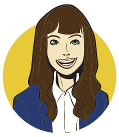
a How many centimetres has the tree grown over 3 months?

b Use the graph to find how tall the tomato plant is after $1\frac{1}{2}$ months.

c Use the graph to find how long it took for the plant to grow to 60 centimetres.



Start at 60 cm on the height axis, then go across to the straight line and down to the time axis. Read off the time.

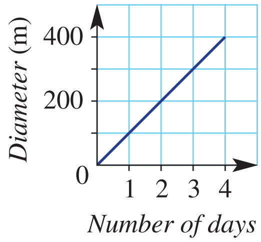


8 The diameter of an oil slick increased every day after an oil tanker hit some rocks. Use the graph to find:

a how wide the oil slick is after 4 days

b how wide the oil slick is after 2.5 days

c how many days it took for the oil slick to reach a diameter of 350 m



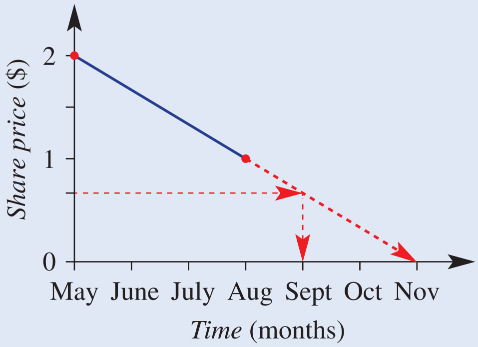
Example 4 Reading off an extended graph (extrapolation)

Due to poor performance, the value of a company's share price is falling.

a By the end of August, how much has the share price fallen?

b At the end of November, what would you estimate the share price to be?

c Near the end of which month would you estimate the share price to be 70 cents?



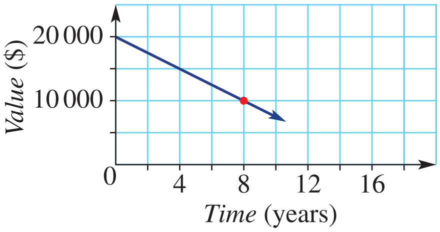
SOLUTION	EXPLANATION
a Price has dropped by $1.	By August the price has changed from $2 to $1.
b $0	Use a ruler to extend your graph (as shown by the dotted line) and read the share price for November.
c September	Move across from 70 cents to the extended line and read the month.

9 The value of a car decreases with time, as shown in the graph below.

a By the end of 8 years, by how much has the car's value fallen?

b At the end of 16 years, what would you estimate the car's value to be?

c Near the end of which year would you estimate the car's value to be $5000?



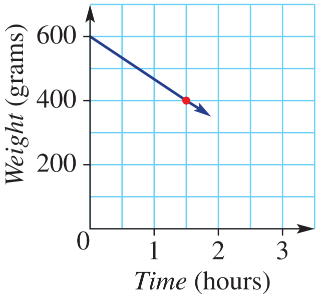
Use your ruler to 'extend' the line.

10 The weight of a wet sponge is reduced after it is left in the sun to dry.

a The weight of the sponge has been reduced by how many grams over the first 1.5 hours?

b What would you estimate the weight of the sponge to be after 3 hours?

c How many hours would it take for the sponge to weigh 300 g?



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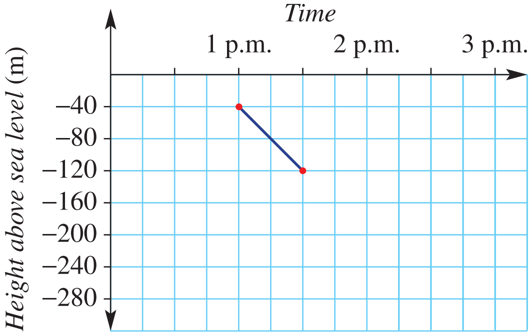
ENRICHMENT – 11

Submarine depth

11 A submarine goes to depths below sea level, as shown in this graph.



- **a** How long did it take for the submarine to drop from 40 to 120 m below sea level?
- **b** At what time of day was the submarine at:
  - **i** −40 m?
  - **ii** −80 m?
  - **iii** −60 m?
  - **iv** −120 m?
- **c** What is the submarine's depth at:
  - **i** 1:30 p.m.?
  - **ii** 1:15 p.m.?
- **d** Extend the graph to find the submarine's depth at:
  - **i** 12:45 p.m.
  - **ii** 1:45 p.m.
  - **iii** 2:30 p.m.
- **e** Use your extended graph to estimate the time when the submarine was at:
  - **i** 0 m
  - **ii** −200 m
  - **iii** −320 m

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6B Distance–time graphs EXTENSION

Interactive

Widgets

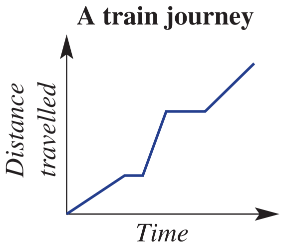
HOTsheets

Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

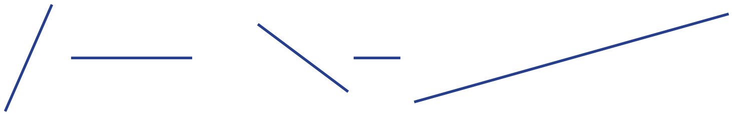
Some of the graphs considered in the previous section were distance–time graphs, which show the *distance* on the vertical axis and the *time* on the horizontal axis. Many important features of a journey can be displayed on such graphs. Each section of a journey that is at a constant rate of movement can be graphed with a straight-line segment and several different line segments make up a total journey.

For example, a train journey could be graphed with a series of sloping line segments showing travel between stations and flat line segments showing when the train is stopped at a station.



Let's start: An imaginary journey

Here are five line segments.

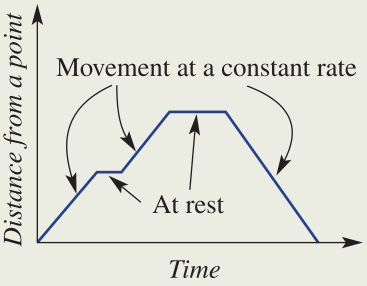


- Use five similar line segments and arrange them in any order you choose to draw a distance–time graph. Each segment must be joined to the one next to it.
- Write a summary of the journey shown by your distance–time graph.
- Swap graphs with a classmate and explain the journey that you think your classmate's graph is showing.

Key ideas

- Graphs of *distance* versus *time* sometimes consist of **line segments**.
- Each segment shows whether the object is moving or at rest.
- To draw a graph of a journey, use time on the horizontal axis and distance on the vertical axis.

Line segment A section of a straight line



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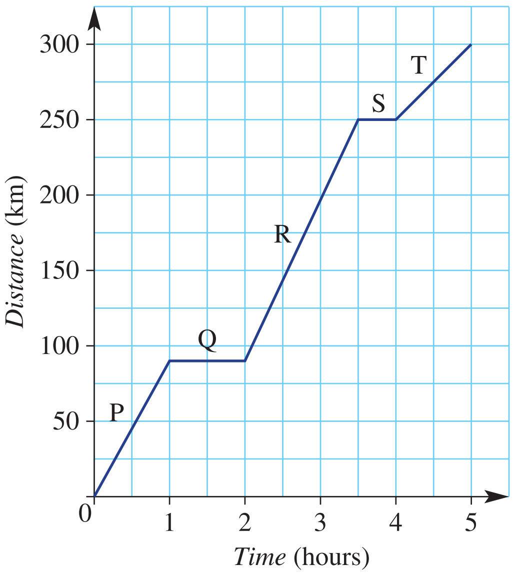
Exercise 6B EXTENSION

UNDERSTANDING AND FLUENCY	1–5	2–4, 6

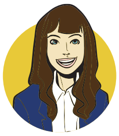
1 The Martin family makes a 300-km car journey, which takes 5 hours. The distance–time graph of this journey is shown at right. For each description below, choose the line segment of the graph that matches it. Some segments will have more than one descriptor.

- **a** A half-hour rest break is taken after travelling 250 km.
- **b** In the first hour the car travels 90 km.
- **c** The car is at rest for 1 hour, 90 km from the start.
- **d** The car takes 1.5 hours to travel from 90 km to 250 km.
- **e** The distance from 250 km to 350 km takes 1 hour.
- **f** The distance travelled stays constant at 250 km for half an hour.
- **g** A 1-hour rest break is taken after travelling 90 km.

Distance–time graph of car journey



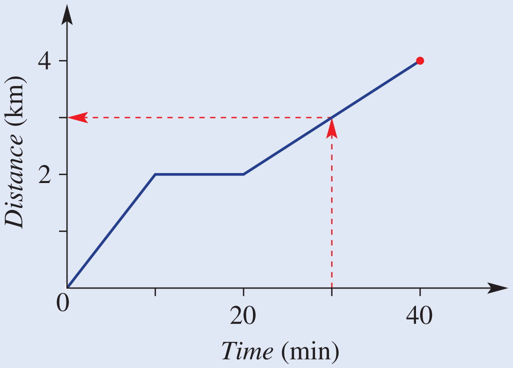
A flat line segment shows that the car is stopped.



Example 5 Interpreting a distance–time graph

This distance–time graph shows a car's journey from home, to school and then to the local shopping centre.

- **a** What was the total distance travelled?
- **b** How long was the car resting at the school?
- **c** What was the total distance travelled after 30 minutes?



SOLUTION	EXPLANATION
a 4 km	Read the distance from the end point of the graph.
b 10 minutes	The rest starts at 10 minutes and finishes at 20 minutes.
c 3 km	Draw a line from 30 minutes and read off the distance.

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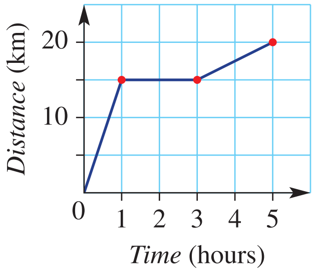
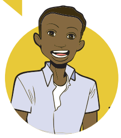
2 A bicycle journey is shown on the distance–time graph below.

- **a** What was the total distance travelled?
- **b** How long was the cyclist at rest?
- **c** How far had the cyclist travelled after 4 hours?

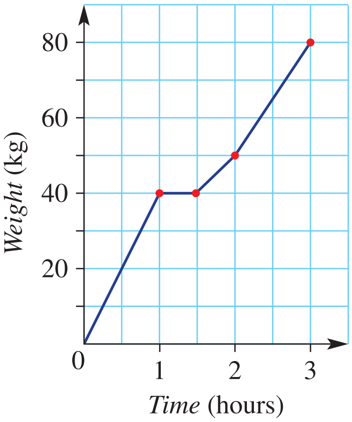


From the end of the line segments, go across to the distance scale. This will show the total distance travelled.



3 The weight of a water container increases while water is poured into it from a tap.

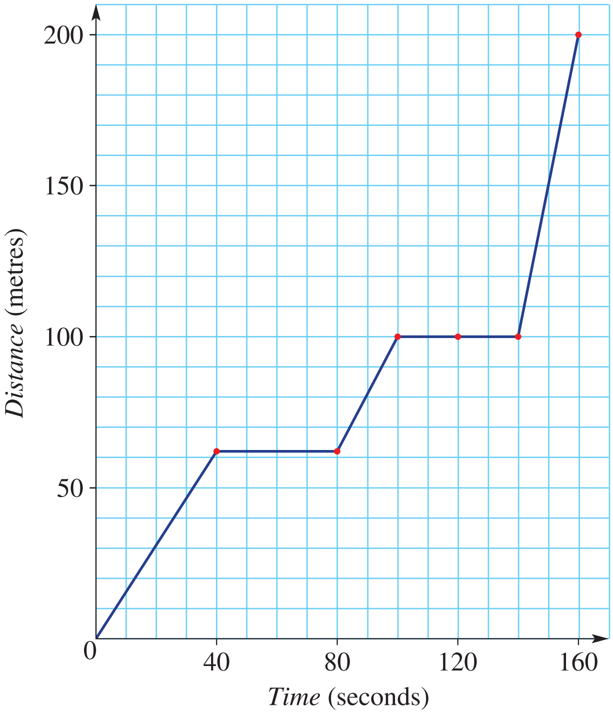
- **a** What is the total weight of the container after:
  - **i** 1 hour?
  - **ii** 2 hours?
  - **iii** 3 hours?
- **b** During the 3 hours, how long was the container not actually being filled with water?
- **c** During which hour was the container filling the fastest?



A flat-line segment shows that the weight is not changing, so no water is being poured in at that time.

4 This graph shows a shopper's short walk in a shopping mall.

- **a** What is the total distance the shopper travelled?
- **b** How long was the shopper not walking?
- **c** What was the total distance the shopper had travelled by the following times?
  - **i** 20 seconds
  - **ii** 80 seconds
  - **iii** 2.5 minutes



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5 A snail makes its way across a footpath, a garden bed and then a lawn, according to this graph.

a How far did the snail travel on:

i the footpath?

ii the garden bed?

iii the lawn?

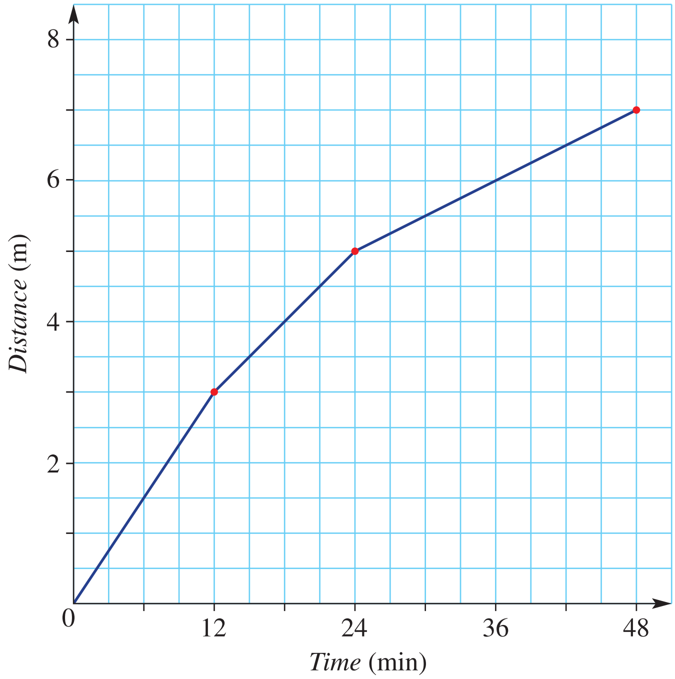
b On which surface did the snail spend the most time?

c Use your graph to find how far the snail travelled after:

i 6 minutes

ii 18 minutes

iii 42 minutes



The line segment that has the largest horizontal change is the surface that the snail spent most time on.

6 The distance travelled during three phases of a rocket launch are shown on this graph.

a How long did it take for the rocket to get to:

i 50 m?

ii 100 m?

iii 200 m?

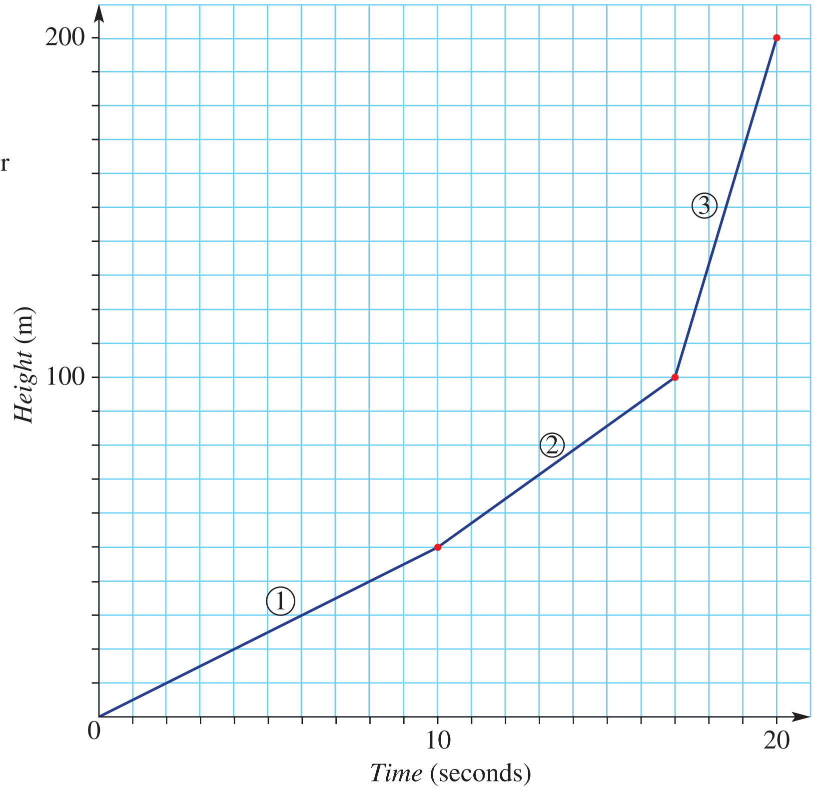
b During which of the three phases did the rocket gain the most height in the shortest time?

c Use your graph to find the height of the rocket after:

i 8 seconds

ii 15 seconds

iii 19 seconds



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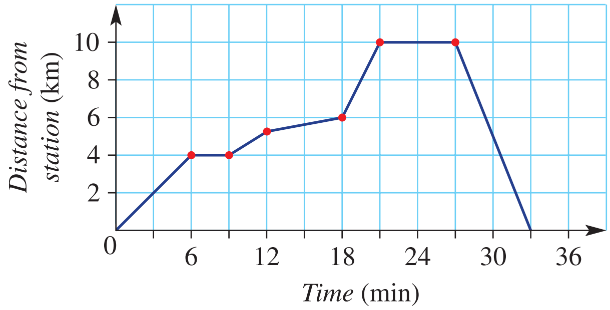
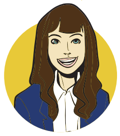
PROBLEM-SOLVING AND REASONING 7–9 8, 10–12

7 This graph shows the distance of a train from the city station over a period of time.

- **a** What was the farthest distance the train travelled from the station?
- **b** What was the total distance travelled?
- **c** After how many minutes did the train begin to return to the station?
- **d** What was the total number of minutes the train was stationary?



Remember to include the return trip in the total distance travelled.

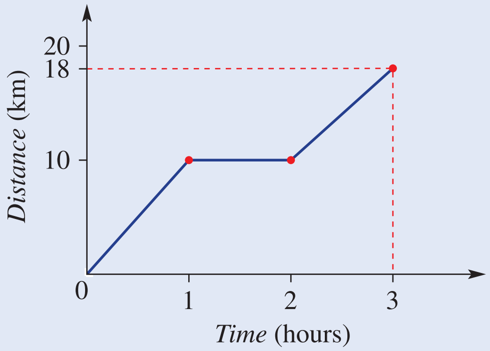


Example 6 Sketching a distance–time graph

Sketch a distance–time graph displaying all of the following information.

- total distance covered is 18 km in 3 hours
- 10 km covered in the first hour
- a 1-hour long rest after the first hour

SOLUTION



EXPLANATION

Draw axes with time on the horizontal (up to 3 hours) and distance on the vertical (up to 18 km).

Start at time zero.

Draw the first hour with 10 km covered.

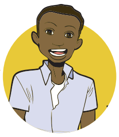
Draw the rest stop, which lasts for 1 hour.

Draw the remainder of the journey, so that 18 km is completed after 3 hours.

8 Sketch a distance–time graph displaying all of the following information.

- total distance covered is 100 km in 2 hours
- 50 km covered in the first hour
- a half-hour rest stop after the first hour

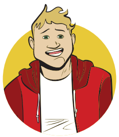
Draw axes with time on the horizontal (up to 2 hours) and distance on the vertical (up to 100 km).



9 Sketch a graph to illustrate a journey described by the following.

- total distance covered is 15 m in 40 seconds
- 10 m covered in the first 10 seconds
- a 25-second rest after the first 10 seconds

Always use a ruler to draw line segments.



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10 A bus travels 5 km in 6 minutes, stops for 2 minutes, travels 10 km in 8 minutes, stops for another 2 minutes and then completes the journey by travelling 5 km in 4 minutes.

a What was the total distance travelled?
b What was the total time taken?
c Sketch a distance–time graph for the journey.

Find the total time taken to determine the scale for the horizontal axis. Find the total distance travelled to determine the scale for the vertical axis.

11 A 1-day, 20-km bush hike included the following features.

- a 3-hour hike to the waterfalls (10 km distance)
- a half-hour rest at the falls
- a 2-hour hike to the mountain peak (5 km distance)
- a 1.5-hour hike to the campsite

Sketch a distance–time graph for the journey.

12 Complete the following for each of the following journeys.

i Draw a distance–time graph.
ii Decide the total travel time, not including rest stops.

a
- 20 km in 1 hour
- a half-hour rest
- 10 km in $\frac{1}{2}$ hour
- 15 km in $1\frac{1}{2}$ hours

b
- 4 m in 3 seconds
- 2-second rest
- 10 m in 5 seconds
- 3-second rest
- 12 m in 10 seconds

ENRICHMENT – 13

Pigeon flight

13 The distance travelled by a pigeon is described by these points.

- a half-hour flight, covering a distance of 18 km
- a 15-minute rest
- a further 15-minute flight covering 12 km
- a half-hour rest
- turning and flying 10 km back towards 'home' over the next $\frac{1}{2}$ hour
- a rest for $\frac{1}{4}$ of an hour
- reaching 'home' after another 45-minute flight

a Sketch a graph illustrating the points above, using 'distance' on the vertical axis.
b What was the fastest speed (in km/h) at which the pigeon flew? $\left(\text{Speed} = \frac{\text{distance}}{\text{time}}\right)$
c Determine the pigeon's average speed in km/h. $\left(\text{Average speed} = \frac{\text{total distance}}{\text{total flying time}}\right)$

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6C Graphing straight lines

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

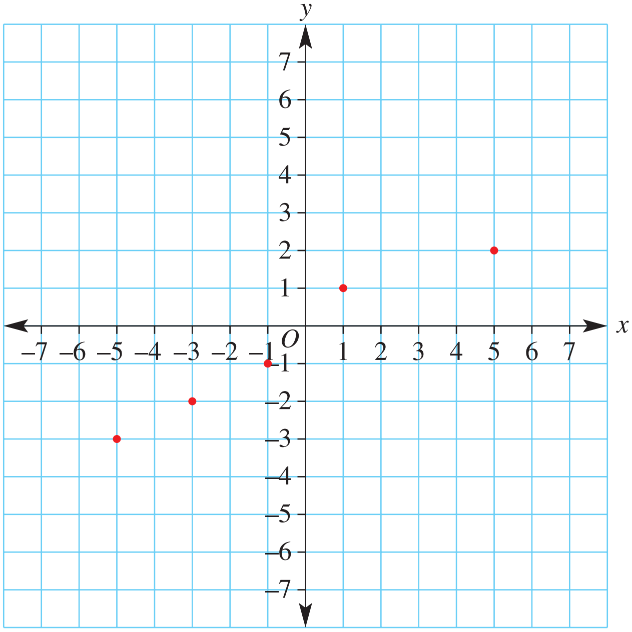
On a number plane (also known as a Cartesian plane), a pair of coordinates gives the exact position of a point. The number plane extends both a horizontal axis (x) and vertical axis (y) to include negative numbers. The point where these axes cross over is called the origin (O). It provides a reference point for all other points on the plane.

A rule that relates two variables can be used to generate a table that shows coordinate pairs (x, y). The coordinates can be plotted to form the graph. Rules that give straight-line graphs are described as being linear.

Architects apply their knowledge of two-dimensional straight lines and geometric shapes to form interesting three-dimensional surfaces. Computers use line equations to produce visual models.

Let's start: What's the error?

- Which point is not in line with the rest of the points on this number plane? What should its coordinates be so it is in line? List two other points that would be in line with the points on this Cartesian plane.



- This table shows coordinates for the rule $y = 4x + 3$. Which y value has been incorrectly calculated in the table? What would be the correct y value?

x	0	1	2	3	4
y	3	7	11	12	19

- Which two points in this list would not be in the same line as the other points?
  (−2, 4), (−1, 2), (0, 0), (1, −2), (2, 4), (3, 6)
  What would be the correct coordinates for these two points using the given x values?
- Points that follow a linear rule will always be in a straight line. Discuss some ways of checking whether the coordinates of a point have been calculated incorrectly.

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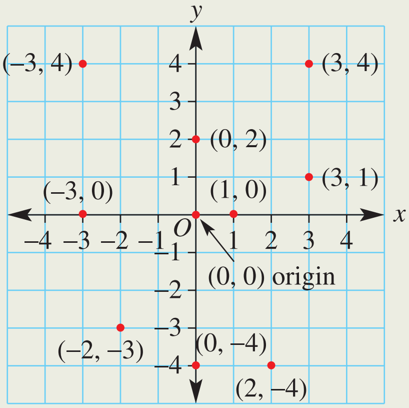
Key ideas

- A **number plane** or **Cartesian plane** includes a vertical *y*-axis and a horizontal *x*-axis intersecting at right angles.
- A point on a number plane has **coordinates** (x, y).
  - The **x-coordinate** is listed first, followed by the **y-coordinate**.
- The point $(0, 0)$ is called the origin (O).
- $(x, y) = \left\{ \begin{matrix}\text{horizontal} \\ \text{units from} \\ \text{origin}\end{matrix} , \begin{matrix}\text{vertical} \\ \text{units from} \\ \text{origin}\end{matrix} \right\}$

x-coordinate The first coordinate of an ordered pair

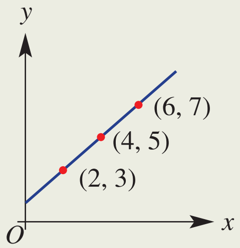
y-coordinate The second coordinate of an ordered pair



- A rule is an equation connecting two or more variables.
- A straight-line graph will result from a rule that is linear.
- For two variables, a linear rule is often written with y as the subject. For example: $y = 2x - 3$ or $y = -x + 7$.
- To graph a linear relationship using a rule:
  - Construct a table of values finding a y-coordinate for each given x-coordinate by substituting each x-coordinate into the rule.

x	2	4	6
y	3	5	7

  - Plot the points given in the table on a set of axes.
  - Draw a line through the points to complete the graph.



  - The **point of intersection** of two lines is the point that sits on both lines.

Point of intersection The point at which two lines cross each other and therefore have the same coordinates

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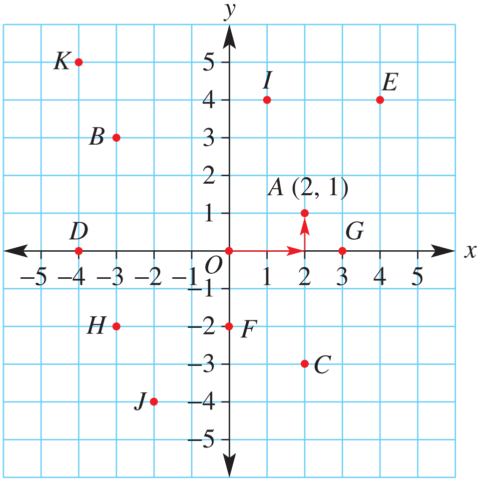
Exercise 6C

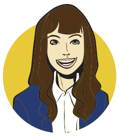
UNDERSTANDING AND FLUENCY 1-4, 5(½) 4, 5–6(½), 7

1 **a** List the coordinates of each point plotted on this number plane.
b Which points are on the x-axis?
c Which points are on the y-axis?
d What are the coordinates of the point called the 'origin'?



$(x, y) = \begin{bmatrix}\text{right} & & \text{up}\\ \text{or} & , & \text{or}\\ \text{left} & & \text{down}\end{bmatrix}$

The 'origin' is the point where the x-axis and y-axis meet.



2 Ethan is finding the coordinates of some points that are on the line $y = -2x + 4$.
Copy and complete these calculations, stating the coordinates for each point.

a $x = -3$, $y = -2 \times (-3) + 4 = 6 + 4 =$ ____; $(-3,\ )$
b $x = -2$, $y = -2 \times (-2) + 4 =$ ____ $=$ ____; $(\ ,\ )$
c $x = -1$, $y = -2 \times (-1) + 4 =$ ____ $=$ ____; $(\ ,\ )$
d $x = 0$, $y = -2 \times 0 + 4 =$ ________ $=$ ____; $(\ ,\ )$
e $x = 1$, $y = -2 \times 1 + 4 =$ ________ $=$ ____; $(\ ,\ )$
f $x = 2$, $y = -2 \times 2 + 4 =$ ________ $=$ ____; $(\ ,\ )$
g $x = 3$, $y = -2 \times 3 + 4 =$ ________ $=$ ____; $(\ ,\ )$

In the order of operations, first do any multiplication, then do addition or subtraction from left to right.

When multiplying, same signs make a positive and different signs make a negative.

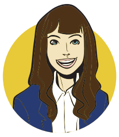
3 Write the coordinates for each point listed in this table.

x	−2	−1	0	1	2
y	1	−1	−3	−5	−7

Coordinates are written as (x, y).

x	−2
y	1

} (−2, 1)



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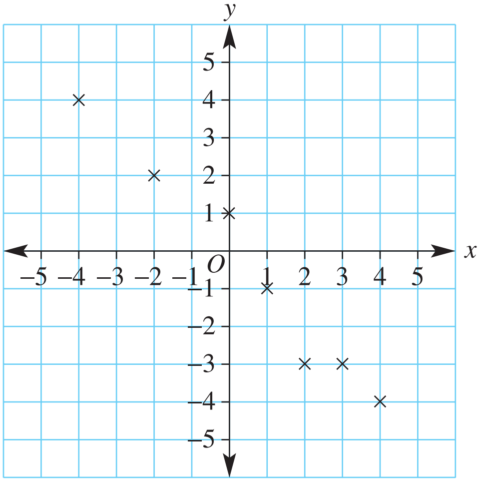
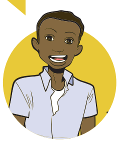
4 Jenna has plotted these points for the rule $y = -x$ and she knows they should all lie in a straight line.

a State the coordinates of any points that are not in line with most of the other points.

b Using the rule $y = -x$, calculate the correct coordinates for these two points.



Place your ruler along the plotted points. Any point not in a straight line needs to be re-calculated.



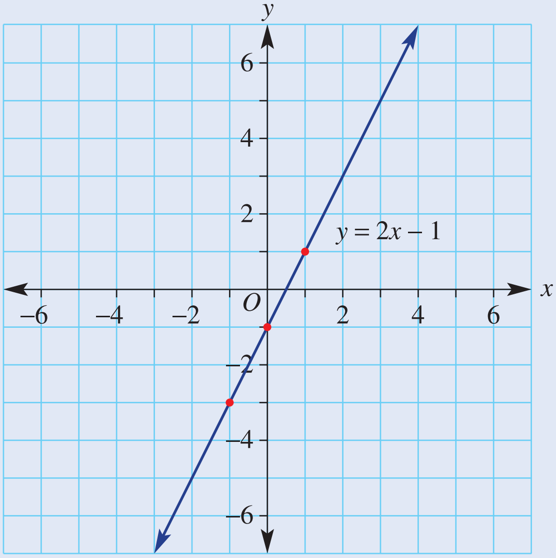
Example 7 Plotting a graph from a rule

Plot the graph of $y = 2x - 1$ by first completing the table of values.

x	−1	0	1
y			

SOLUTION

x	−1	0	1
y	−3	−1	1



EXPLANATION

Substitute each value into the equation:

$x = -1$, $y = 2 \times (-1) - 1 = -3$ $(-1, -3)$

$x = 0$, $y = 2 \times 0 - 1 = -1$ $(0, -1)$

$x = 1$, $y = 2 \times 1 - 1 = 1$ $(1, 1)$

Plot the points and draw the line with a ruler.

When labelling axes, put the numbers on the grid lines, not in the spaces.

5 Complete the following tables, then plot the graph of each one on a separate number plane.

a $y = 2x$

x	−1	0	1
y			

b $y = x + 4$

x	0	1	2
y			

c $y = 2x - 3$

x	0	1	2
y			

d $y = -2x$

x	−1	0	1
y			

e $y = x - 4$

x	1	2	3
y			

f $y = 6 - x$

x	0	1	2
y			

When multiplying, same signs make a positive; e.g. $-2 \times (-1) = 2$

6 Complete the following tables, then plot the graph of each pair on the same axes.

a i $y = x + 2$

x	0	2	4
y			

ii $y = -x + 2$

x	0	2	4
y			

b i $y = x - 4$

x	0	4	6
y			

ii $y = 4 - x$

x	0	1	2
y			

c i $y = 2 + 3x$

x	−3	0	3
y			

ii $y = 3x - 4$

x	−3	0	3
y			

For each part, draw line **i** and line **ii** on the same axes.

7 By plotting the graphs of each of the following pairs of lines on the same axes, find the coordinates of the point of intersection. Use a table of values, with x from −2 to 2.

a $y = 2x$ and $y = x$

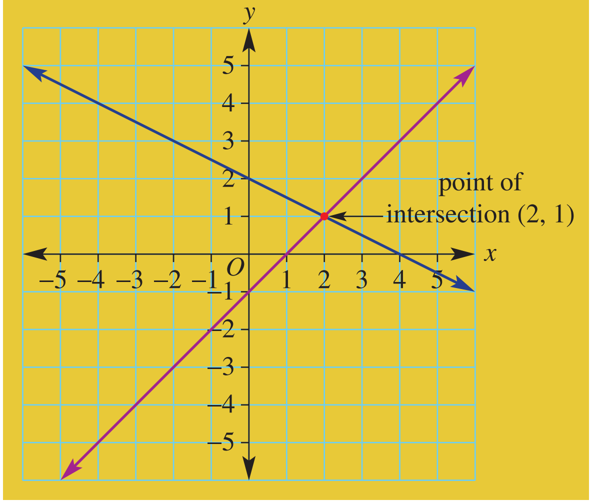
b $y = x + 3$ and $y = 2x + 2$

c $y = 2 - x$ and $y = 2x + 5$

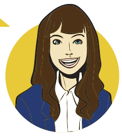
d $y = 2 - x$ and $y = x + 2$

e $y = 2x - 3$ and $y = x - 4$

The point of intersection of two lines is where they cross each other.
For example:



point of intersection (2, 1)



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PROBLEM-SOLVING AND REASONING 8, 10 9–11

Example 8 Interpreting a graph when given a table of values

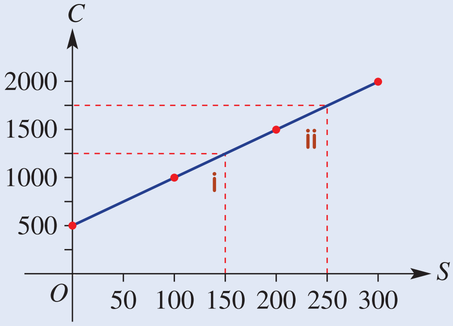
Jasmine is organising a school dance. The venue is chosen and the costs are shown in the table.

Number of students (S)	0	100	200	300
Total cost in dollars (C)	500	1000	1500	2000

a Plot a graph of the total cost against the number of students.

b Use the graph to determine:

- **i** the total cost for 150 students
- **ii** how many students could attend the dance if Jasmine has a budget of $1750 to spend

SOLUTION	EXPLANATION
a 	Construct a set of axes using S between 0 and 300 and C between 0 and 2000. 'Number of students' is placed on the horizontal axis. Plot each point using the information in the table.
b i The total cost for 150 students is $1250.	Draw a vertical dotted line at $S = 150$ to meet the graph, then draw another dotted line horizontally to the C-axis.
ii 250 students could attend the dance for $1750.	Draw a horizontal dotted line at $C = 1750$ to meet the graph, then draw a dotted line vertically to the S-axis.

8 A furniture removalist charges by the hour. His rates are shown in the table below.

No. of hours (n)	0	1	2	3	4	5
Cost (C)	200	240	280	320	360	400

Place 'No. of hours' on the horizontal axis.

a Plot a graph of cost against hours.

b Use the graph to determine:

- **i** the total cost for 2.5 hours' work
- **ii** the number of hours the removalist will work for $380

9 Olive oil is sold in bulk for $8 per litre.

No. of litres (L)	1	2	3	4	5
Cost (C)	8	16	24	32	40

a Plot a graph of cost against number of litres.

b Use the graph to determine:

- **i** the total cost for 3.5 litres of oil
- **ii** the number of litres of oil you can buy for $20

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Example 9 Constructing a table and graph for interpretation

An electrician charges \$50 for a service call and \$60 an hour for labour.

a Complete the table of values.

No. of hours (n)	0	1	2	3	4	5
Cost (C)						

b Plot a graph of cost against number of hours.

c Use the graph to determine:

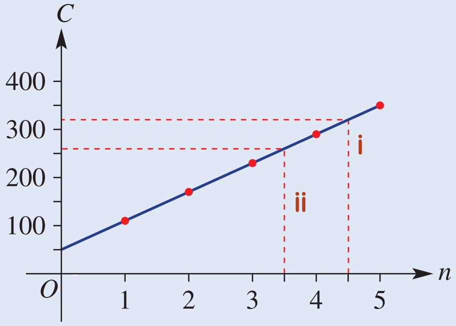
i the cost for 4.5 hours' work **ii** how long the electrician will work for \$260

SOLUTION

a

No. of hours (n)	0	1	2	3	4	5
Cost (C)	50	110	170	230	290	350

b



c i The cost is \$320.

ii The electrician worked for 3.5 hours

EXPLANATION

Initial cost (i.e. $n = 0$) is \$50.
Cost for 1 hour = \$50 + \$60 = \$110
Cost for 2 hours = \$50 + 2 × \$60 = \$170
Cost for 3 hours = \$50 + 3 × \$60 = \$230 etc.

Plot the points from the table using C on the vertical axis and n on the horizontal axis.
Join all the points to form the straight line.

Draw a vertical dotted line at $n = 4.5$ to meet the graph, then draw a line horizontally to the C-axis.

Draw a horizontal dotted line at $C = 260$ to meet the graph, then draw vertically to the n-axis.

10 A car rental firm charges \$200 plus \$1 for each kilometre travelled.

a Complete the table of values below.

No. of km (k)	0	100	200	300	400	500
Cost (C)						

b Plot a graph of cost against kilometres.

c Use the graph to determine:

i the cost if you travel 250 km

ii how many kilometres you can travel on a \$650 budget

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11 Matthew delivers pizza for a fast-food outlet. He is paid \$20 a shift plus \$3 per delivery.

a Complete the table of values below.

No. of deliveries (d)	0	5	10	15	20
Wages (W)					

b Plot a graph of Matthew's wages against number of deliveries.

c Use the graph to determine:

- **i** Matthew's wages for 12 deliveries
- **ii** the number of deliveries made if Matthew is paid \$74

ENRICHMENT – 12

Which mechanic?

12 Two mechanics charge different rates for their labour. Paul charges \$75 for a service call plus \$50 per hour. Sherry charges \$90 for a service call plus \$40 per hour.

a Create a table for each mechanic for up to 5 hours of work.

b Plot a graph for the total charge against the number of hours worked for Paul and Sherry on the same axes.

c Use the graph to determine:

- **i** the cost of hiring Paul for 3.5 hours
- **ii** the cost of hiring Sherry for 1.5 hours
- **iii** the number of hours of work if Paul charges \$100
- **iv** the number of hours of work if Sherry charges \$260
- **v** the number of hours of work if the cost from Paul and Sherry is the same

d Write a sentence describing who is cheaper for different hours of work.

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6D Midpoint and length of line segments

A line extends infinitely in both directions, whereas a line segment (or interval) has a defined length with two end points. A line segment also has a point in the middle of the segment called the midpoint. Both the midpoint and length can be found by using the coordinates of the end points.

Builders use mathematical calculations to determine the length, midpoint and angle of inclination of wooden beams when constructing the timber frame of a house.

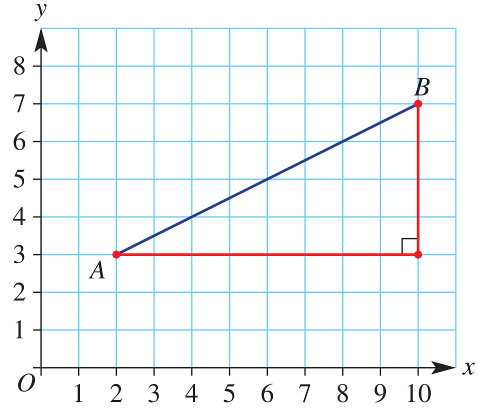
Stage

- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

Let's start: Finding a method

This is a graph of the line segment *AB*. A right-angled triangle has been drawn so that *AB* is the hypotenuse (longest side).

- How many units long are the horizontal and vertical sides of this right-angled triangle?
- Discuss and explain a method for finding the length of the line segment *AB*.
- What is the *x* value of the middle point of the horizontal side of the right-angled triangle?
- What is the *y* value of the middle point of the vertical side of the right-angled triangle?
- What are the coordinates of the point in the middle of the line segment *AB*?
- Discuss and explain a method for finding the midpoint of a line segment.

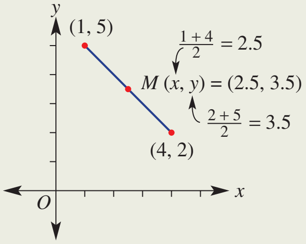


Key ideas

- The **midpoint** (*M*) of a line segment is the halfway point between the two end points.

  - $$\text{Midpoint} = \left(\begin{matrix}\text{average of two}\\ x \text{ values at}\\ \text{end points}\end{matrix}, \begin{matrix}\text{average of two}\\ y \text{ values at}\\ \text{end points}\end{matrix}\right)$$

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$$



  - When finding the average, add the values in the numerator before dividing by 2.

Midpoint The point on an interval that is equidistant from the end points of the interval

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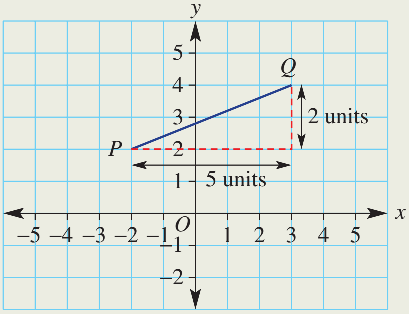
Key ideas

- The length of a line segment is found using **Pythagoras' theorem**. To find the length of the line segment PQ:
  - Draw a right-angled triangle with the line segment PQ as the hypotenuse (longest side).
  - Count the grid squares to find the length of each smaller side.
  - Apply Pythagoras' theorem.

$$\begin{aligned} PQ^2 &= 5^2 + 2^2 \\ &= 25 + 4 \\ &= 29 \\ PQ &= \sqrt{29} \text{ units} \end{aligned}$$

  - $\sqrt{29}$ is the length of line segment PQ in square root form.



Pythagoras' theorem
In a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides

Exercise 6D

UNDERSTANDING AND FLUENCY	1, 2, 3–4(½), 5, 6(½), 8(½)	4–8(½)

1 Imagine that a fireman's ladder is extended to the top of a 12 m building, with the foot of the ladder on the ground 5 m out from the base of the building.

a What is the rule called that can be used to find the length of the ladder?

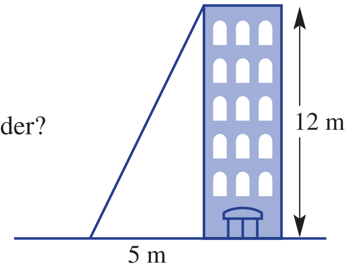
b Apply this method and calculate the length of this ladder.

Fireman Fred stands exactly halfway along the ladder.

c What height of the building is level with Fred's feet?

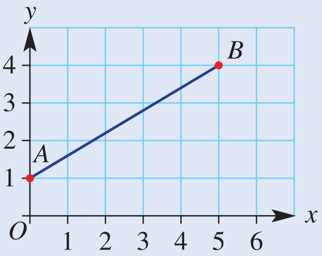
d How far out are his feet from the building?

e Write the missing words needed to complete this sentence:
The middle point of the hypotenuse is level with the __________ point of the horizontal side and the __________ point of the vertical side of a right-angled triangle.



Example 10 Finding the length of a line segment from a graph

Find the length of the line segment between $A(0, 1)$ and $B(5, 4)$.



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SOLUTION

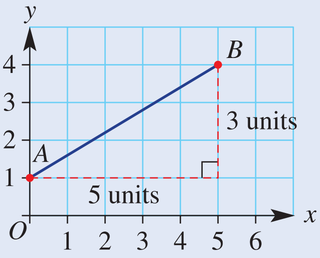
$AB^2 = 5^2 + 3^2$

$AB^2 = 25 + 9$

$AB^2 = 34$

$AB = \sqrt{34}$ units

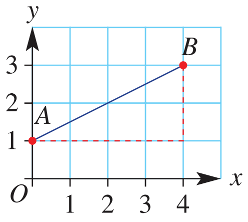
EXPLANATION



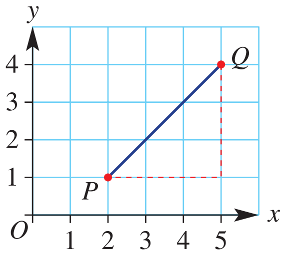
Create a right-angled triangle and use Pythagoras' theorem. For $AB^2 = 34$, take the square root of both sides to find AB. $\sqrt{34}$ is the exact answer.

2 Find the length of each of the following line segments. Leave each answer in square root form.

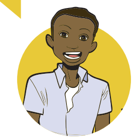
a



b

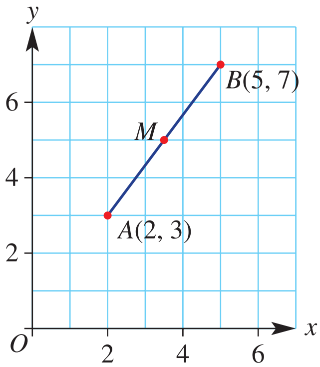


Count the 'spaces' to find the number of units for the horizontal and vertical sides.

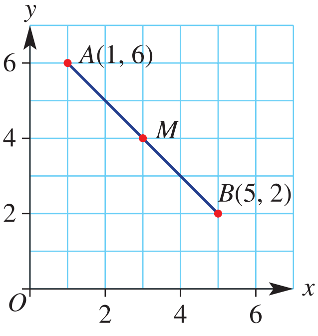


3 Find the midpoint, M, of each of the following intervals.

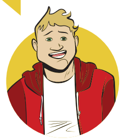
a



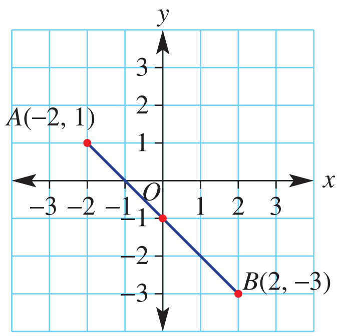
b



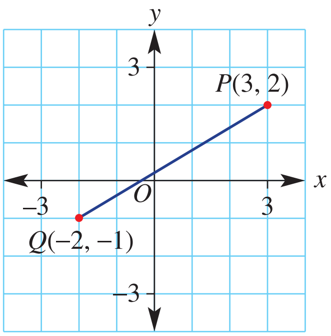
In finding the average, add the numerator values before dividing by 2.



c



d



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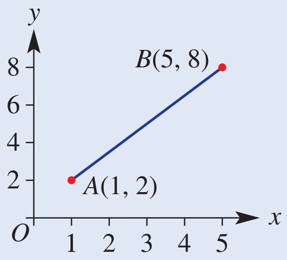
Example 11 Finding the midpoint of a line segment from a graph

Find the midpoint of the interval between $A(1, 2)$ and $B(5, 8)$.

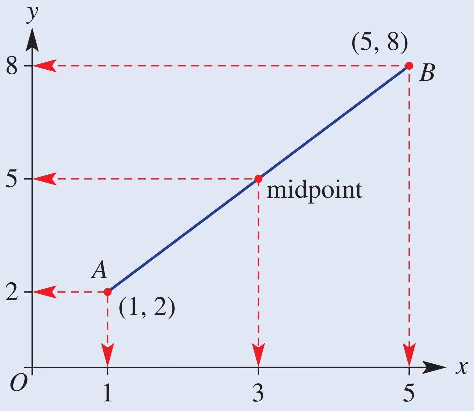


SOLUTION

$$\begin{aligned}\text{Average of } x \text{ values} &= \frac{1+5}{2}\\ &= \frac{6}{2}\\ &= 3\\ \text{Average of } y \text{ values} &= \frac{2+8}{2}\\ &= \frac{10}{2}\\ &= 5\end{aligned}$$

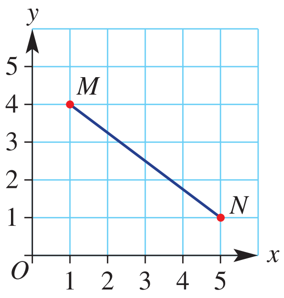
Midpoint is (3, 5).

EXPLANATION

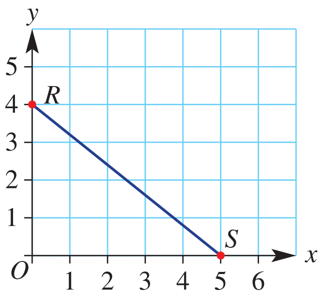


4 Find the length of each of the following line segments.

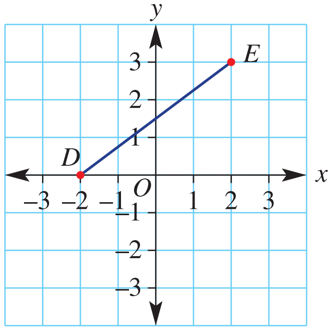
a



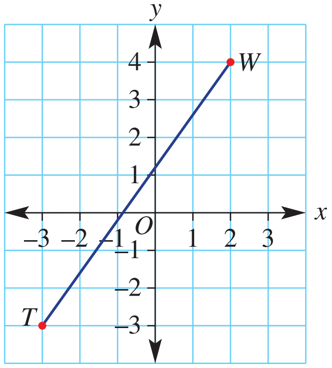
b



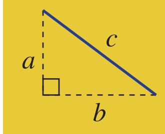
c



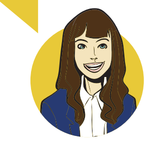
d



Use Pythagoras' theorem ($c^2 = a^2 + b^2$) by forming a right-angle triangle:

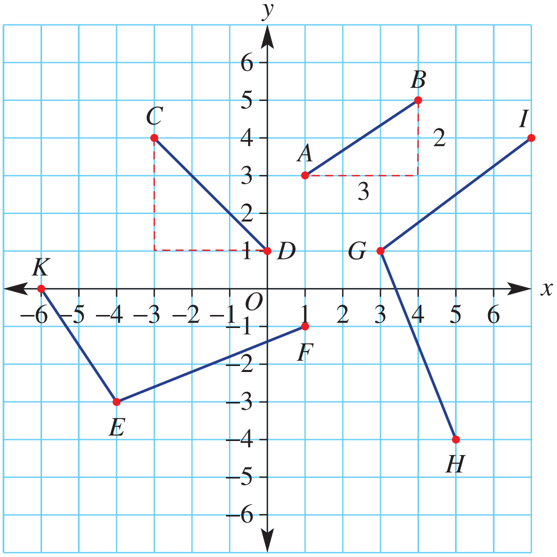


Write the answer in square root form if it is not a known square root.

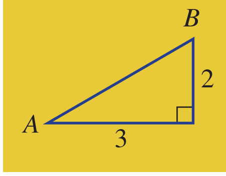


5 Find the length of each line segment on the Cartesian plane shown. Leave your answers in square root form.

a AB **b** CD **c** EF **d** GH **e** KE **f** GI



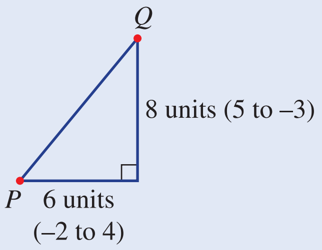
First sketch a right-angle triangle for each line segment, labelling the known sides.



Example 12 Finding the length of a line segment when given the coordinates of the end points

Find the distance between the points P and Q if P is at $(-2, -3)$ and Q is at $(4, 5)$.

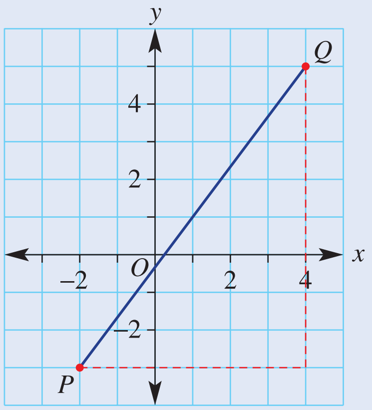
SOLUTION



$$PQ^2 = 6^2 + 8^2$$
$$PQ^2 = 36 + 64$$
$$PQ^2 = 100$$
$$PQ = \sqrt{100}$$
$$PQ = 10 \text{ units}$$

EXPLANATION

Use Pythagoras' theorem to find PQ, the hypotenuse.



If you know the value of the square root, write its value.

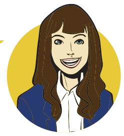
6 Plot each of the following pairs of points and find the distance between them, correct to 1 decimal place where necessary.

a $(2, 3)$ and $(5, 7)$ **b** $(0, 1)$ and $(6, 9)$

c $(0, 0)$ and $(-5, 10)$ **d** $(-4, -1)$ and $(0, -5)$

e $(-3, 0)$ and $(0, 4)$ **f** $(0, -1)$ and $(2, -4)$

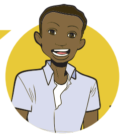
First rule up axes with x from -5 to 10 and y from -5 to 10.



7 Find the exact length between these pairs of points.

a (1, 3) and (2, 2)
b (4, 1) and (7, 3)
c (−3, −1) and (0, 4)
d (−2, −3) and (3, 5)
e (−1, 0) and (−6, 1)
f (1, −3) and (4, −2)

Exact length means leave the $\sqrt{\ }$ sign in the answers.



Example 13 Finding the midpoint of a line segment when given the coordinates of the end points

Find the midpoint of the line segment joining $P(-3, 1)$ and $Q(5, -4)$.

SOLUTION	EXPLANATION
$x = \dfrac{-3 + 5}{2}$	Average the x coordinates. Calculate the numerator before dividing by 2. $-3 + 5 = 2$
$= \dfrac{2}{2}$	
$= 1$	
$y = \dfrac{1 + (-4)}{2}$	Average the y coordinates. Calculate the numerator before dividing by 2. $1 + (-4) = 1 - 4 = -3$
$= \dfrac{-3}{2}$	
$= -1.5$	
Midpoint is (1, −1.5).	Write the coordinates of the midpoint.

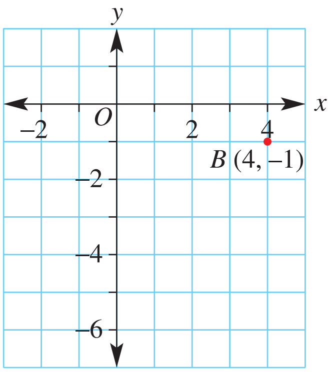
8 Find the midpoint of the line segment that is joining the following points.

a (1, 4) and (3, 6)
b (3, 7) and (5, 9)
c (0, 4) and (6, 6)
d (2, 4) and (3, 5)
e (7, 2) and (5, 3)
f (1, 6) and (4, 2)
g (0, 0) and (−2, −4)
h (−2, −3) and (−4, −5)
i (−3, −1) and (−5, −5)
j (−3, −4) and (5, 6)
k (0, −8) and (−6, 0)
l (3, −4) and (−3, 4)

Check that your answer appears to be halfway between the end points.

PROBLEM-SOLVING AND REASONING 9, 10 10, 11

9 Copy the diagram on the right. Mark the point $B(4, -1)$, as shown, then mark the point $M(1, -3)$. Find the coordinates of A if M is the midpoint of the interval AB.



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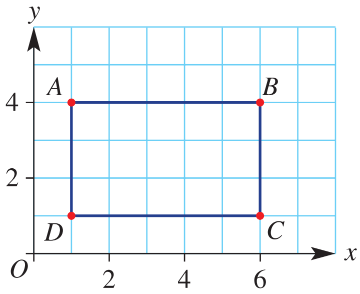
10 Copy the diagram of rectangle *ABCD*.

a What are the coordinates of each vertex?

b Find the midpoint of the diagonal *AC*.

c Find the midpoint of the diagonal *BD*.

d What does this tell us about the diagonals of a rectangle?



11 Draw up a four-quadrant number plane like the one shown.

a Plot the points $A(-4, 0)$, $B(0, 3)$ and $C(0, -3)$, then form the triangle *ABC*.

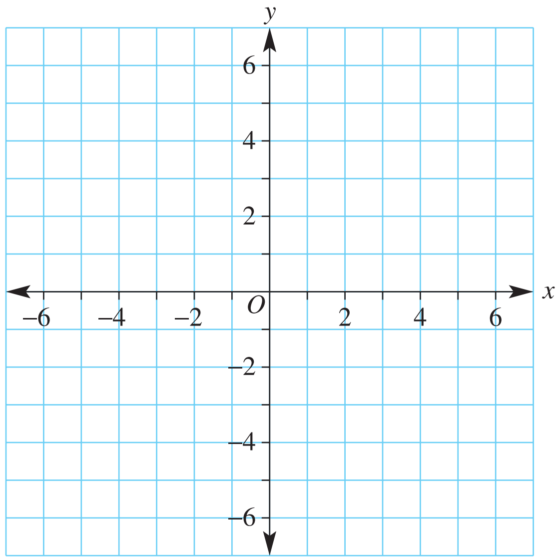
b What is the length of:

i *AB*? **ii** *AC*?

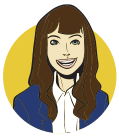
c What type of triangle is *ABC*?

d Calculate its perimeter and area.

e Write down the coordinates of *D* such that *ABDC* is a rhombus.



A rhombus has all sides of equal length.



ENRICHMENT – 12

Features of a circle

12 The diameter of a circle is shown on this graph.

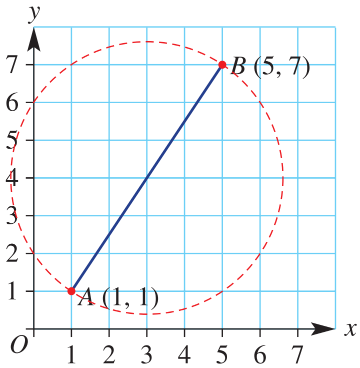
a What are the coordinates of *X*, the centre of the circle? Mark this point on your graph.

b What is the length of the radius *XA*?

c Find the distance from *X* to the point $(5, 1)$. How can we tell that $(5, 1)$ lies on the circle?

d Use $C = 2\pi r$ to find the circumference of the circle shown. Round your answer to 1 decimal place.

e Calculate the area of this circle using $A = \pi r^2$, correct to 1 decimal place.



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6E Exploring gradient

Interactive

Widgets

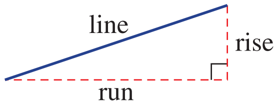
HOTsheets

Walkthrough

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

The gradient of a line is a measure of its slope. It is a number that shows the steepness of a line. It is calculated by knowing how far a line rises or falls (called the *rise*) within a certain horizontal distance (called the *run*). The gradient is equal to the *rise* divided by the *run*. The letter m is used to represent gradient.



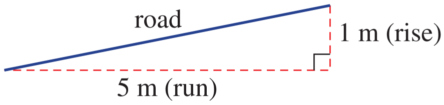
$$\text{Gradient of line} = m = \frac{\text{rise}}{\text{run}}$$

Engineers apply their knowledge of gradients when designing roads, bridges, railway lines and buildings. Some mountain railways have a gradient greater than 1, which is a slope far too steep for a normal train or even a powerful car.

For example, the train shown on the right takes tourists to the Matterhorn, a mountain in Switzerland. To cope with the very steep slopes it has an extra wheel with teeth, which grips a central notched line.

The Gornergrat Bahn in Switzerland needs to cope with very steep slopes on its way to the Matterhorn.

Let's start: What's the gradient?



A road that rises by 1 m for each 5 m of horizontal distance has a gradient of 0.2 or 20%.

Trucks would find this gradient very steep.

The gradient is calculated by finding the rise divided by the run.

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{1}{5} = 0.2 = 20\%$$

1 Find the gradient for each of these roads. Give the answer as a decimal and a perentage.

- **a** Baldwin Street, Dunedin, New Zealand is known as the steepest street in the world. For each 2.86 m of horizontal distance (run), the road rises by 1 m.
- **b** Gower Street, Toowong, is Brisbane's steepest street. For each 3.2 m of horizontal distance (run), the road rises by 1 m.

2 The Scenic Railway, Katoomba, NSW has a maximum gradient of 122% as it passes through a gorge in the cliff. What is its vertical distance (rise) for each 1 metre of horizontal distance (run)?

Use computer software (dynamic geometry) to produce a set of axes and grid.

- Construct a line segment with end points on the grid. Show the coordinates of the end points.
- Calculate the rise (vertical distance between the end points) and the run (horizontal distance between the end points).

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- Calculate the gradient as the *rise* divided by the *run*.
- Now drag the end points and explore the effect on the gradient.
- Can you drag the end points but retain the same gradient value? Explain why this is possible.
- Can you drag the end points so that the gradient is zero or undefined? Describe how this can be achieved.

Key ideas

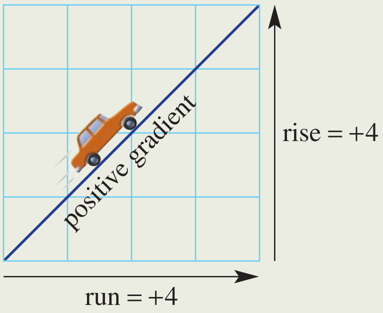
- **Gradient** is given by the formula $m = \dfrac{\text{rise}}{\text{run}}$

  The value of the gradient can be written as:
  - a fraction (which may simplify to a whole number)
  - a decimal
  - a percentage or
  - a ratio.

  Always move from left to right when considering the rise and the run.
  - The horizontal 'run' always goes to the right and is always positive. The vertical 'rise' can go up (positive) or down (negative).
  - If the line slopes up from left to right, the rise is positive and the gradient is positive.

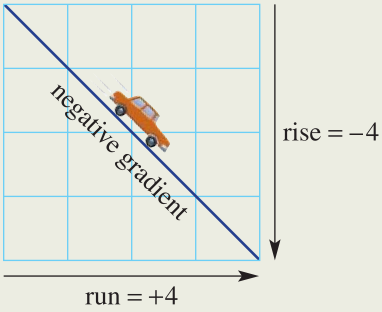
    For example: $m = \dfrac{\text{rise}}{\text{run}} = \dfrac{+4}{+4} = 1$

Gradient (*m*) The steepness of a slope

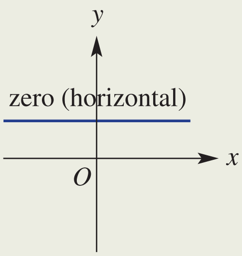


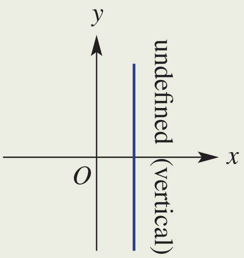
  - If the line slopes down from left to right, the rise is negative and the gradient is negative.

    For example: $m = \dfrac{\text{rise}}{\text{run}} = \dfrac{-4}{+4} = -1$



- The gradient can also be zero (when a line is horizontal) and undefined (when a line is vertical).





- Between two points (x_1, y_1) and (x_2, y_2), the gradient (m) is $m = \dfrac{y_2 - y_1}{x_2 - x_1} = \dfrac{\text{rise}}{\text{run}}$.

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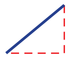
Exercise 6E

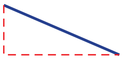
UNDERSTANDING AND FLUENCY 1–6 4–7

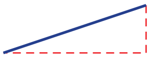
1 Use the words ‘positive’, ‘negative’, ‘zero’ or ‘undefined’ to complete each sentence.

- **a** The gradient of a horizontal line is ____________.
- **b** The gradient of the line joining (0, 3) and (5, 0) is ___________.
- **c** The gradient of the line joining (−6, 0) and (1, 1) is ___________.
- **d** The gradient of a vertical line is ___________.

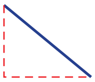
2 Decide whether each of the following lines would have a positive or negative gradient.

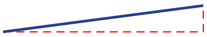
a


b


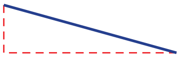
c


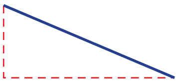
d


e


f


g

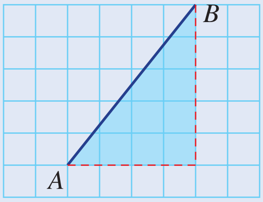

h


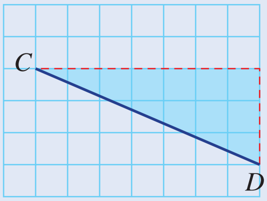
i


Lines going downhill from left to right have a negative gradient.

Example 14 Finding the gradient from a grid

Find the gradient of the following line segments, where each grid box equals 1 unit.

a


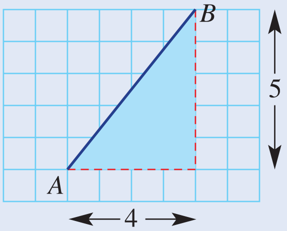
b


SOLUTION

a Gradient of $AB = \frac{\text{rise}}{\text{run}}$

$= \frac{5}{4}$

EXPLANATION

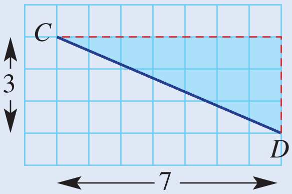


The slope is upwards and therefore the gradient is positive.
The rise is 5 and the run is 4.

b Gradient of $CD = \frac{\text{rise}}{\text{run}}$

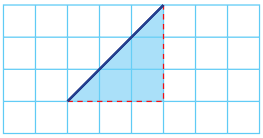
$= \frac{-3}{7}$

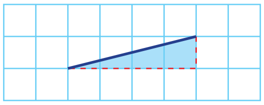
$= -\frac{3}{7}$

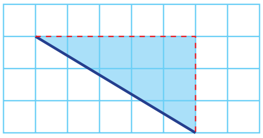


The slope is downwards and therefore the gradient is negative.
The fall is 3, so we write rise = −3, and the run is 7.

3 Find the gradient of the following line segments.

a


b


c


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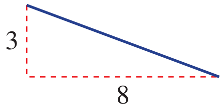
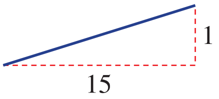
4 Find the gradient of the following.

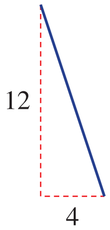
a



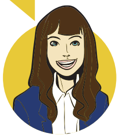
b



c



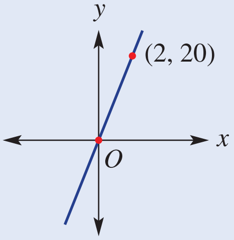
The gradient is written as a fraction or a whole number.



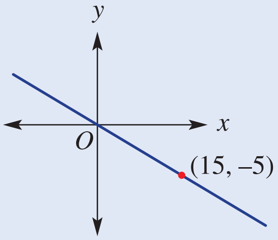
Example 15 Finding the gradient from graphs

Find the gradient of the following lines.

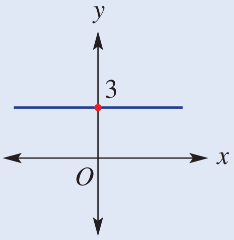
a



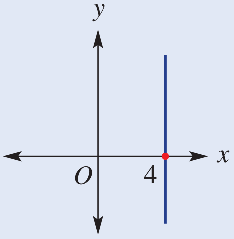
b



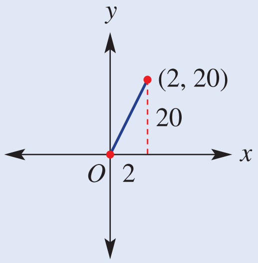
c



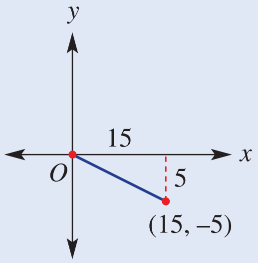
d



SOLUTION	EXPLANATION
a Gradient $= \dfrac{\text{rise}}{\text{run}}$	Write the rule each time.
$= \dfrac{20}{2}$	The rise is 20 and the run is 2 between the two points (0, 0) and (2, 20).
$= 10$	Simplify by cancelling.



SOLUTION	EXPLANATION
b Gradient $= \dfrac{\text{rise}}{\text{run}}$	Note this time that, when working from left to right, there will be a slope downwards.
$= \dfrac{-5}{15}$	The fall is 5 (rise = −5) and the run is 15.
$= \dfrac{-1}{3}$	Simplify.
$= -\dfrac{1}{3}$	
c Gradient = 0	Horizontal lines have a zero gradient.
d Gradient is undefined.	Vertical lines have an undefined gradient.



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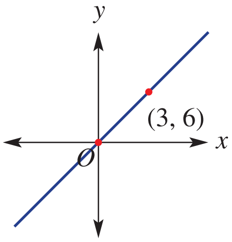
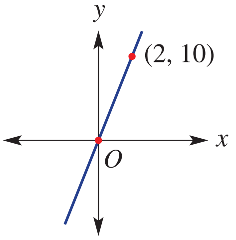
5 Find the gradient of the following lines.

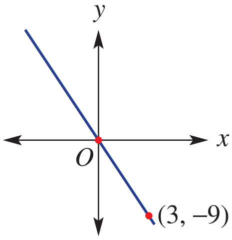
a



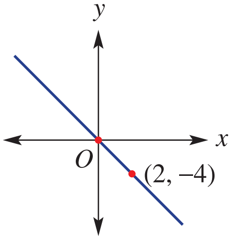
b



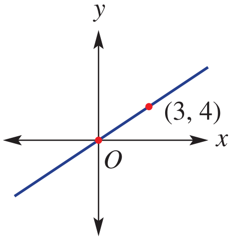
c



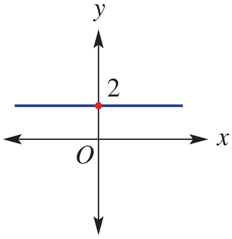
d



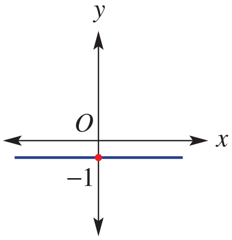
e



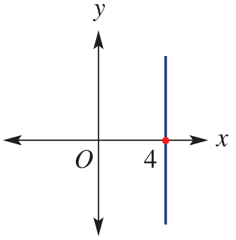
f



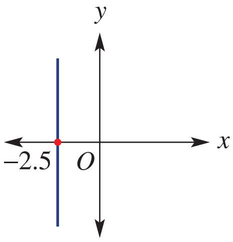
g



h

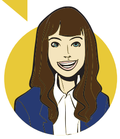


i

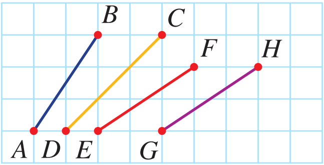


A horizontal line has zero rise, so its gradient is zero.

A vertical line has no 'run', so it has undefined gradient.

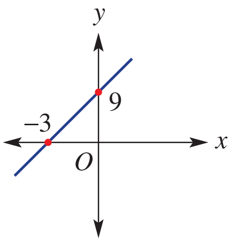


6 Use the grid to find the gradient of the following line segments. Then order the segments from least to steepest gradient.

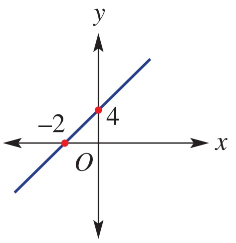


7 Determine the gradient of the following lines.

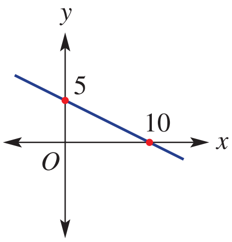
a



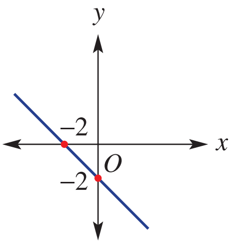
b



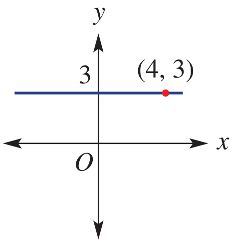
c



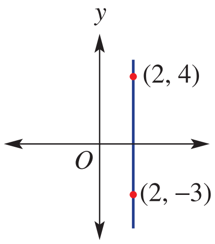
d

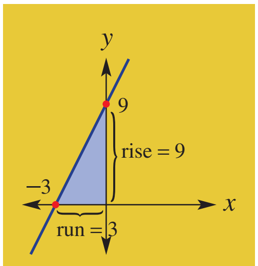


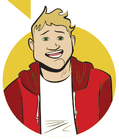
e



f







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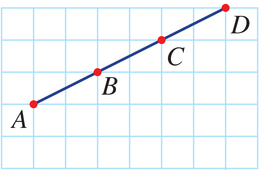
PROBLEM-SOLVING AND REASONING 8, 9–10(½) 9–10(½), 11

8 **a** Copy and complete the table below.

Line segment	Rise	Run	Gradient
AB			
AC			
AD			
BC			
BD			
CD			

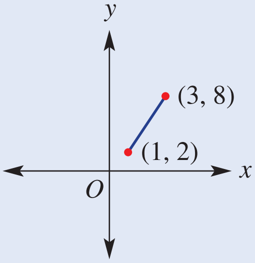


b What do you notice about the gradient between points on the same line?

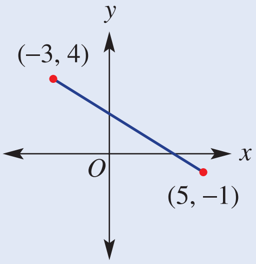
Example 16 Using a formula to calculate gradient

Use the formula $m = \frac{y_2 - y_1}{x_2 - x_1}$ to find the gradient of the line segments between the following pairs of points.

a



b



SOLUTION

a $m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{8 - 2}{3 - 1}$

$= \frac{6}{2}$

$= 3$

b $m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{-1 - 4}{5 - (-3)}$

$= \frac{-5}{8}$

$= -\frac{5}{8}$

EXPLANATION

Write the rule.

$$\begin{array}{cccc} (1, & 2) & (3, & 8) \\ \downarrow & \downarrow & \downarrow & \downarrow \\ x_1 & y_1 & x_2 & y_2 \end{array}$$

It does not matter which point is labelled (x_1, y_1) and which is (x_2, y_2).

Write the rule.

$$\begin{array}{cccc} (5, & -1) & (-3, & 4) \\ \downarrow & \downarrow & \downarrow & \downarrow \\ x_1 & y_1 & x_2 & y_2 \end{array}$$

Remember that $5 - (-3) = 5 + 3 = 8$.

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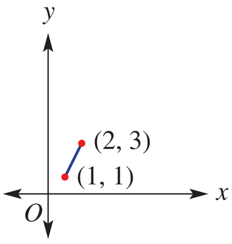
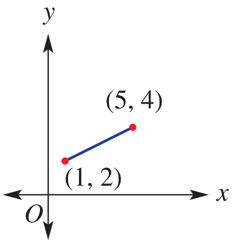
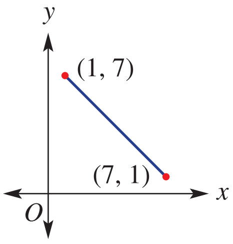
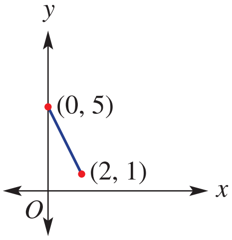
9 Use the formula $m = \frac{y_2 - y_1}{x_2 - x_1}$ to find the gradient between these pairs of points.

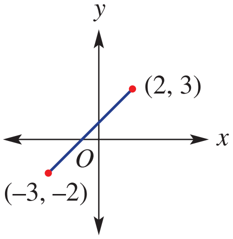
First, copy the coordinates and label them.
e.g. (1, 1) (2, 3)
$\downarrow\ \downarrow\quad \downarrow\ \downarrow$
$x_1\ y_1\quad x_2\ y_2$

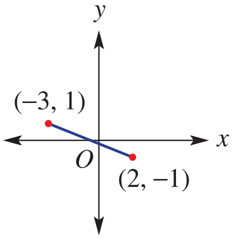
a


b


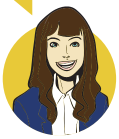
c


d


e


f


You can choose either point to be (x_1, y_1).



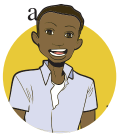
10 Find the gradient between the following pairs of points:

a (1, 3) and (5, 7)
b (−1, −1) and (3, 3)
c (−3, 4) and (2, 1)
d (−6, −1) and (3, −1)
e (1, −4) and (2, 7)
f (−4, −2) and (−1, −1)

Use $m = \frac{y_2 - y_1}{x_2 - x_1}$.

11 The first section of the Cairns Skyrail travels from Caravonica terminal at 5 m above sea level to Red Peak terminal, which is 545 metres above sea level. This is across horizontal distance of approximately 1.57 km. What the overall gradient of this section of the Skyrail? Round answer to 3 decimal places.

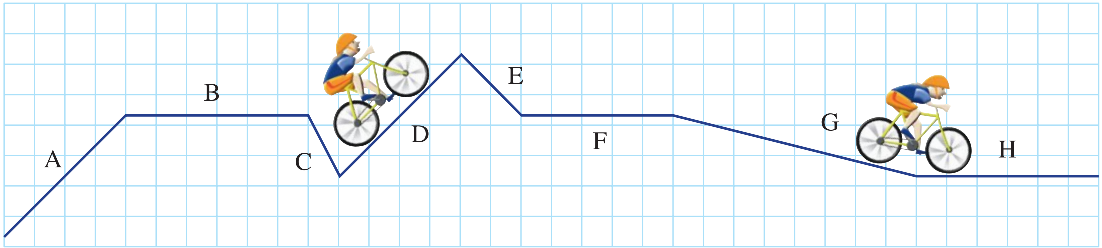
Both distance need to be in the same units.



ENRICHMENT – 12

From Bakersville to Rolland

12 A transversal map for a bike ride from Bakersville to Rolland is shown.



a Which sections, A, B, C, D, E, F, G or H, indicate travelling a positive gradient?
b Which sections indicate travelling a negative gradient?
c Which will be the hardest section to ride?
d Which sections show a zero gradient?
e Which section is the flattest of the downhill rides?
f Design your own travel graph with varying gradients and ask a classmate to find the section with the steepest gradient.

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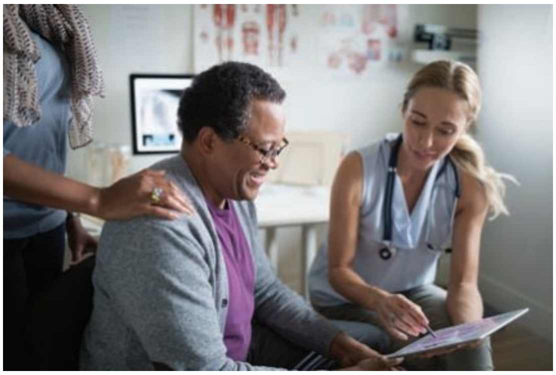
6F Rates from graphs

Interactive
Widgets
HOTsheets
Walkthrough

The speed or rate at which something changes can be analysed by looking at the gradient (steepness) of a graph. Two common rates are kilometres per hour (km/h) and litres per second (L/s).

Graphs of a patient's records provide valuable information to a doctor. For example, from a graph of temperature versus time, the rate of temperature change in °C/minute can be calculated. This rate provides important information to help a doctor diagnose an illness.



Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

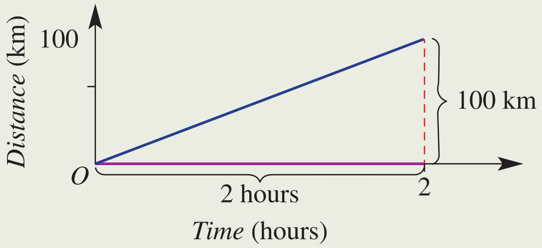
Let's start: What's the rate?

Calculate each of these rates.

a $60 000 for 200 tonnes of wheat.
b Lee travels 840 km in 12 hours.
c A foal grows 18 cm in height in 3 months.
d Petrol costs $96 for 60 litres.
e Before take-off, a hot-air balloon of volume 6000 m^3 is filled in 60 seconds.

Key ideas

- A **rate** compares two quantities. Many rates show how a quantity changes over *time*.



$$\text{Rate} = \frac{\text{rise}}{\text{run}}$$
$$= \frac{100}{2}$$
$$= 50 \text{ km/h}$$

Rate A measure of one quantity against another

- Rate comparing to time = change in quantity ÷ change in time
  (L, kg, …) (seconds, hours, …)

- A common rate is speed.
  - Speed = change in distance ÷ change in time
    (cm, km, …) (seconds, hours, …)

- The gradient of a line gives the rate.

- To determine a rate from a linear graph, calculate the gradient and include the units (y unit/x unit); e.g. km/h.

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Exercise 6F

UNDERSTANDING AND FLUENCY 1–3, 5 2, 4, 5, 6

1 Complete the sentences.

a A rate is found from a linear graph by calculating the ____________ of the line.

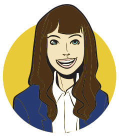
b A rate compares ____________ quantities.

c A rate has two ____________.

d A speed of 60 kilometres per hour is written as 60 ____________.

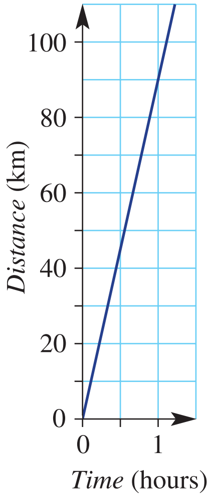
e If the rate of filling a bath is 50 litres per minute, this is written as 50 ____________.

Choose from: km/h, gradient, units, L/min, two.

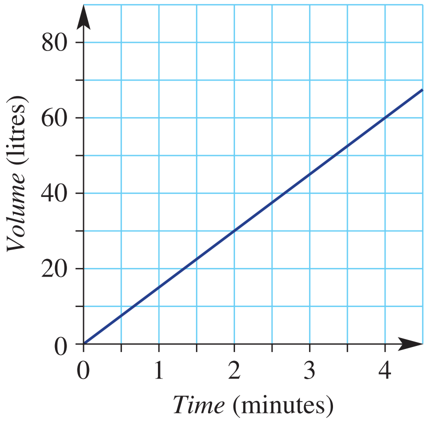


2 Write down the rate by calculating the gradient of each line graph.

a



b



A rate = gradient with units.

Gradient = $\frac{\text{rise}}{\text{run}}$.

Example 17 Calculating speed from a graph

A 4WD vehicle completes a journey, which is described by this graph.

a For the first hour, find:

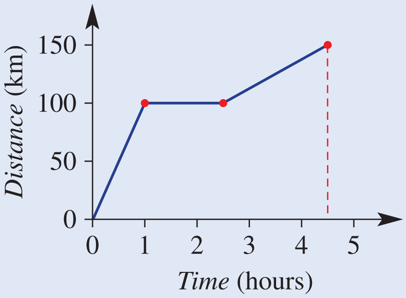
i the total distance travelled

ii the speed

b How fast was the 4WD travelling during:

i the second section?

ii the third section?



SOLUTION	EXPLANATION
a **i** 100 km	Read the distance at 1 hour.
ii 100 km/1h = 100 km/h	Speed = distance ÷ time
b **i** 0 km/1.5 h = 0 km/h	The vehicle is at rest.
ii (150 – 100) km/(4.5 – 2.5) h = 50 km/2 h = 25 km/h	Determine the distance travelled and the amount of time, then apply the rate formula. Speed = distance ÷ time 50 km in 2 hours is $\frac{50}{2}$ = 25 km in 1 hour.

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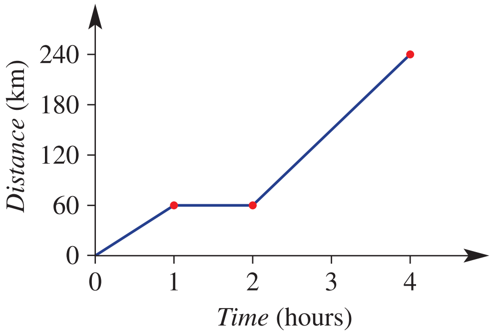
3 A car completes a journey, which is described by this graph.

a For the first hour find:
  - **i** the total distance travelled
  - **ii** the speed

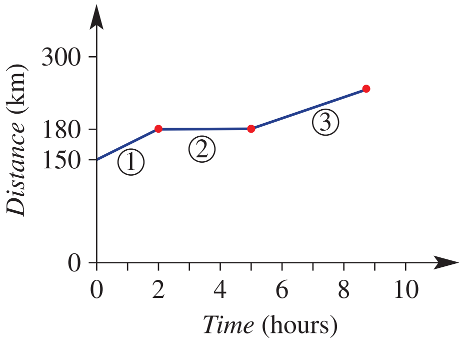
b How fast was the car travelling during:
  - **i** the second section?
  - **ii** the third section?



4 A bike rider training for a professional race includes a rest stop between two travelling sections.

a For the first hour, find:
  - **i** the total distance travelled
  - **ii** the speed

b How fast was the bike travelling during:
  - **i** the second section?
  - **ii** the third section?

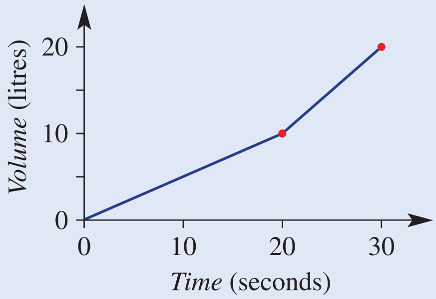


Example 18 Calculating the rate of change of volume in L/s

A container is being filled with water from a hose.

a How many litres were filled during:
  - **i** the first 10 seconds?
  - **ii** the final 10 seconds?

b How fast (what rate in L/s) was the container being filled:
  - **i** during the first 10 seconds?
  - **ii** during the final 10 seconds?
  - **iii** between the 10- and 20-second marks?



SOLUTION	EXPLANATION
a **i** 5 litres	Read the number of litres after 10 seconds.
ii 10 litres	Read the change in litres from 20 to 30 seconds.
b **i** 5 L/10 s = 0.5 L/s	5 litres is added in the first 10 seconds.
ii 10 L/10 s = 1 L/s	10 litres is added in the final 10 seconds.
iii 5 L/10 s = 0.5 L/s	5 litres is added between 10 and 20 seconds.

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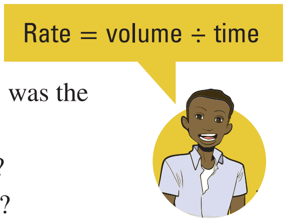
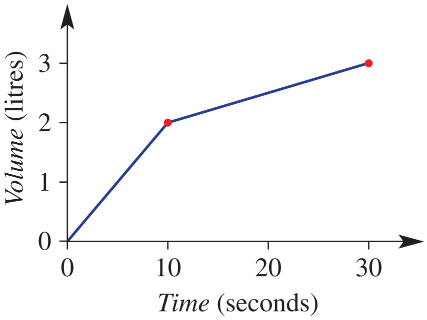
5 A large carton is being filled with milk.

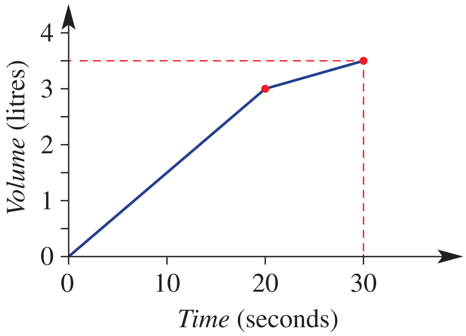
- **a** How many litres were filled during:
  - **i** the first 10 seconds?
  - **ii** the final 10 seconds?
- **b** How fast (i.e. what rate in L/s) was the container being filled:
  - **i** during the first 10 seconds?
  - **ii** during the final 10 seconds?
  - **iii** between the 10- and 20-second marks?





6 A large bottle with a long narrow neck is being filled with water.

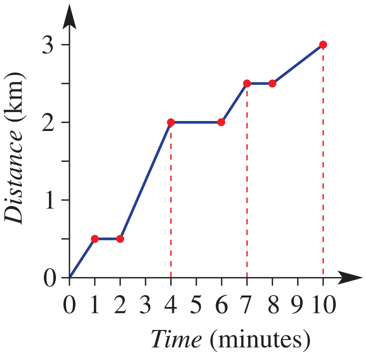
- **a** How many litres were filled during:
  - **i** the first 10 seconds?
  - **ii** the final 10 seconds?
- **b** How fast (i.e. what rate in L/s) was the bottle being filled:
  - **i** during the first 10 seconds?
  - **ii** during the final 10 seconds?
  - **iii** between the 10- and 20-second marks?



PROBLEM-SOLVING AND REASONING		
	7, 8	7, 9, 10

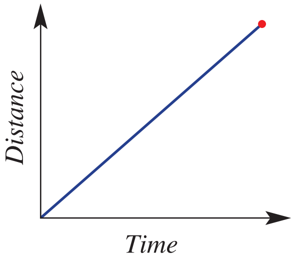
7 A postal worker stops to deliver mail to each of three houses along a country lane.

- **a** What was the total length of the country lane?
- **b** What was the total time the postal worker spent standing still?
- **c** Find the speed (use km/min) of the postal worker at the following times.
  - **i** before the first house
  - **ii** between the first and the second house
  - **iii** between the second and the third house
  - **iv** after the delivery to the third house

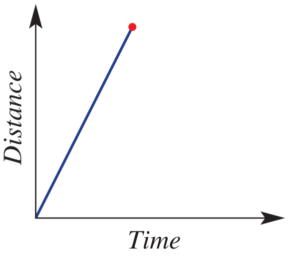


8 Three friends, Anna, Billy and Cianne, travel 5 km from school to the library. Their journeys are displayed in the three graphs below. All three graphs are drawn to the same scale.

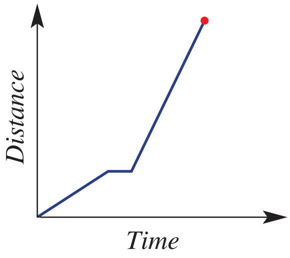
A



B



C



- **a** If Anna walked a short distance before getting picked up by her mum and driven to the library, which graph represents her trip?
- **b** If Cianne arrived at the library last, which graph best represents her journey?
- **c** Which graph represents the fastest journey? Explain your answer.

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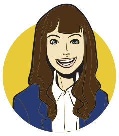
9 **a** Draw your own graph to show the following journey: 10 km/h for 2 hours, then rest for 1 hour, and then 20 km/h for 2 hours.

b Now use your graph to find the total distance travelled.

Mark each segment one at a time. 10 km/h for 2 hours covers a distance of 10 × 2 = 20 km.



10 A lift starts on the ground floor (height 0 m) and moves to floor 3 at a rate of 3 m/s for 5 seconds. After waiting at floor 3 for 9 seconds, the lift rises 45 m to floor 9 in 9 seconds. The lift rests for 11 seconds before returning to ground level at a rate of 6 m/s. Draw a graph to help find the total time taken to complete these movements. Use time in seconds on the horizontal axis.

ENRICHMENT – 11

Sienna's training

11 Sienna is training for the Sydney Marathon. Her distance–time graph is shown below.

a How many stops did Sienna make?

b How far did she jog between:

i 6 a.m. and 7 a.m.? **ii** 7.30 a.m. and 8.30 a.m.?

c Which sections of the graph have a zero gradient?

d Which sections of the graph have the steepest gradient?

e At what speed did Sienna run in these sections?

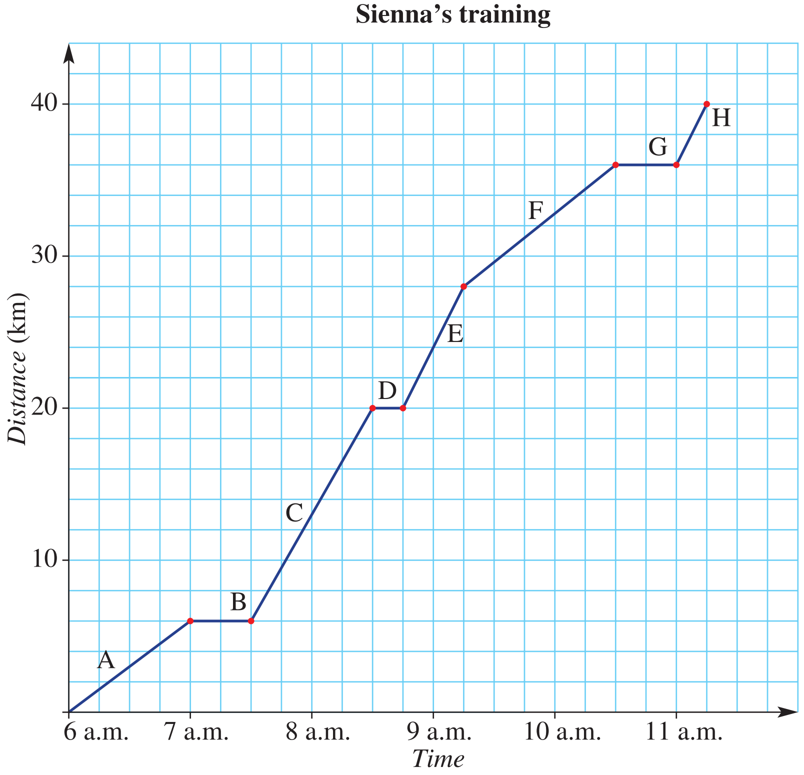
i A **ii** C **iii** E **iv** F **v** H

f In which sections is Sienna travelling at the same speed? How does the graph show this?

g How long did the training session last?

h What was the total distance travelled by Sienna during the training session?

i What was her average speed for the entire trip, excluding rest periods?



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6G $y = mx + b$ and special lines

Interactive

Widgets

HOTsheets

Walkthrough

Stage

- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

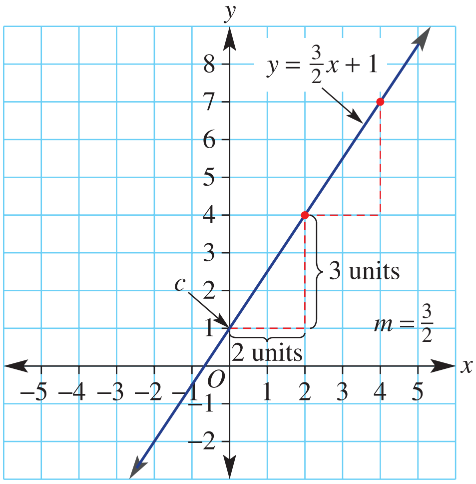
Most straight line graphs can be described by the linear equation $y = mx + b$.

The gradient, m, is the coefficient of x, and b is the y-intercept. This is why this rule is called the gradient–intercept form.

Here is a graph of $y = \frac{3}{2}x + 1$

gradient $m = \frac{3}{2}$

y-intercept $b = +1$



Mathematicians use rules and graphs to help determine how many items should be manufactured to make the maximum profit. For example, profit would be reduced by making too many of a certain style of mobile phone that will be outdated soon. A knowledge of graphs is important in business.

Let's start: Matching lines with equations

Below are some equations of lines and some graphs. Work with a classmate and help each other to match each equation with its correct line graph.

a $y = 2x - 3$

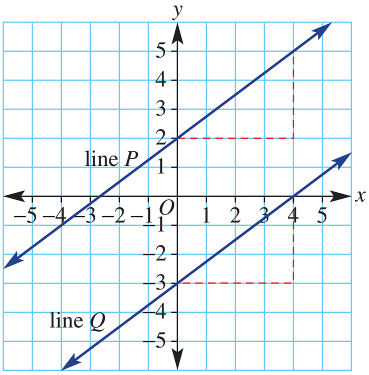
b $y = \frac{3}{4}x + 2$

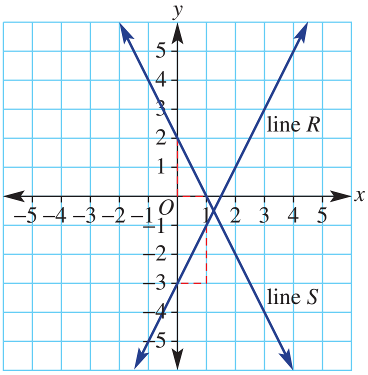
c $y = -\frac{2}{3}x + 1$

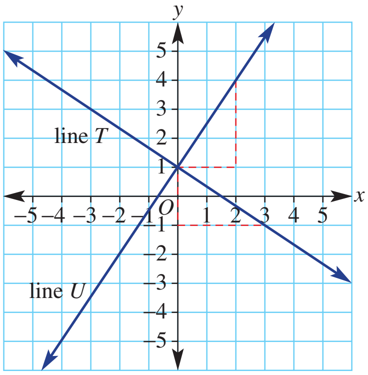
d $y = -2x + 2$

e $y = \frac{3}{4}x - 3$

f $y = \frac{3}{2}x + 1$

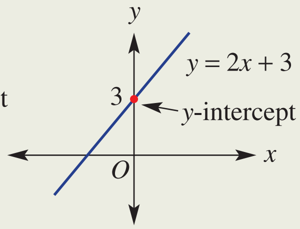




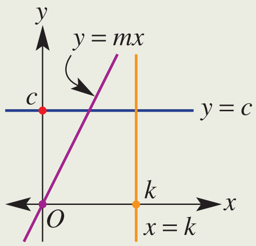


Key ideas

- $y = mx + b$ called the **gradient–intercept form**, where m and b are constants. For example: $y = 3x + 4$, $y = \frac{1}{2}x - 3$ and $y = 2$.
- The gradient or slope equals m (the **coefficient** of x).
- The **y-intercept** is the y value of the point where the line cuts the y axis. In $y = mx + b$, the y-intercept is b.



- Some special lines include:
  - horizontal lines: $y = b\,(m = 0)$
  - vertical lines: $x = a$ (m is undefined)
  - lines passing through the origin (0, 0): $y = mx\,(b = 0)$



Gradient–intercept form The equation of a straight line, written with y as the subject of the equation

Coefficient A numeral placed before a pronumeral, showing that the pronumeral is multiplied by that factor

y-intercept The y value of the point at which a line or curve cuts the y-axis

Exercise 6G

UNDERSTANDING AND FLUENCY 1, 2–5(½) 2–6(½)

1 Complete the sentences.

a $y = mx + b$ is called the _________ – _________ form of a straight line.

b The symbol m stands for the _________.

c In the equation, the gradient, m, is the _________ of x.

d The symbol b stands for the _________.

Example 19 Reading the gradient and y-intercept from an equation

For the following equations, state the:

i gradient **ii** y-intercept

a $y = 3x + 4$ **b** $y = -\frac{3}{4}x - 7$

SOLUTION	EXPLANATION
a i Gradient is 3.	The coefficient of x is 3; i.e. $m = 3$.
ii y-intercept is 4.	The value of b is +4.
b i Gradient is $-\frac{3}{4}$.	The coefficient of x is $-\frac{3}{4}$; i.e. $m = -\frac{3}{4}$.
ii y-intercept is −7.	The value of b is −7; don't forget to include the negative sign.

2 For the following equations state the:

i gradient **ii** y-intercept

a $y = 2x + 4$ **b** $y = 6x - 7$ **c** $y = -\frac{2}{3}x + 7$

d $y = -7x - 3$ **e** $y = \frac{3}{5}x - 8$ **f** $y = 9x - 5$

The gradient is the coefficient of x, which is the number multiplied by x, it does not include the x.

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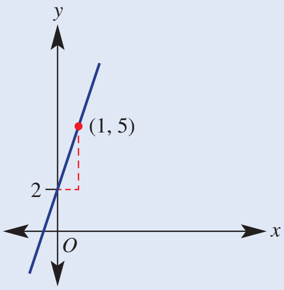
Example 20 Sketching a line using the y-intercept and gradient

Sketch the graph of $y = 3x + 2$ by considering the y-intercept and the gradient.

SOLUTION



EXPLANATION

Consider $y = mx + b$; the value of b is 2 and therefore the y-intercept is 2.

The value of m is 3 and therefore the gradient is 3 or $\frac{3}{1}$.

Start at the y-intercept 2 and, with the gradient of $\frac{3}{1}$, move 1 unit right (run) and 3 units up (rise) to the point $(1, 5)$. Join the points in a line.

3 Sketch the graph of the following by considering the y-intercept and the gradient.

- **a** $y = 2x + 3$
- **b** $y = 3x - 12$
- **c** $y = x + 4$
- **d** $y = -2x + 5$
- **e** $y = -5x - 7$
- **f** $y = -x - 4$

Plot the y-intercept first.
For a line with
$m = -2$: $m = -2 = \frac{-2}{1} = \frac{\text{down } 2}{\text{right } 1}$
From the y-intercept, go right 1 then down 2 to plot the next point.

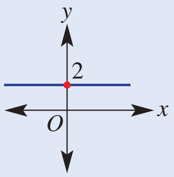
Example 21 Sketching special lines

Sketch the graphs of these equations.

a $y = 2$ **b** $x = -3$ **c** $y = -2x$

SOLUTION

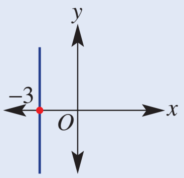
a



EXPLANATION

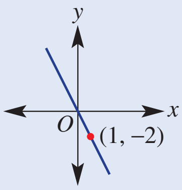
Sketch a horizontal line with a y-intercept at 2.

b



Sketch a vertical line passing through $(-3, 0)$.

c When $x = 0, y = -2 \times (0) = 0$.
When $x = 1, y = -2 \times 1 = -2$.



The line passes through the origin $(0, 0)$.
Use $x = 1$ to find another point.
Sketch the graph passing through $(0, 0)$ and $(1, -2)$.

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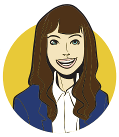
4 Sketch the following lines.

- **a** $y = 3x$
- **b** $y = 6x$
- **c** $y = -2x$
- **d** $y = 4$
- **e** $y = -2$
- **f** $y = 5$
- **g** $x = 5$
- **h** $x = -2$
- **i** $x = 9$

For the equation $y = 2$, every point on the line has a y value of 2
e.g. $(-3, 2)$, $(0, 2)$, $(1, 2)$, $(3, 2)$
For the equation $x = -3$, every point on the line has an x value of -3.
e.g. $(-3, 1)$, $(-3, 0)$, $(-3, -4)$

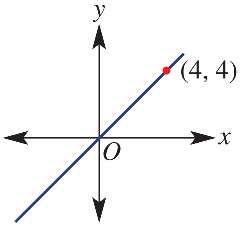


5 Write the equation of the following lines.

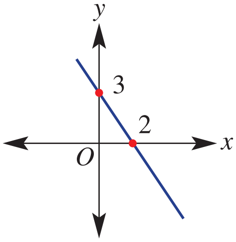
- **a** gradient = 4
  y-intercept at 2
- **b** gradient = 3
  y-intercept at -2
- **c** gradient = 5
  y-intercept at 0
- **d** gradient = -3
  y-intercept at 5
- **e** gradient = -4
  y-intercept at -3
- **f** gradient = -2
  y-intercept at 0

6 Determine the gradient and y-intercept for the following lines.

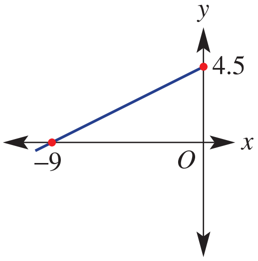
a



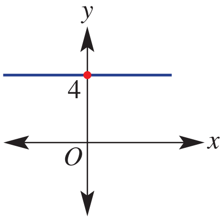
b



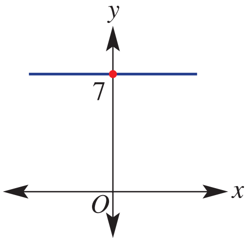
c



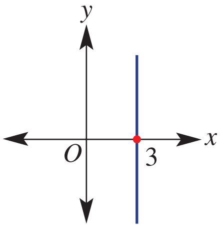
d



e

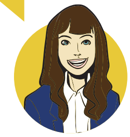


f



A line has the equation
$y = \underset{\uparrow \atop \text{gradient}}{m}x + \underset{\uparrow \atop y\text{-intercept}}{b}$.

Use $m = \frac{\text{rise}}{\text{run}}$ for the gradient between two known points.



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PROBLEM-SOLVING AND REASONING 7, 8, 10 7, 9–12

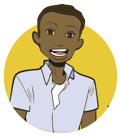
7 Match each of the following linear equations **a**–**i** with one of the sketches **A**–**I** shown.

a $y = -\frac{2}{3}x + 2$ **b** $y = -x + 4$ **c** $y = x + 3$

d $y = 2x + 4$ **e** $y = 4$ **f** $y = 7x$

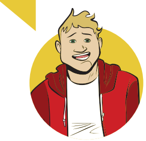
g $y = -3x + 6$ **h** $x = 2$ **i** $y = -3x$

A linear equation is an equation that gives a straight-line graph.

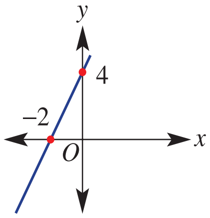


For a negative gradient, move the negative sign to the numerator.

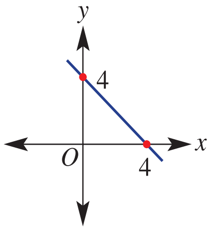
$m = -\frac{2}{3} = \frac{-2}{3} = \frac{\text{down } 2}{\text{right } 3}$



A



B



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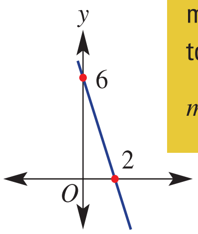

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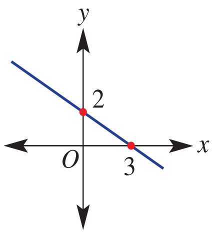
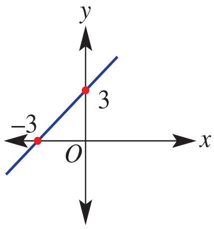
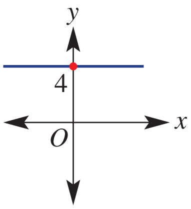


E



F



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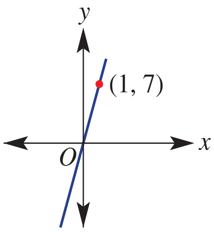
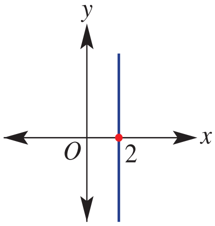
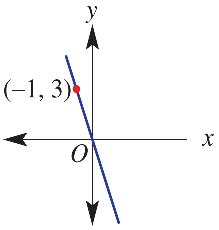


H



I



8 **a** Write down three different equations that have a graph with a y-intercept of 5.

b Write down three different equations that have a graph with a y-intercept of −2.

c Write down three different equations that have a graph with a y-intercept of 0.

9 **a** Write down three different equations that have a graph with a gradient of 3.

b Write down three different equations that have a graph with a gradient of −1.

c Write down three different equations that have a graph with a gradient of 0.

d Write down three different equations that have a graph with an undefined gradient.

10 **a** Which of the following points lie on the line $y = 2$?

- **i** (2, 3)
- **ii** (1, 2)
- **iii** (5, 2)
- **iv** (−2, −2)

b Which of the following points lie on the line $x = 5$?

- **i** (5, 3)
- **ii** (3, 5)
- **iii** (1, 7)
- **iv** (5, −2)

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Example 22 Identifying points on a line

Does the point (3, −4) lie on the line $y = 2x - 7$?

SOLUTION

$$y = 2x - 7$$

$$\begin{array}{l|l} \text{LHS} = y & \text{RHS} = 2 \times 3 - 7 \\ \quad = -4 & \quad = -1 \end{array}$$

LHS ≠ RHS

No, (3, −4) is *not* on the line.

EXPLANATION

Copy the equation and substitute $x = 3$ and $y = -4$.

Compare the LHS and RHS.

So (3, −4) is *not* on the line.

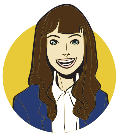
11 **a** Does the point (3, 2) lie on the line $y = x + 2$?

b Does the point (−2, 0) lie on the line $y = x + 2$?

c Does the point (1, −5) lie on the line $y = 3x + 2$?

d Does the point (2, 2) lie on the line $y = x$?

e Does the line $y - 2x = 0$ pass through the origin?



Substitute the x value into the equation and compare the two y values. When the y values are the same, the point is on the line.

12 Draw each of the following on a number plane and write down the equation of the line.

a

x	0	1	2	3
y	4	5	6	7

b

x	0	1	2	3
y	−1	0	1	2

c

x	−2	0	4	6
y	−1	0	2	3

d

x	−2	0	2	4
y	−3	1	5	9

Use your graph to find the gradient between two points (m) and locate the y-intercept (b). Then use $y = mx + b$.

ENRICHMENT – 13, 14

Sketching graphs using technology

13 Use technology to sketch a graph of these equations.

a $y = x + 2$

b $y = -4x - 3$

c $y = \frac{1}{2}x - 1$

d $y = 1.5x + 3$

e $y = 2x - 5$

f $y = 0.5x + 5$

g $y = -0.2x - 3$

h $y = 0.1x - 1.4$

14 **a** On the same set of axes, plot graphs of $y = 2x$, $y = 2x + 1$, $y = 2x + 4$, $y = 2x - 2$ and $y = 2x - 3$, using technology.

Discuss what you see and describe the connection with the given equations.

b On the same set of axes, plot graphs of $y = x - 1$, $y = 2x - 1$, $y = 3x - 1$, $y = \frac{1}{2}x - 1$ and $y = \frac{3}{4}x - 1$, using technology.

Discuss what you see and describe the connection with the given equations.

c On some forms of technology, the equations of families of graphs can be entered using one line only. For example, $y = 2x + 1$, $y = 2x + 2$ and $y = 2x + 3$ can be entered as $y = 2x + \{1, 2, 3\}$ using set brackets. Use this notation to draw the graphs of the rules in parts **a** and **b**.

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6H Parallel lines and perpendicular lines

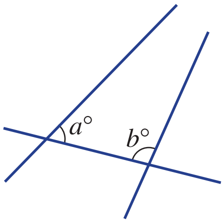
Interactive
Widgets
HOTsheets
Walkthrough

Euclid of Alexandria (300 BC) was a Greek mathematician and is known as the 'Father of geometry'. In his texts, known as *Euclid's Elements*, his work is based on five simple axioms.

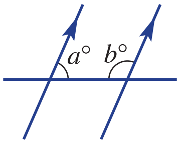
His fifth axiom, the Parallel Postulate, says that if cointerior angles do not sum to 180°, then the two lines are not parallel. Furthermore, if the two interior angles are equal and also sum to 180°, then the third line must be perpendicular to the other two.

A painting of Euclid of Alexandria, whose *Elements* is one of the most influential mathematical texts in history.

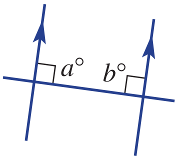
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4



$a + b \neq 180$



$a + b = 180$



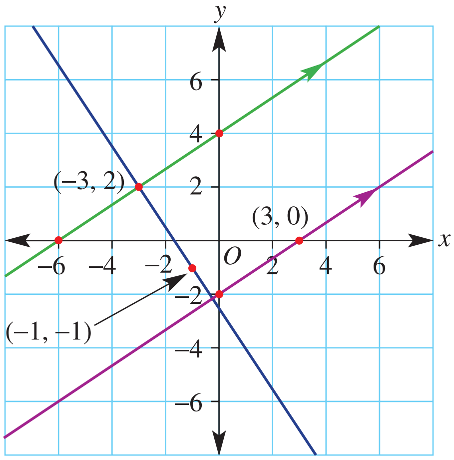
$a = b = 90$

Parallel and perpendicular lines, including their gradient and rule, are the focus of this section.

Let's start: Gradient connection

Shown here is a pair of parallel lines and a third line that is perpendicular to the other two lines.

- Find the gradient of each line using the coordinates shown on the graph.
- What is common about the gradients for the two parallel lines?
- Is there any connection between the gradients of the parallel lines and the perpendicular line? Can you write down this connection as a formula?



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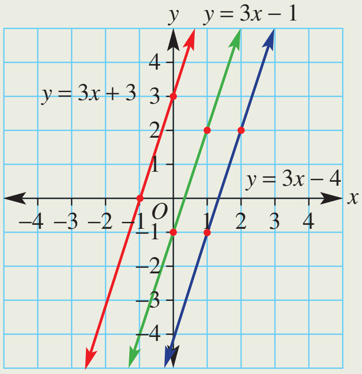
Key ideas

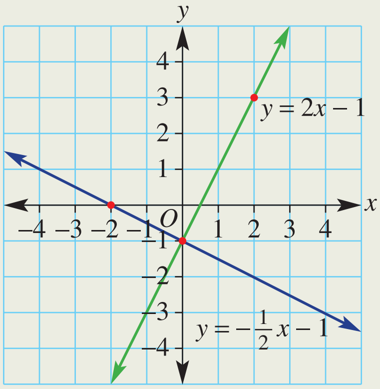
- Two **parallel lines** have the same gradient.
  For example: $y = 3x - 1$ and $y = 3x + 8$ have the same gradient of 3.



- Two **perpendicular lines** with gradients m_1 and m_2 satisfy the following rule:
  $m_1 \times m_2 = -1$ or $m_2 = -\frac{1}{m_1}$ (i.e. m_2 is the negative reciprocal of m_1).

  For example: In the graph shown, $m_1 \times m_2 = 2 \times -\frac{1}{2} = -1$.

- Equations of parallel or perpendicular lines can be found by:
  - first finding the gradient (m)
  - then substituting a point to find b in $y = mx + b$



Exercise 6H

UNDERSTANDING AND FLUENCY 1, 2, 4–6(½) 3–6(½)

1 Complete the following for this diagram.

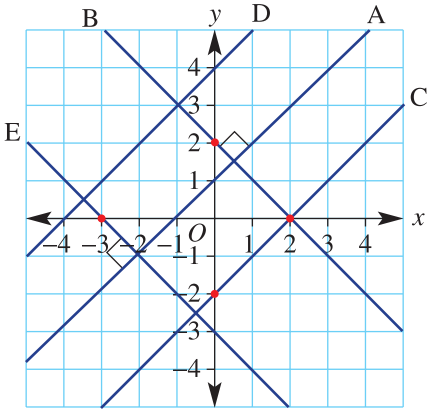
a Which lines, B, C, D or E, are parallel to line A?

b Which lines, B, C, D or E, are perpendicular to line A?

c Are lines C and D parallel?

d Are lines B and E parallel?

e Are lines E and C perpendicular?



2 Write down the gradient of a line that is parallel to the graph of these equations.

a $y = 4x - 6$

b $y = -7x - 1$

c $y = -\frac{3}{4}x + 2$

d $y = \frac{8}{7}x - \frac{1}{2}$

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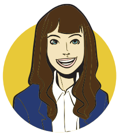
3 Use $m_2 = -\frac{1}{m_1}$ to find the gradient of the line that is perpendicular to the graphs of these equations.

a $y = 3x - 1$ **b** $y = -2x + 6$

c $y = \frac{7}{8}x - \frac{2}{3}$ **d** $y = -\frac{4}{9}x - \frac{4}{7}$

In part **a**, $m_1 = 3$ so find m_2, which is the perpendicular gradient. Note:

$$-\frac{1}{\left(\frac{7}{8}\right)} = -1 \div \frac{7}{8} = -1 \times \frac{8}{7}$$



Example 23 Deciding if lines are parallel or perpendicular

Decide if the graph of each pair of rules will be parallel, perpendicular or neither.

a $y = 4x + 2$ and $y = 4x - 6$

b $y = -3x - 8$ and $y = \frac{1}{3}x + 1$

SOLUTION	EXPLANATION
a $y = 4x + 2, m = 4$ (1) $y = 4x - 6, m = 4$ (2) So the lines are parallel.	Note that both equations are in the form $y = mx + b$. Both lines have a gradient of 4, so the lines are parallel.
b $y = -3x - 8, m = -3$ (1) $y = \frac{1}{3}x + 1, m = \frac{1}{3}$ (2)	Both equations are in the form $y = mx + b$.
$-3 \times \frac{1}{3} = -1$ So the lines are perpendicular.	Test $m_1 \times m_2 = -1$.

4 Decide if the line graphs of each pair of rules will be parallel, perpendicular or neither.

a $y = 2x - 1$ and $y = 2x + 1$

b $y = 3x + 3$ and $y = -\frac{1}{3}x + 1$

c $y = 5x + 2$ and $y = 6x + 2$

d $y = -4x - 1$ and $y = \frac{1}{5}x - 1$

e $y = 3x - 1$ and $y = 3x + 7$

f $y = \frac{1}{2}x - 6$ and $y = \frac{1}{2}x - 4$

g $y = -\frac{2}{3}x + 1$ and $y = \frac{2}{3}x - 3$

h $y = -4x - 2$ and $y = x - 7$

i $y = -\frac{3}{7}x - \frac{1}{2}$ and $y = \frac{7}{3}x + 2$

j $y = -8x + 4$ and $y = \frac{1}{8}x - 2$

If the gradients are equal then the lines are parallel. If $m_1 \times m_2 = -1$, then the lines are perpendicular.

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Example 24 Finding the equation of a parallel or perpendicular line when given the y-intercept

Find the equation of the line, given the following description.

a A line passes through (0, 2) and is parallel to another line with gradient 3.

b A line passes through (0, −1) and is perpendicular with another line with gradient −2.

SOLUTION	EXPLANATION
a $m = 3$ and $b = 2$ So $y = 3x + 2$.	A parallel line has the same gradient. Use $y = mx + b$ with $m = 3$ and y-intercept is 2.
b $m = -\left(\frac{1}{-2}\right) = \frac{1}{2}$ and $b = -1$ So $y = \frac{1}{2}x - 1$.	Being perpendicular, use $m_2 = \frac{-1}{m_1}$. Note also that the y-intercept is −1.

5 Find the equation of the lines with the following description.

a A line passes through (0, 2) and is parallel to another line with gradient 4.

b A line passes through (0, 4) and is parallel to another line with gradient 2.

In $y = mx + b$, m is the gradient and b is the y-intercept.

c A line passes through (0, −3) and is parallel to another line with gradient −1.

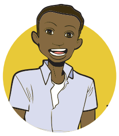
d A line passes through (0, 3) and is perpendicular to another line with gradient 2.

e A line passes through (0, −5) and is perpendicular to another line with gradient 3.

f A line passes through (0, −10) and is perpendicular to another line with gradient $\frac{1}{2}$.

g A line passes through (0, 6) and is perpendicular to another line with gradient $\frac{1}{6}$.

h A line passes through (0, −7) and is perpendicular to another line with gradient $-\frac{1}{4}$.



$$-\frac{1}{\left(\frac{1}{2}\right)} = -2$$

Example 25 Finding the equation of a parallel or perpendicular line

Find the equation of the line that is:

a parallel to $y = -2x - 7$ and passes through $(1, 9)$

b perpendicular to $y = \frac{1}{4}x - 1$ and passes through $(3, -2)$

SOLUTION	EXPLANATION
a $y = mx + b$ $m = -2$ $y = -2x + b$	Since the line is parallel to $y = -2x - 7$, $m = -2$.
Substitute $(1, 9)$: $9 = -2(1) + b$ $11 = b$ $\therefore y = -2x + 11$	Substitute the given point $(1, 9)$, where $x = 1$ and $y = 9$, and solve for b.

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b $y = mx + b$

$$m = \frac{-1}{\frac{1}{4}}$$

The gradient is the negative reciprocal of $\frac{1}{4}$.

$$= -1 \times \frac{4}{1}$$

$$= -4$$

$$y = -4x + b$$

Substitute $(3, -2)$: $-2 = -4(3) + b$

$$-2 = -12 + b$$

$$b = 10$$

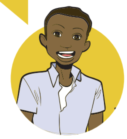
$$\therefore y = -4x + 10$$

Substitute $(3, -2)$ and solve for b.

6 Find the equation of the line that is:

- **a** parallel to $y = x + 3$ and passes through $(1, 5)$
- **b** parallel to $y = -x - 5$ and passes through $(1, -7)$
- **c** parallel to $y = -4x - 1$ and passes through $(-1, 3)$
- **d** parallel to $y = \frac{2}{3}x + 1$ and passes through $(3, -4)$
- **e** parallel to $y = -\frac{4}{5}x + \frac{1}{2}$ and passes through $(5, 3)$
- **f** perpendicular to $y = 2x + 3$ and passes through $(2, 5)$
- **g** perpendicular to $y = -4x + 1$ and passes through $(-4, -3)$
- **h** perpendicular to $y = \frac{2}{3}x - 4$ and passes through $(4, -1)$
- **i** perpendicular to $y = \frac{4}{3}x + \frac{1}{2}$ and passes through $(-4, -2)$
- **j** perpendicular to $y = -\frac{2}{7}x - \frac{3}{4}$ and passes through $(-8, 3)$

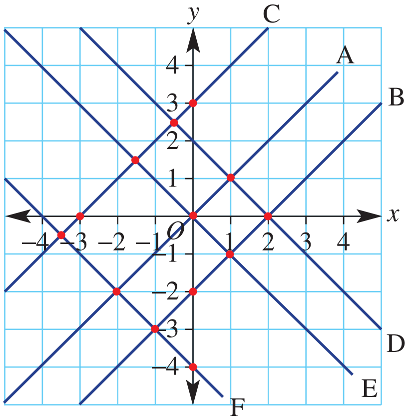
First find m. Then write $y = mx + b$. Substitute a point to find b; e.g. for $(1, 5)$ substitute $x = 1$ and $y = 5$.



PROBLEM-SOLVING AND REASONING	7, 8	7, 9, 10

7 The lines on this grid are either parallel or perpendicular to each other.

- **a** What is the gradient of each of these lines?
  - **i** A
  - **ii** D
- **b** What is the equation for the following lines?
  - **i** A
  - **ii** B
  - **iii** C
  - **iv** D
  - **v** E
  - **vi** F



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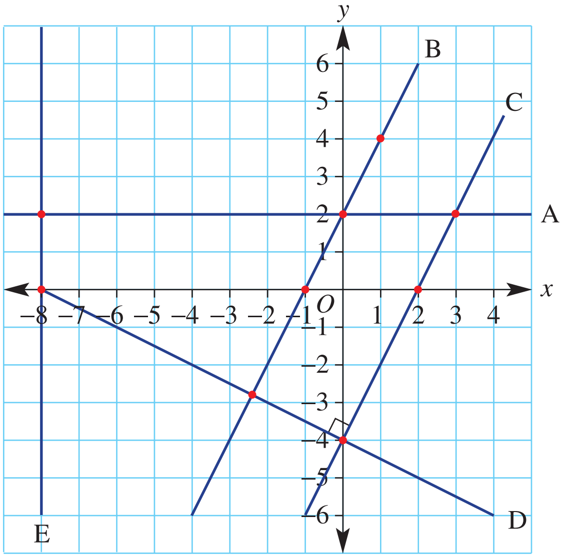


8 In its original position, the line A has equation $y = 2$, as shown.

- **a** Line A is rotated to form line B. What is its new rule?
- **b** Line B is shifted to form line C. What is its new rule?
- **c** Line C is rotated 90° to form line D. What is its new rule?
- **d** Line A is rotated 90° to form line E. What is its new rule?

9 Recall that the negative reciprocal of, say, $\frac{2}{3}$ is $-\frac{3}{2}$

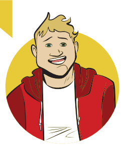
Use this to help find the equation of a line that:

- **a** passes through (0, 7) and is perpendicular to $y = \frac{2}{3}x + 3$
- **b** passes through (0, −2) and is perpendicular to $y = \frac{2}{3}x + 1$
- **c** passes through (0, 2) and is perpendicular to $y = -\frac{4}{5}x - 3$
- **d** passes through (1, −2) and is perpendicular to $y = -\frac{2}{3}x - 1$

10 Decide if the graphs of each pair of rules will be parallel, perpendicular or neither.

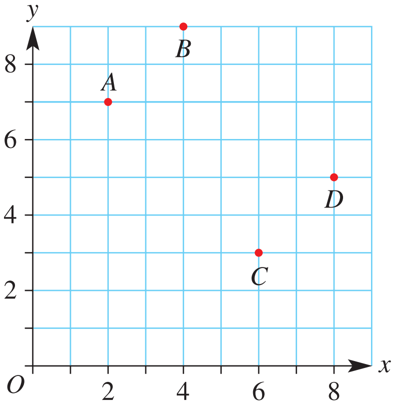
- **a** $2y + x = 2$ and $y = -\frac{1}{2}x - 3$
- **b** $x - y = 4$ and $y = x + \frac{1}{2}$
- **c** $8y + 2x = 3$ and $y = 4x + 1$
- **d** $3x - y = 2$ and $x + 3y = 5$

First write in the form $y = mx + b$.



ENRICHMENT – 11, 12

Perpendicular and parallel geometry



11 A quadrilateral *ABCD* has vertex coordinates $A(2, 7)$, $B(4, 9)$, $C(6, 3)$ and $D(8, 5)$.

- **a** Find the gradient of these line segments.
  - **i** *AB*
  - **ii** *CD*
  - **iii** *BD*
  - **iv** *AC*
- **b** What do you notice about the gradient of the opposite sides?
- **c** What type of quadrilateral is *ABCD*?

12 The vertices of triangle *ABC* are $A(0, 0)$, $B(3, 4)$ and $C\left(\frac{25}{3}, 0\right)$.

- **a** Find the gradient of these line segments.
  - **i** *AB*
  - **ii** *BC*
  - **iii** *CA*
- **b** What type of triangle is ΔABC?

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6I Graphing straight lines using intercepts

Interactive

Widgets

HOTsheets

Walkthrough

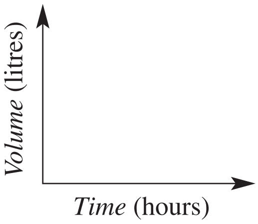
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Only two points are required to define a straight line. Two convenient points are the *x*- and *y*-intercepts. These are the points where the graph crosses the *x*-axis and *y*-axis, respectively.

The axis intercepts are quite significant in practical situations. For example, imagine that 200 m^3 of dirt needs to be removed from a construction site before foundations for a new building can be laid. The graph of volume remaining versus time taken to remove the dirt has a *y*-intercept of 200 showing the total volume to be removed, and an *x*-intercept showing the time taken for the job.

Let's start: Leaking water

A family that is camping has 20 litres of water in a plastic container. The water begins to slowly leak at a rate of 2 litres per hour.

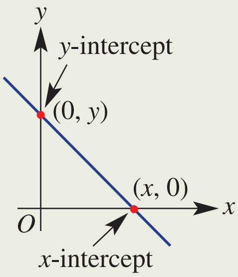


- Sketch two axes labelled 'Volume' and 'Time'.
- At $t = 0$, what is the volume of water in the tank? Mark and label this point on the Volume axis.
- How long will it take for the water container to become empty? Mark this point on the Time axis.
- Join these two points with a straight line.
- Write the coordinates of the Volume axis intercept and the Time axis intercept. Follow the order x, y (Time, Volume).
- Can you suggest a rule for finding the volume of the water in the tank after t hours?

Key ideas

To sketch a straight line by finding intercepts:

- The ***x*-intercept** is where $y = 0$.
  Find the *x*-intercept by substituting $y = 0$ into the equation.
- The ***y*-intercept** is where $x = 0$.
  Find the *y*-intercept by substituting $x = 0$ into the equation.



***x*-intercept** The point at which a line or curve cuts the *x*-axis

***y*-intercept** The point at which a line or curve cuts the *y*-axis

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Exercise 6I

UNDERSTANDING AND FLUENCY

1, 2, 3–4(½), 5, 6 | 3–4(½), 5, 6(½), 7

1 Copy and complete the following.

a The x-intercept is where _____ = 0.

b The y-intercept is where _____ = 0.

2 Complete the following for the line $y = x + 3$.

a Find the value of y when $x = 0$.

b Find the value of x when $y = 0$.

Example 26 Finding the x-intercept

Find the x-intercept for each line equation.

a $y = -2x - 7$ **b** $y = -\frac{3}{4}x + 6$

SOLUTION	EXPLANATION
a $y = -2x - 7$	
To find x-intercept, let $y = 0$.	Substitute $y = 0$ for an x-intercept calculation.
$0 = -2x - 7$	The opposite of -7 is $+7$, so add 7 to both sides.
$7 = -2x$	Divide both sides by -2.
$x = \frac{7}{-2}$	When dividing two numbers with different signs, the answer is negative.
$x = -3\frac{1}{2}$	Write the answer as a mixed numeral.
$\therefore$ x-intercept is $-3\frac{1}{2}$.	
b $y = -\frac{3}{4}x + 6$	Substitute $y = 0$.
To find x-intercept, let $y = 0$.	The opposite of $+6$ is -6, so subtract 6 from both sides.
$0 = -\frac{3}{4}x + 6$	Change the fraction $-\frac{3}{4}$ to $\frac{-3}{4}$.
$-6 = \frac{-3}{4}x$	Multiply both sides by 4.
$-24 = -3x$	Divide both sides by -3.
$x = 8$	When dividing two numbers with the same sign, the answer is positive. $8 = x$ can be written with x as the subject; i.e. $x = 8$.
$\therefore$ x-intercept is 8.	

3 Find the x-intercept for each line.

a $y = 2x - 8$

b $y = -3x - 10$

c $y = \frac{3}{2}x + 9$

d $y = -\frac{1}{2}x + 9$

e $y = -\frac{3}{4}x + 9$

f $y = -\frac{5}{3}x - 10$

At the x-intercept, $y = 0$. Show all steps in each calculation.

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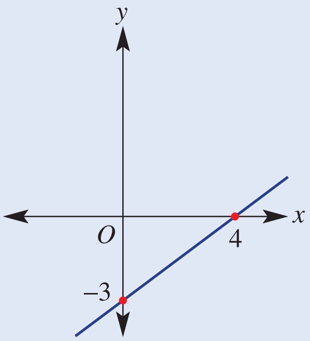
Example 27 Sketching lines in the form $ax + by = d$ using x- and y-intercepts

Sketch a graph of $3x - 4y = 12$ by finding the x- and y-intercepts.

SOLUTION		EXPLANATION
$3x - 4y = 12$		
x-intercept (let $y = 0$):	$3x - 4(0) = 12$	Find the x-intercept by substituting $y = 0$.
	$3x = 12$	Simplify. Any number multiplied by 0 is 0.
	$x = 4$	Divide both sides by 3 to solve for x.
y-intercept (let $x = 0$):	$3(0) - 4y = 12$	Find the y-intercept by substituting $x = 0$.
	$-4y = 12$	Simplify and retain the negative sign.
	$y = -3$	Divide both sides by -4 to solve for y.



Sketch the graph by first marking the x-intercept and the y-intercept and join in a line.

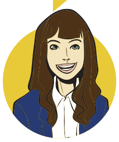
4 Sketch graphs of the following equations by finding the x- and y-intercepts.

a $3x + 2y = 6$ **b** $2x + 6y = 12$ **c** $3x - 4y = 12$

d $5x - 2y = 20$ **e** $-2x + 7y = 14$ **f** $-x + 3y = 3$

g $-x - 2y = 8$ **h** $-5x - 9y = 90$ **i** $-6x - y = -24$

Two calculations are required: Substitute $y = 0$ and solve for x-intercept. Substitute $x = 0$ and solve for y-intercept.

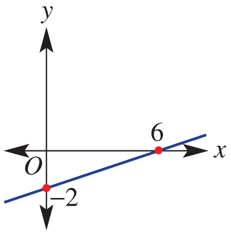


5 Match each of the following linear equations of the form $ax + by = d$ to one of the sketches shown.

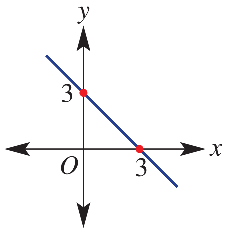
a $x + y = 3$ **b** $2x - y = 4$

c $x - 3y = 6$ **d** $3x - 2y = -6$

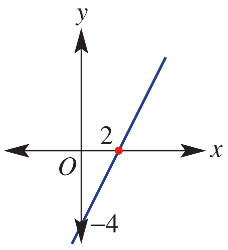
A



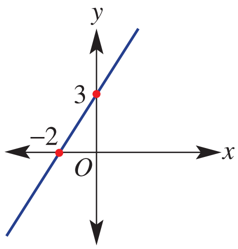
B



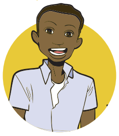
C



D



First find the x- and y-intercepts for the line equation.



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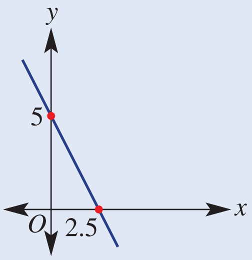
Example 28 Sketching lines in the form $y = mx + b$ using x- and y-intercepts

Sketch the graph of $y = -2x + 5$ by finding the x- and y-intercepts.

SOLUTION		EXPLANATION
$y = -2x + 5$		
x-intercept (let $y = 0$):	$0 = -2x + 5$	Substitute $y = 0$.
	$-5 = -2x$	Subtract 5 from both sides.
	$x = 2.5$	Divide both sides by -2.
y-intercept (let $x = 0$):	$y = -2(0) + 5$	Substitute $x = 0$.
	$y = 5$	Simplify. (Recall: In $y = mx + b$, b is the y-intercept.)
		Sketch the graph by first marking the x-intercept and the y-intercept.

6 Sketch graphs of the following equations by finding the x- and y-intercepts.

a $y = 2x + 1$
b $y = 3x - 2$
c $y = -4x - 3$
d $y = -x + 2$
e $y = -\frac{1}{2}x + 1$
f $y = \frac{3}{2}x - 3$

6e:

$0 = -\frac{1}{2}x + 1$

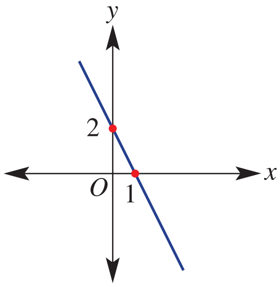
$\frac{1}{2}x = 1$

Now multiply both sides by 2.

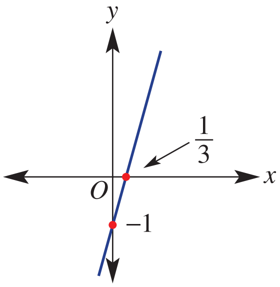
7 Match each of the following linear equations of the form $y = mx + b$ (**a**–**c**) to one of the sketches (**A**–**C**) shown.

a $y = x + 1$ **b** $y = 3x - 1$ **c** $y = -2x + 2$

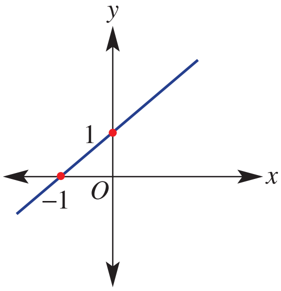
A



B



C



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PROBLEM-SOLVING AND REASONING	8, 9	8, 10–12

8 Match each of the following linear equations (**a**–**f**) to one of the sketches (**A**–**F**) shown.

a $2x + y = 4$

b $x - y = 3$

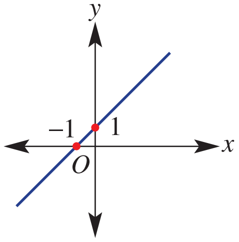
c $y = x + 1$

d $y = -2x - 3$

e $3x - 5y = 15$

f $y = \frac{2}{5}x - 1$

A



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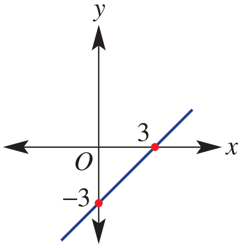

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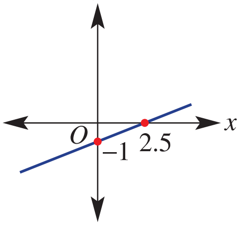

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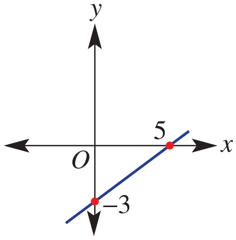

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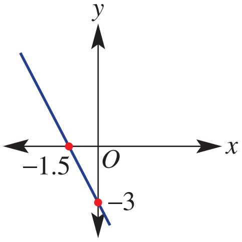

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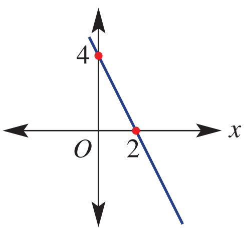


9 By first finding the x- and y-intercepts of the graphs of these equations, find the gradient in each case.

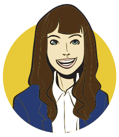
a $2x + y = 4$

b $x - 5y = 10$

c $4x - 2y = 5$

d $-1.5x + 3y = 4$

A quick sketch of each line and the axes intercepts will help to show the rise and run.



10 For the graphs of each of the following equations, find:

- **i** the x- and y-intercepts
- **ii** the area of the triangle enclosed by the x- and y-axes and the graph of each equation

Remember that the area of a triangle is $A = \frac{1}{2}bh$.

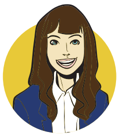
a $2x - y = 4$

b $-3x + 3y = 6$

c $y = -2x - 3$

d $y = \frac{1}{2}x + 2$

Draw the graph to help with the triangle area.



11 The height, h, in metres, of a lift above ground after t seconds is given by $h = 90 - 12t$.

a How high is the lift initially (i.e. at $t = 0$)?

b How long does it take for the lift to reach the ground (i.e. at $h = 0$)?

12 If $ax + by = d$, can you find a set of numbers a, b and d that give an x-intercept of 2 and y-intercept of 4.

Use trial and error to start.

ENRICHMENT	–	13

Finding axes intercepts using technology

13 For the following rules, use technology to sketch a graph and find the x- and y-intercepts.

a $y = 2x - 4$

b $y = -2x - 10$

c $y = -x + 1$

d $y + 2x = 4$

e $2y - 3x = 12$

f $3y - 2x = 2$

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6J Linear modelling FRINGE

Interactive

Widgets

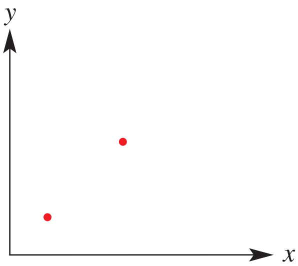
HOTsheets

Walkthrough

Given at least two points, you can find the equation of a straight line.

If the relationship between two variables is linear, then:

- the graph of the relation is a straight line
- a rule can be written in the form $y = mx + b$.



Only one straight line can be drawn to pass through these two points.

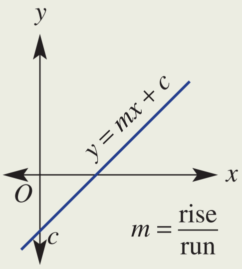
Let's start: How much does Isabella earn?

Isabella has a trainee scholarship to complete her apprenticeship as a mechanic. She is paid \$50 per week plus \$8/h for work at the garage. Isabella's weekly wage can be modelled by the rule: Wage $= 8t + 50$, where t is the number of hours worked in a week.

- Explain why the rule for Isabella's wage is Wage $= 8t + 50$
- Show how the rule can be used to find Isabella's wage after 10, 20 and 35 hours per week.
- Show how the rule can be used to find how long Isabella worked if she earned \$114, \$202 and \$370 in different weeks.

Key ideas

- The equation of a straight line can be determined using:
  - $y = mx + b$
  - Gradient $= m = \frac{\text{rise}}{\text{run}}$
  - y-intercept $= b$



- If the y-intercept is not obvious, then it can be found by substituting a point.
- Vertical and horizontal lines:
  - Vertical lines have the equation $x = a$, where a is the x-intercept.
  - Horizontal lines have the equation $y = b$, where b is the y-intercept.
- Modelling may involve:
  - writing a rule linking two variables
  - sketching a graph
  - using the rule or the graph to help solve related problems.

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Exercise 6J FRINGE

UNDERSTANDING AND FLUENCY 1, 2, 3–6(½) 3–7(½)

1 Each week Ava gets paid \$30 plus \$15 per hour. Decide which rule shows the relationship between Ava's total weekly wage, \$$W$, and the number of hours she works, n.

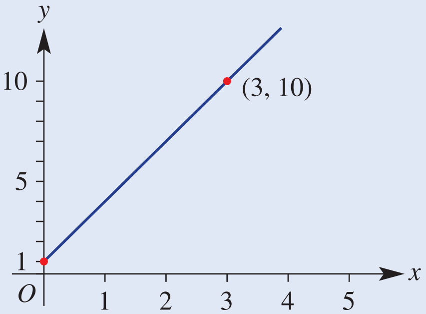
A $W = 30 + n$ **B** $W = 15n$ **C** $W = 30 + 15$ **D** $W = 30 + 15n$

2 Riley is 100 km from home and is cycling home at 20 km/h. Decide which rule shows the relationship between Riley's distance from home, d km, and the number of hours he has been cycling, t.

A $d = 100t$ **B** $d = 100t - 20$ **C** $d = 100 - 20t$ **D** $d = 100 + 20t$

Example 29 Finding the equation of a line from a graph with a known y-intercept

For the straight line shown:



a Determine its gradient.

b Find the y-intercept.

c Write the equation of the line.

SOLUTION

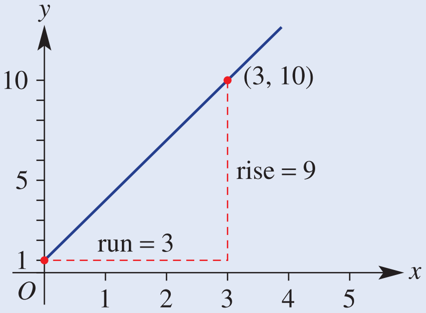
EXPLANATION

a $m = \frac{\text{rise}}{\text{run}}$

$= \frac{9}{3}$

$= 3$

Draw a triangle on the graph and decide whether the gradient is positive or negative.



b The y-intercept is 1, so $b = 1$.

Look at where the graph meets the y-axis.

c $y = 3x + 1$

Substitute m and b into $y = mx + b$.

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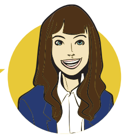
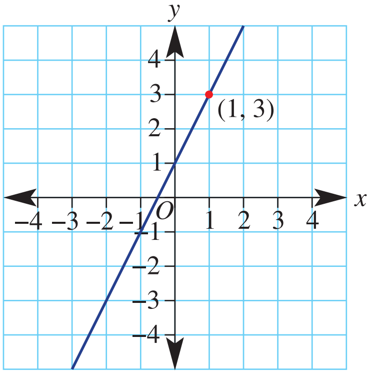
3 For the straight lines shown:
- **i** Determine the gradient.
- **ii** Find the y-intercept.
- **iii** Write the equation of the line.

To find the rise and run, form a right-angled triangle using the y-intercept and the second point.



a



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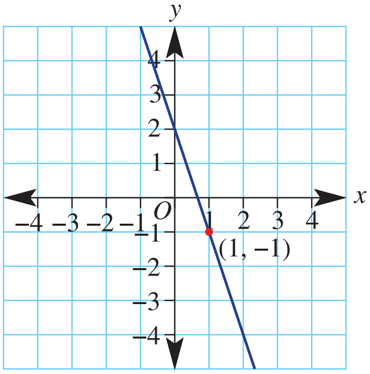

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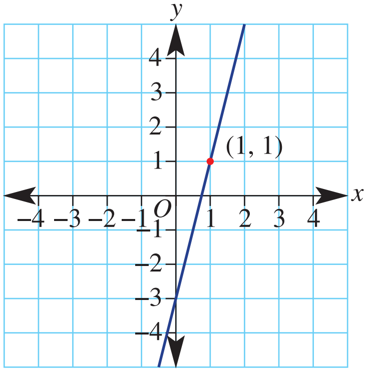

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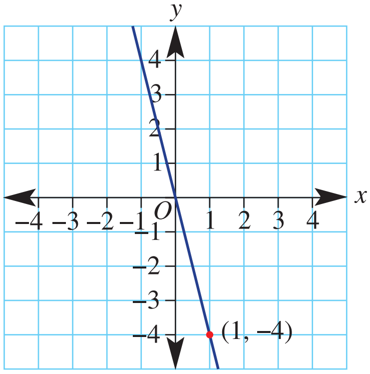

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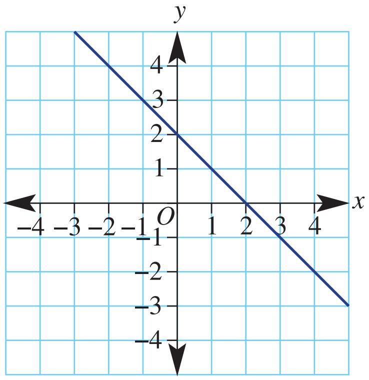

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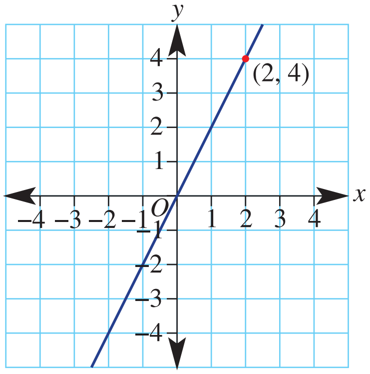

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PROBLEM-SOLVING AND REASONING 8, 10 11

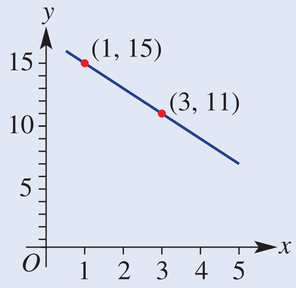
Example 30 Finding the equation of a line given a graph with two known points

For the straight line shown:

a Determine its gradient.

b Find the y-intercept.

c Write the equation of the line.



SOLUTION

a $m = \dfrac{\text{rise}}{\text{run}}$

$= \dfrac{-4}{2}$

$= -2$

b $y = -2x + b$

$11 = -2(3) + b$

$11 = -6 + b$

$17 = b$, so the y-intercept is 17.

c $y = -2x + 17$

EXPLANATION

The gradient is negative.

Run $= 3 - 1 = 2$

Rise $= 11 - 15 = -4$

A 'fall' of 4 means rise $= -4$.

Simplify.

Write $y = mx + b$ using $m = -2$.

Substitute a chosen point into $y = -2x + b$

(e.g. use (3, 11) or (1, 15)). Here, $x = 3$ and $y = 11$.

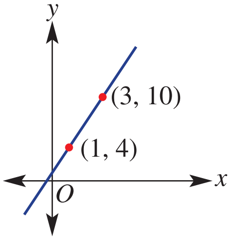
Simplify and solve for b.

Substitute $m = -2$ and $b = 17$ into $y = mx + b$.

4 Complete the following for the straight lines shown.

- **i** Determine the gradient.
- **ii** Find the y-intercept.
- **iii** Write the equation of the line.

a



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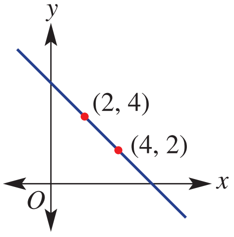

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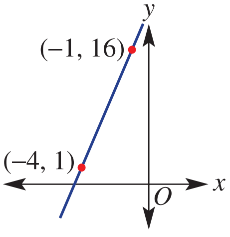

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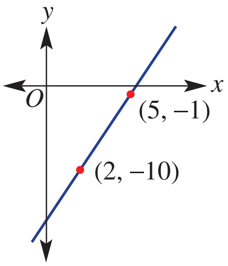

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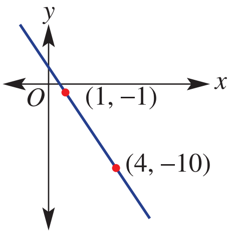

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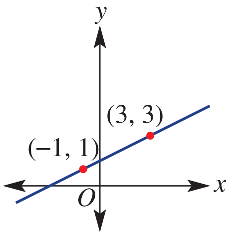


Use the rise and run between the two given points to find m.

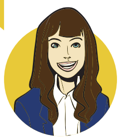
Choose either point to substitute when finding b. If $m = 4$ and (3, 5) is a point:

$y = mx + b$

$\downarrow \quad \downarrow \quad \searrow \quad \searrow$

$5 = 4 \times 3 + b$

Solve for b.



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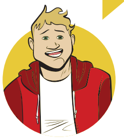
5 Determine the equation of the following lines. Remember from Section 6G that vertical and horizontal lines have special equations.

Vertical lines cut the x-axis and have an equation such as $x = 3$. Horizontal lines cut the y-axis and have an equation such as $y = -4$.



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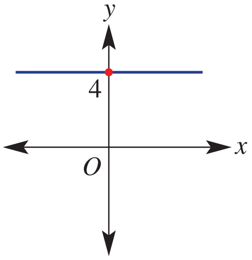

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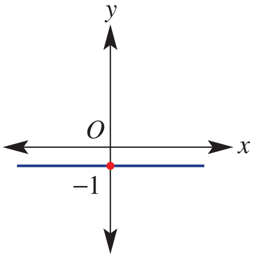

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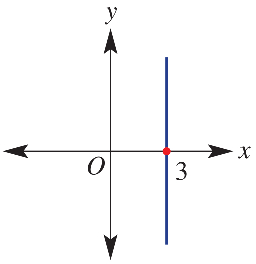

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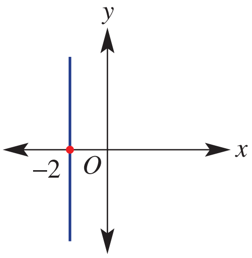

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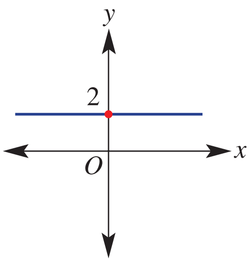

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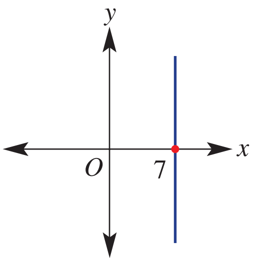
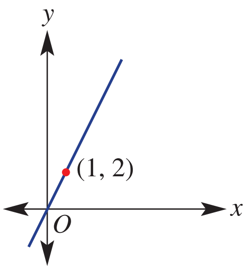


6 Remember that equations of graphs that pass through the origin are of the form $y = mx$ (since $b = 0$). Find the equation of these graphs.

a



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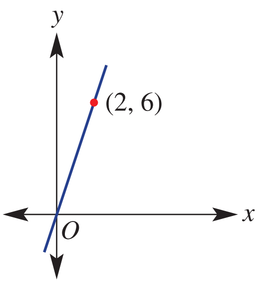

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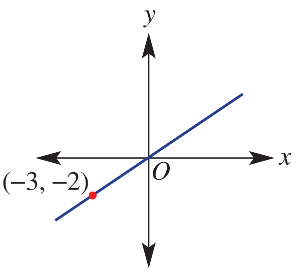

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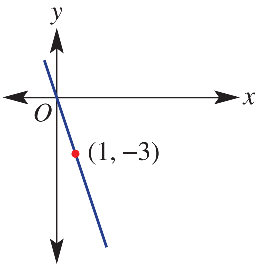

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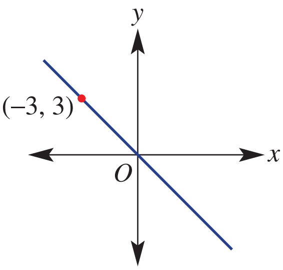

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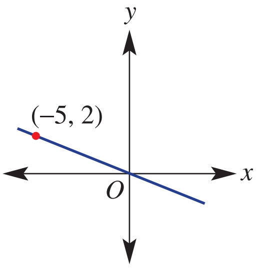

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7 For the line joining the following pairs of points, find:

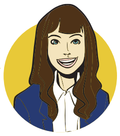
i the gradient **ii** the equation of the line

a $(0, 0)$ and $(1, 7)$ **b** $(0, 0)$ and $(2, -3)$

c $(-1, 1)$ and $(1, 3)$ **d** $(-2, 3)$ and $(2, -3)$

e $(-4, 2)$ and $(7, 2)$ **f** $(3, -3)$ and $(3, 1)$

Substitute the gradient and a point in $y = mx + b$ to find b in part **ii**.



PROBLEM-SOLVING AND REASONING		
	8, 10	9–11

Example 31 Modelling with linear graphs

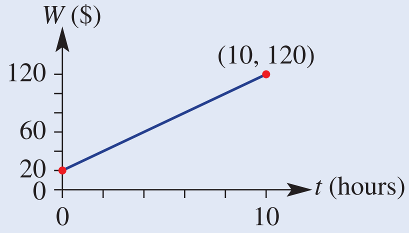
A woman gets paid \$20 plus \$10 for each hour of work. If she earns \$$W$ for t hours work, complete the following.

a Write a rule for W in terms of t.

b Sketch a graph using t between 0 and 10.

c Use your rule to find:

- **i** the amount earned after working for 8 hours
- **ii** the number of hours worked if \$180 is earned

SOLUTION	EXPLANATION
a $W = 10t + 20$	\$10 is earned for each hour and \$20 is a fixed amount.
b 	20 is the y-intercept and the gradient is $10 = \frac{10}{1}$. For $t = 10$, $W = 10(10) + 20 = 120$.
c **i** $W = 10(8) + 20$	Substitute $t = 8$ into $W = 10t + 20$.
$= 100$	Simplify.
\$100 is earned.	Write your answer in words.
ii $180 = 10t + 20$	Substitute $W = 180$ into $W = 10t + 20$.
$160 = 10t$	Subtract 20 from both sides.
$t = 16$	Divide both sides by 10.
16 hours' work is completed.	Write your answer in words.

8 A boy gets paid \$10 plus \$2 per kg of tomatoes that he picks. Given that the boy earns \$$P$ for n kg of tomatoes picked, complete the following.

a Write a rule for P in terms of n.

b Sketch a graph of P against n for n between 0 and 10.

c Use your rule to find:

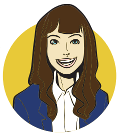
- **i** the amount earned after picking 9 kg of tomatoes
- **ii** the number of kilograms of tomatoes picked if he earns \$57

$$\underset{P}{\underset{\uparrow}{y}} = \overset{\text{rate of pay}}{\overset{\downarrow}{m}}\underset{n}{\underset{\uparrow}{x}} + \underset{\text{fixed amount}}{\underset{\uparrow}{b}}$$

9 An architect charges \$100 for an initial consultation plus \$60 per hour thereafter. If the architect earns \$$A$ for t hours of work, complete the following.

- **a** Write a rule for A in terms of t.
- **b** Sketch a graph of A against t for t between 0 and 15.
- **c** Use your rule to find:
  - **i** the amount earned after working for 12 hours
  - **ii** the number of hours worked if she earns \$700

Draw a line between the points at $t = 0$ and $t = 15$.



10 A man's weight when holding two empty buckets of water is 80 kg. 1 kg is added for each litre of water poured into the buckets. If the man's total weight is W kg with x litres of water, complete the following.

- **a** Write a rule for W in terms of x.
- **b** Sketch a graph of W against x for x between 0 and 20.
- **c** Use your rule to find:
  - **i** the man's weight after 7 litres of water are added
  - **ii** the number of litres of water added if the man's weight is 109 kg

11 The amount of water (W litres) in a leaking tank after t hours is given by the rule $W = -2t + 1000$.

- **a** State the gradient and y-intercept for the graph of the rule.
- **b** Sketch a graph of W against t for t between 0 and 500.
- **c** State the initial water volume at $t = 0$.
- **d** Find the volume of water after:
  - **i** 320 hours **ii** 1 day **iii** 1 week
- **e** Find the time taken, in hours, for the water volume to fall to:
  - **i** 300 litres **ii** 185 litres

ENRICHMENT – 12

Production lines

12 An assembly plant needs to order some new parts. Three companies can supply them but at different rates.

- Mandy's Millers charge: set-up fee \$0 + \$1.40 per part
- Terry's Turners charge: set-up fee \$3000 + \$0.70 per part
- Lenny's Lathes charge: set-up fee \$4000 + \$0.50 per part

a Complete a table of values similar to the following for each of the companies.

No. of parts (p)	0	1000	2000	3000	4000	5000	6000	7000	8000	9000
Total cost (C)										

b Plot a graph of the *total cost* against the *number of parts* for each company on the same set of axes. Make your axes quite large as there are three graphs to complete.

c Use the graphs to find the lowest price for:

- **i** 1500 parts **ii** 1000 parts **iii** 6500 parts **iv** 9500 parts

d Advise the assembly plant when it is best to use Mandy's, Terry's or Lenny's company.

6K Direct and indirect proportion

Interactive
Widgets
HOTsheets
Walkthrough

Two variables are said to be directly proportional if the rate of change of one variable with respect to the other is constant. So if one variable increases, then the other also increases and at the same rate. For example, distance is directly proportional to speed because, in a given time, if the speed is doubled then the distance travelled is doubled also.

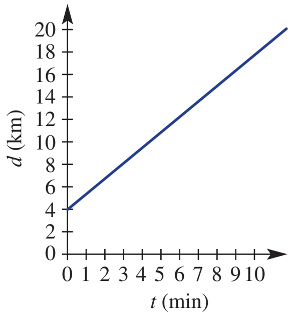
Two variables are said to be indirectly proportional if an increase in one variable causes the other variable to decrease. For example, when a pizza is shared equally, the size of each pizza slice is indirectly (or inversely) proportional to the number of people sharing it. If the number of people sharing increases, then the size of each pizza slice decreases.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Discovering the features of direct variation

Here are five different travel graphs showing how the distance from home varies with time.

A



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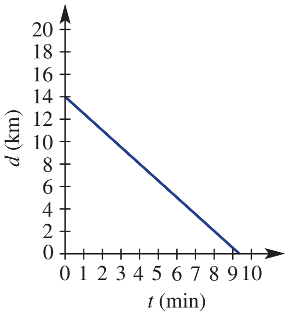

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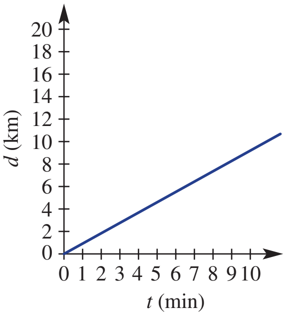

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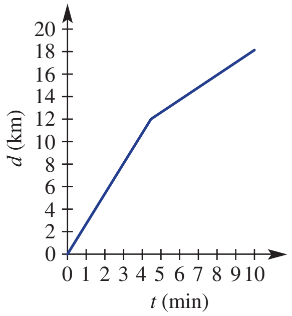

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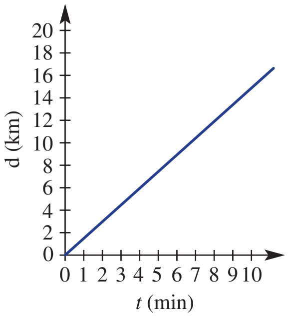

List all the graphs that show the:

- distance from home increases as the time increases
- distance from home decreases as the time increases
- person travels at a constant speed throughout the trip
- person starts from home
- person starts from home and also travels at a constant speed throughout the trip
- graph starts at (0, 0) and the gradient is constant
- distance is directly proportional to the time (i.e. the equation is of the form $y = mx$).

List three features of graphs that show when two variables are directly proportional to each other.

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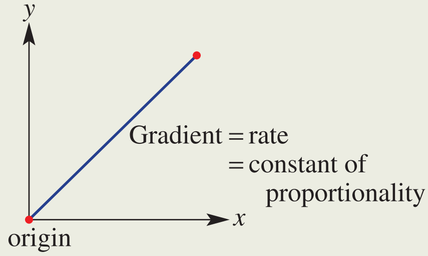
Key ideas

- For two variables that are **directly proportional**:
  - Both variables will increase together or decrease together. For example: The cost of buying some sausages is directly proportional to the weight of the sausages. If the weight increases, then the cost increases; when the weight decreases, the cost decreases.
  - The rate of change of one variable with respect to the other is constant.
  - The graph is a straight line passing through the origin $(0, 0)$.
  - The rule is of the form $y = mx$ (i.e. $b = 0$).
  - The rule is usually written as $y = kx$, where k is the constant of proportionality.
  - The constant of proportionality, k, is the gradient with units.
  - The constant of proportionality, k, is the same as the rate.

Directly proportional When two variables increase together or decrease together at the same rate.

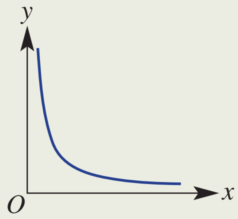
Graph of direct variation



- For two variables that are **indirectly or inversely proportional**:
  - When one variable increases, then the other variable decreases.
  - The graph is a curve showing that as x increases, then y decreases. For example: Speed is indirectly or inversely proportional to travelling time. As the speed decreases, the time taken to travel a particular distance increases; as the speed increases, the time taken to travel a particular distance decreases.

Indirectly (or inversely) proportional When one variable increases, then the other variable decreases

Graph of indirect or inverse variation



- Changing rate units
  - Each of the units can be changed to the required unit.
  - Then find the value of the rate per 1 ‘unit’.

    For example: 90 km/h = 90 000 m/60 min

    ÷60 ÷60

    = 1500 m in 1 min

    90 km/h = 1500 m/min

Exercise 6K

UNDERSTANDING AND FLUENCY	1–5, 6, 8	5, 7, 8, 9(½)

1 For each part, state whether the variables are directly or indirectly (i.e. inversely) proportional.

a As the number of questions correct increases, the total mark for the test increases.

b As the speed decreases, the time taken to travel a particular distance increases.

c As the number of hours worked increases, the pay for that work increases.

d As the size of a computer file decreases, the time required to transfer it decreases.

e As the rate of typing words per minute increases, the time needed to type an assignment decreases.

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2 Write in the missing words for these statements.

a As the volume of fuel decreases, the distance a car can travel ________.

b The volume of remaining fuel and the distance travelled are in ________ proportion.

c As the volume of fuel decreases, the cost of filling the tank ________.

d The volume of *remaining* fuel and the cost of filling the tank are in ________ or ________ proportion.

3 **a** Which of these equations show that y is directly proportional to x?

i $y = 2x + 4$
ii $y = 3x$
iii $y = x - 2$
iv $y = 8x + 5$
v $y = 70x$

The direct proportion rule is $y = kx$, where k is the constant of proportionality.

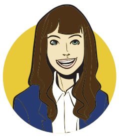
b State the value of k, the constant of proportionality, for each of these direct proportion equations.

i $y = 5x$
ii $y = 12x$
iii $d = 40t$
iv $V = 22t$
v $C = 7.5w$

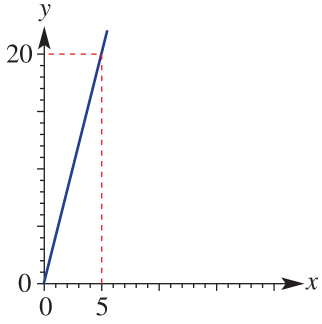
4 For each of the following graphs of direct variation, determine the value of k and write the equation.

$k = \text{gradient} = \dfrac{\text{rise}}{\text{run}}$

Equation: $y = kx$



a



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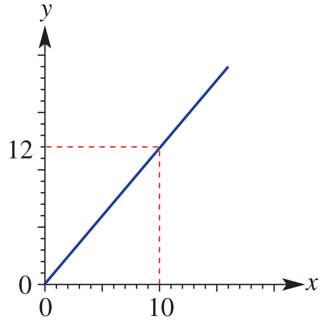

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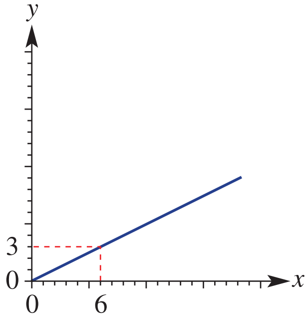

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5 The cost (C) of buying fuel is directly proportional to the volume (V) of fuel pumped.

a Copy and complete this table for the cost of diesel, using the rule $C = 1.5\ V$.

Rate = gradient with units
Rate = constant of proportionality, k.

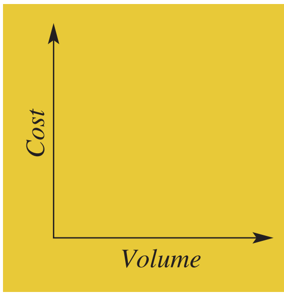
Volume (V) of diesel, in litres	0	10	20	30	40	50
Cost (C), in dollars						

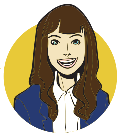
b Plot these points and then use a ruler to join them to form a neat graph of Volume (V) vs Cost (C).

c Find the gradient, m, of the line.

d At what rate is the cost of fuel increasing, in \$/L?

e What is the constant of proportionality, k, between cost and volume?





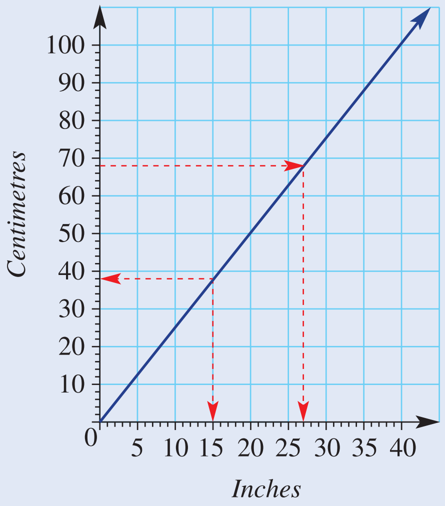
Example 32 Using a unit conversion graph

A length measured in centimetres is directly proportional to that length in inches. Use the graph below to make the following unit conversions.

a 15 inches to cm

b 68 cm to inches

Length unit conversion graph



SOLUTION	EXPLANATION
a 38 cm	Start at 15 inches. Now move up to the line and then across to the centimetre scale.
b 27 inches	Start at 68 cm. Now move across to the line and then down to the inches scale. Round your answer to the nearest whole number.

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6 Use the graph in Example 32 to make the following unit conversions. Round your answers to the nearest whole number.

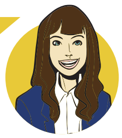
- **a** 19 inches to cm
- **b** 25 cm to inches
- **c** 1 foot (12 inches) to cm
- **d** 1 hand (4 inches) to cm
- **e** The height in cm of a miniature pony that is 7.5 hands high (30 inches).
- **f** The height in inches of the world's shortest living man, who was 54.6 cm high in 2013.
- **g** The height in cm of the world's shortest living woman, who was about 2 feet and 1 inch tall in 2013.
- **h** The length in cm of a giant Australian earthworm that is 39.5 inches long.

7 Use the length unit conversion graph in Example 32 to answer these questions.

- **a** Convert 94 cm to inches and use these values to find the gradient of the line, to 2 decimal places.
- **b** State the conversion rate in cm/inch, to 2 decimal places.
- **c** State the value of k, the constant of proportionality, to 2 decimal places.
- **d** Write the direct proportion equation between centimetres (y) and inches (x).
- **e** Use the equation to calculate the number of centimetres in 50 inches.

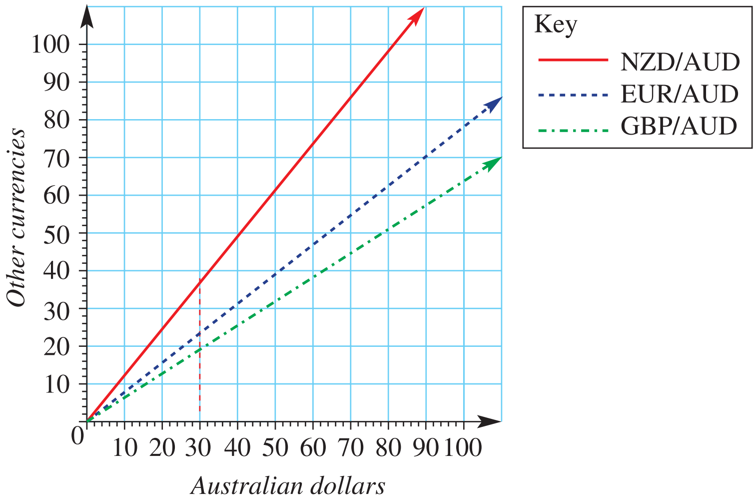
$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{\text{cm}}{\text{inches}}$$

k = rate = gradient with units



8 At any given time, an amount in Australian dollars is directly proportional to that amount in a foreign currency. This graph shows the direct variation (in 2013) between Australian dollars (AUD) and New Zealand dollars (NZD), European euros (EUR) and Great British pounds (GDP).

Currency conversion graph



- **a** Use the graph to make these currency conversions.
  - **i** 80 AUD to NZD
  - **ii** 80 AUD to EUR
  - **iii** 80 AUD to GBP
  - **iv** 50 NZD to AUD
  - **v** 32 EUR to AUD
  - **vi** 26 GBP to AUD

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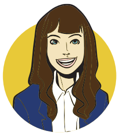
b Answer these questions using the line that shows the direct variation between the euro (EUR) and the Australian dollar (AUD).

- **i** Find 40 EUR in AUD and, hence, find the gradient of the line, to 1 decimal place.
- **ii** State the conversion rate in EUR/AUD, to 1 decimal place.
- **iii** State the value of k, the constant of proportionality, to 1 decimal place.
- **iv** Write the direct proportion equation between EUR (y) and AUD (x).
- **v** Use the equation to calculate the value in euros for 625 Australian dollars.

The rate in EUR/AUD = ?
euros per 1 Australian dollar.
The rate = the constant of
proportionality, k.



Example 33 Converting units between rates

Convert the following rates to the units given in brackets.

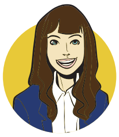
- **a** \$12/h (cents/min)
- **b** 7.2 L/h (mL/s)
- **c** 90 km/h (m/s)
- **d** 300 g/month (kg/year)

SOLUTION	EXPLANATION
a \$12/h = \$12 in 1 hour	
= 1200 cents in 60 minutes	Change each unit to the required unit.
= 20 cents in 1 minute	Divide both amounts by 60 so that it is ‘per 1 unit’.
= 20 cents/min	The solidus or forward slash (/) is read as ‘per’.
b 7.2 L/h = 7.2 litres in 1 hour	
= 7200 mL in 3600 seconds	7.2 L × 1000 = 7200 mL; 1 h × 60 × 60 = 3600 s
= 2 mL in 1 second	Divide both amounts by 3600 so that it is ‘per 1 unit’.
= 2 mL/s	
c 90 km/h = 90 km in 1 hour	
= 90 000 m in 3600 seconds	90 km × 1000 = 90 000 m;1 h × 60 × 60 = 3600 s
= 25 m in 1 second	Divide both amounts by 3600 so that it is ‘per 1 unit’.
= 25 m/s	
d 300 g/month = 300 grams in 1 month	Multiply both amounts by 12 to get 1 year’s amount.
= 3600 grams in 12 months	3600 g ÷ 1000 = 3.6 kg
= 3.6 kg in 1 year	
= 3.6 kg/year	

9 Convert the following rates to the units given in brackets.

- **a** \$9/h (cents/min)
- **b** \$24/h (cents/min)
- **c** 10.8 L/h (mL/s)
- **d** 18 L/h (mL/s)
- **e** 72 km/h (m/s)
- **f** 18 km/h (m/s)
- **g** \$15/kg (cents/g)
- **h** \$32/kg (cents/g)
- **i** 400 g/month (kg/year)
- **j** 220 g/day (kg/week)

1000 m = 1 km
1000 mL = 1 L
1000 g = 1 kg



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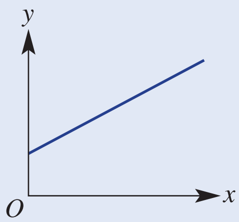
PROBLEM-SOLVING AND REASONING	10, 11	11–13

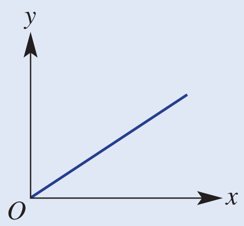
Example 34 Recognising direct and inverse proportion from graphs

Decide whether the following graphs show x and y in direct proportion or inverse (indirect) proportion and state the reason why.

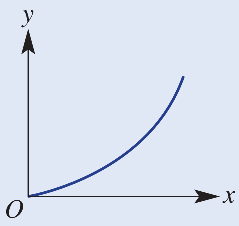
a



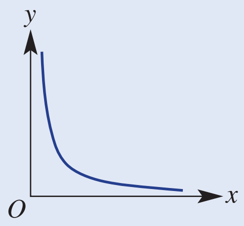
b



c



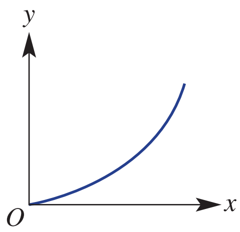
d



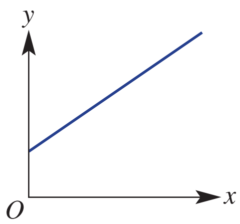
SOLUTION	EXPLANATION
a Not in direct proportion because the line doesn't pass through the origin.	A graph showing direct proportion is a straight line through the origin (0, 0).
b Yes, in direct proportion because it is a straight line through the origin.	
c Not in direct proportion because it is not a straight line.	As x increases then y increases, so this graph is not showing inverse proportion.
d Yes, in inverse proportion because as x increases, y decreases.	A graph showing inverse (or indirect) proportion is a curve showing that when x increases, then y decreases.

10 Decide if the following graphs show direct proportion or inverse proportion and state your reasons.

a



b



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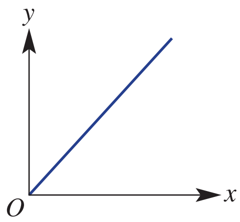
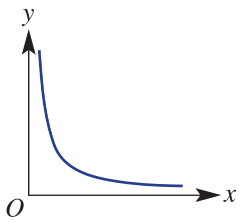


d



11 For each of the following pair of variables, describe, using sentences, why the variables are in direct proportion to each other or why they are not in direct proportion.

- **a** The number of *hours* worked and *wages* earned at a fixed rate per hour.
- **b** The *cost* of buying tomatoes and the *number of kilograms* at a fixed price per kilogram.
- **c** The *speed* and *time* taken to travel a certain distance.
- **d** The *size* of a movie file and the *time* taken to download it to a computer at a constant rate of kB/s.
- **e** The *cost* of a taxi ride and the *distance* travelled. The cost includes flag fall (i.e. a starting charge) and a fixed rate of $/km.

Example 35 Forming direct proportion equations when given the constant of proportionality, k

For a fixed price per litre, the cost (C) of buying fuel is directly proportional to the number (n) of litres.

- **a** Write the direct proportion equation, given that $k = \$1.45/\text{L}$.
- **b** Use this equation to calculate the cost of 63 L.

SOLUTION	EXPLANATION
a $C = 1.45n$	$y = kx$ becomes $C = kn$, where $k = 1.45$.
b $C = 1.45 \times 63$	Substitute $n = 63$ into the equation.
$= \$91.35$	Write the answer in dollars.

12 **a** For a fixed price per litre, the cost (C) of buying fuel is directly proportional to the number (n) of litres of fuel pumped.
  - **i** Write the direct proportion equation, given that $k = \$1.38/\text{L}$.
  - **ii** Use this equation to calculate the cost of 48 L.

b For a fixed rate of pay, wages (W) are directly proportional to the number (n) of hours worked.
  - **i** Write the direct proportion equation, given that $k = \$11.50/\text{h}$.
  - **ii** Use this equation to calculate the wages earned for 37.5 hours worked.

c At a fixed flow rate, the volume (V) of water flowing from a tap is directly proportional to the amount of time (t) the tap has been turned on.
  - **i** Write the direct proportion equation, given that $k = 6$ L/min.
  - **ii** Use this equation to calculate the volume of water, in litres, flowing from a tap for 4 hours.
  - **iii** Change the constant of proportionality to units of L/day and re-write the equation with this new value of k.
  - **iv** Use this equation to calculate the volume of water, in litres, flowing from a tap for 1 week.

d For a fixed speed, the distance (d) that a car travels is directly proportional to time (t).
  - **i** Write the direct proportion equation, given that $k = 90$ km/h.
  - **ii** Use this equation to calculate the distance travelled after 3.5 h.
  - **iii** Change the constant of proportionality to units of m/s and re-write the equation with this new value of k.
  - **iv** Use this equation to calculate the distance, in metres, that a car would travel in 4 seconds.

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Example 36 Forming direct proportion equations from given information

The amount of wages Chloe earns is in direct proportion to the number of hours she works.

a Find the constant of proportionality, k, given that Chloe earned \$166.50 in 18 hours.

b Write the direct proportion equation relating Chloe's wages (W) and the number of hours (n) that she worked.

c Calculate the wages earned for 8 hours and 45 minutes of work.

d Calculate the number of hours Chloe needs to work to earn \$259.

SOLUTION	EXPLANATION
a $k = \frac{166.50}{18}$	The constant of proportionality, k, is the rate of pay.
$= \$9.25/\text{h}$	Include units in the answer.
b $W = 9.25n$	$y = kx$ becomes $W = kn$, where $k = 9.25$.
c $W = 9.25n$	Write the equation.
$= 9.25 \times 8.75$	45 min = 45 ÷ 60 = 0.75 h. Substitute $n = 8.75$.
$= \$80.94$	Write \$ in the answer and round to 2 decimal places.
d $W = 9.25n$	Write the equation.
$259 = 9.25n$	Substitute $W = 259$.
$\frac{259}{9.25} = n$	Divide both sides by 9.25.
$n = 28$	Write the answer in words.
∴ Chloe must work for 28 h.	
Check: $W = 9.25 \times 28 = \$259$	Check that your answer is correct.

13 a Daniel's wages earned are in direct proportion to the hours he works at the local service station.

- **i** Find the constant of proportionality, k, given that Daniel earned \$200 in 16 hours.
- **ii** Write the direct proportion equation relating Daniel's wages (W) and the number of hours (n) worked.
- **iii** Calculate the wage earned for 6 hours of work.
- **iv** Calculate the number of hours Daniel must work to earn a wage of \$237.50.

b The amount that a farmer earns from selling wheat is in direct proportion to the number of tonnes harvested.

- **i** Find the constant of proportionality, k, given that a farmer receives \$8296 for 34 tonnes of wheat.
- **ii** Write the direct proportion equation relating selling price (P) and number of tonnes (n).
- **iii** Calculate the selling price of 136 tonnes of wheat.
- **iv** Calculate the number of tonnes of harvested wheat that is sold for \$286 700.

c When flying at a constant speed, the distance that an aeroplane has travelled is in direct proportion to the time it has been flying.
  - **i** Find the constant of proportionality, k, given that the plane flies 1161 km in 1.5 h.
  - **ii** Write the direct proportion equation relating distance (d) and time (t).
  - **iii** Calculate the time taken in hours for the aeroplane to fly from Sydney to Perth, a distance of around 3300 km. Round your answer to 2 decimal places.
  - **iv** Change the constant of proportionality, k, to units of km/min and re-write the equation with this new value of k.
  - **v** Calculate the distance that the plane would fly in 48 minutes.
  - **vi** If the plane is 200 km from a city, determine how many minutes it would take for the plane to be flying over the city.

ENRICHMENT		–	14

Currency conversions

14 At any given time, an amount of money in a foreign currency is in direct proportion to the corresponding amount in Australian dollars.

For example: If 8 Hong Kong dollars is equivalent to 1 Australian dollar, the conversion rate is HK \$8/AUD and the direct proportion equation is HK = 8 × AUD.

- To change A\$24 to Hong Kong dollars, we must substitute 24 for AUD:

$$\begin{aligned}\text{HK} &= 8 \times 24\\ &= \$192\end{aligned}$$

- To change HK\$24 to Australian dollars, we substitute 24 for HK:

$$24 = 8 \times \text{AUD}$$
$$\frac{24}{8} = \text{AUD}$$
$$\text{AUD} = \$3$$

Follow the example above to complete the following questions.

a Singapore dollar (SGD)
  - **i** Write the direct proportion equation given the conversion rate is 1.2 SGD/AUD.
  - **ii** Convert AUD 240 to SGD.
  - **iii** Convert SGD 240 to AUD.

b Chinese yuan (CNY)
  - **i** Write the direct proportion equation given the conversion rate is 6.47 CNY/AUD.
  - **ii** Convert AUD 75 to CNY.
  - **iii** Convert CNY 75 to AUD.

c Korean won (KRW)
  - **i** Write the direct proportion equation given the conversion rate is 1160 KRW/AUD.
  - **ii** Convert AUD 1000 to KRW.
  - **iii** Convert KRW 1000 to AUD.

d South African rand (ZAR)
  - **i** Write the direct proportion equation given the conversion rate is 9.5 ZAR/AUD.
  - **ii** Convert AUD 50 to ZAR.
  - **iii** Convert ZAR 50 to AUD.

1 ‘What is not so devious?’ Solve the puzzle to find the answer. Match the letter beside each question to the answers below.

Find where each line cuts the x-axis:

O $y = 3x - 4$

! $y = -\frac{3}{2}x - 9$

N $4x - 2y = -20$

I This line joins $(0, 4)$ to $(5, -1)$.

S $x = -7$

___	___	___	___	___	___	___	___
−2	−2.5	8	−0	−0	4	−5	−1

Find the gradient of each line:

E $y = 3x - 4$

L $y = -\frac{5}{2}x + 7$

P This line joins the origin to $(3, -6)$.

G This line joins $(2, 5)$ to $(-4, 11)$.

T $y = 5$

___	___	___	___	___	___
−2.5	4	−5	3	−7	−6

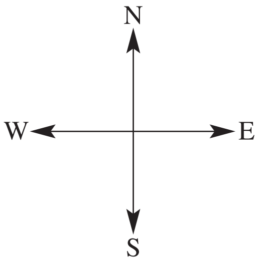
2 Solve the word find below.

T	F	Z	T	V	M	V	Z	J	H	E	R
O	W	I	M	J	G	R	J	O	A	L	A
T	M	G	T	E	R	K	R	U	T	B	T
E	C	N	A	T	S	I	D	N	E	A	E
S	T	M	P	R	Z	A	E	S	I	I	F
R	P	H	G	O	X	M	E	O	Z	R	E
D	Y	E	N	Z	G	J	U	R	X	A	F
H	G	T	E	E	J	Q	W	G	C	V	H
I	A	L	S	D	R	U	S	G	U	N	A
L	P	G	R	A	P	H	A	P	R	P	I

- DISTANCE
- GRAPH
- HORIZONTAL
- INCREASE
- RATE
- SEGMENT
- SPEED
- TIME
- VARIABLE

3 Cooper and Sophie are in a cycling orienteering competition.

- From the starting point, Cooper cycles 7 km east, then 3 km south to checkpoint 1. From there, Cooper cycles 5 km east and 8 km north to checkpoint 2.
- Sophie cycles 10 km north from the starting point to checkpoint 3.



Use calculations to show that the distance between where Sophie and Cooper are now is the same as the direct distance that Cooper is now from the starting point.

4 Lucas and Charlotte want to raise money for their school environment club, so they have volunteered to run a strawberry ice-cream stall at their town’s annual show.

It costs $200 to hire the stall and they make $1.25 profit on each ice-cream sold.

a How many ice-creams must be sold to make zero profit (i.e. not a loss)?

b If they make a total profit of $416.25, how many ice-creams did they sell?

Chapter summary

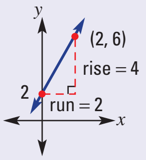
Linear relationships

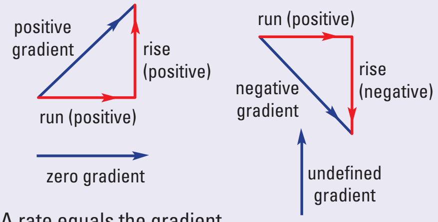
Gradient of a line

Gradient measures the slope of a line

Gradient $m = \frac{\text{rise}}{\text{run}}$ e.g.

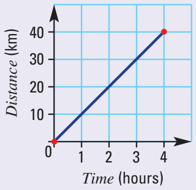
$m = \frac{4}{2} = 2$





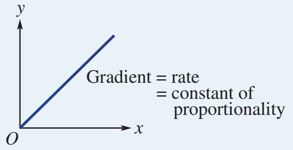
A rate equals the gradient with units

e.g. Speed $= \frac{40}{4} = 10$ km/h



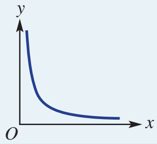
For two variables that are directly proportional

- Both variables will increase or decrease together at the same rate.
- The rule is $y = kx$, where k is the constant of proportionality.



For two variables that are indirectly (or inversely) proportional

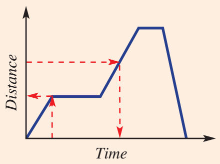
- When one variable increases, then the other variable decreases.
- The graph is a curve.



Linear modelling

- Find a rule in the form $y = mx + b$ using the appropriate pronumerals.
- Sketch a graph.
- Apply the rule to solve problems.
- Answer the problem in words.

Distance–time graph



- Flat segment means the object is at rest.

Reading a graph:
- Start on given distance; move across to line then down to time scale (or in reverse).

Equation of a line

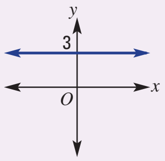
$y = mx + b$

gradient y-intercept

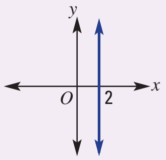
- The rule is a linear equation.
- The graph is made up of points in a straight line.

Special lines

Horizontal lines
e.g. $y = 3$



Vertical lines
e.g. $x = 2$



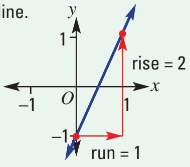
Sketching a line

Plotting straight-line graphs
- Complete a table of values.
- Plot points and join them to form a straight line.

Using the y-intercept and gradient
- Plot the y-intercept (b).
- Use the gradient to plot the next point.
- Join to form a straight line.

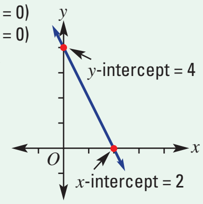
e.g. $y = 2x - 1$

$b = -1$ $m = \frac{2}{1}$



Using the axes intercepts

- Plot each axis intercept e.g. $y = -2x + 4$
  - x-intercept (when $y = 0$)
  - y-intercept (when $x = 0$)
- Join points to form a straight line.



Midpoint of a line segment

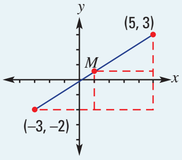
Find the average of the end point coordinates

$$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$$

$$x = \frac{-3+5}{2} = \frac{2}{2} = 1$$

$$y = \frac{-2+3}{2} = \frac{1}{2} = 0.5$$

$\therefore M = (1, 0.5)$

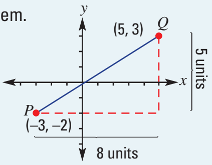


Length of a line segment

Use Pythagoras' theorem.

$$PQ^2 = 8^2 + 5^2$$
$$PQ^2 = 64 + 25$$
$$PQ^2 = 89$$
$$PQ = \sqrt{89} \text{ units}$$

$\sqrt{89}$ is an exact length.



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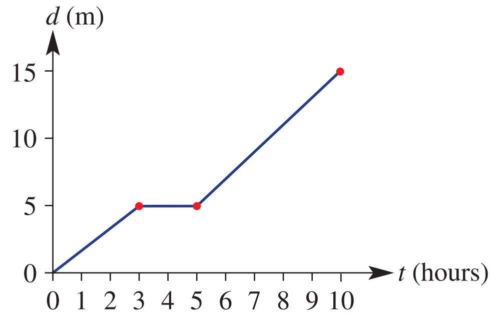
Multiple-choice questions

Questions **1** to **4** refer to the following graph of the movement of a snail.



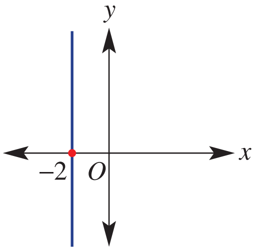
1 The total number of hours the snail was at rest is:
A 2 **B** 4 **C** 5
D 6 **E** 10

2 The distance travelled by the snail in the first 3 hours was:
A 3 m **B** 3 hours **C** 7 m
D 4 m **E** 5 m

3 The speed of the snail in the last 5 hours was:
A 5 hours **B** 10 m **C** 10 m/h
D 2 m/h **E** 5 m/h

4 The total distance travelled by the snail is:
A 15 m **B** 10 m **C** 5 m **D** 12 m **E** 8 m

5 The equation of the line shown at right is:
A $x = 2$ **B** $x = -2$ **C** $y = 1$
D $y = -2$ **E** $y = -2x$



6 The graph of $C = 10t + 5$ would pass through which of the following points?
A (1, 10) **B** (1, 20) **C** (2, 20) **D** (4, 50) **E** (5, 55)

7 The gradient of the line joining (0, 0) and (2, −6) is:
A 2 **B** 3 **C** −3 **D** 6 **E** −6

8 A vertical line has gradient:
A undefined **B** zero **C** positive **D** negative **E** 1

9 A line passes through (−2, 7) and (1, 2). The gradient of the line is:
A −3 **B** $-\frac{5}{3}$ **C** 3 **D** $\frac{5}{3}$ **E** $-\frac{3}{5}$

10 The line $3x - y = 4.5$ meets the x-axis and y-axis, respectively, at:
A (0, 3.5) and (4.5, 0)
B (−1.5, 0) and (4.5, 0)
C (1.5, 0) and (0, 4.5)
D (1.5, 0) and (0, −4.5)
E (0, 3.5) and (−4.5, 0)

11 Which of the following equations has a gradient of 2 and a y-intercept of −1?
A $2y + x = 2$ **B** $y - 2x = 1$ **C** $y = -2x + 1$ **D** $y = 2x - 1$ **E** $2x + y = 1$

12 A line has x- and y-intercepts of 1 and 2, respectively. Its equation is:
A $2x - y = 2$ **B** $y = -x + 2$ **C** $y = 2x + 2$ **D** $x + 2y = 1$ **E** $y = -2x + 2$

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13 The gradient of the line that is perpendicular to the line with equation $y = -2x - 5$ is:

A 2 **B** -2 **C** $\frac{1}{2}$ **D** $-\frac{1}{2}$ **E** $\frac{1}{5}$

14 Which equation shows that y is directly proportional to x?

A $y = 5x - 6$ **B** $y = \frac{6}{x}$ **C** $y = 2x + 4$ **D** $y = 12x$ **E** $y = 20 - 3x$

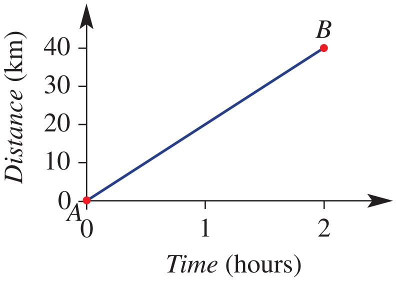
Short-answer questions

1 This graph shows the journey of a cyclist from place A to place B.

a How far did the cyclist travel?

b How long did it take the cyclist to complete the journey?

c If the cyclist rode from A to B and then halfway back to A, how far was the journey?



2 The value of a poor investment has decreased according to this graph.

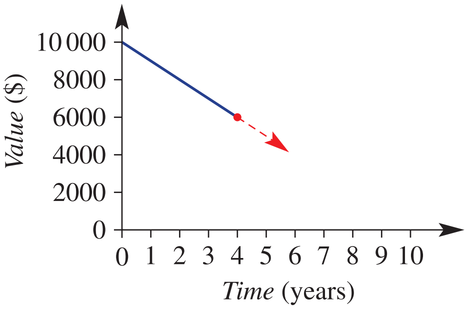
a Find the value of the investment after:

i 4 years **ii** 2 years **iii** 1 year

b Extend the graph and use it to estimate the value of the investment after:

i 8 years **ii** 6 years **iii** 5 years

c After how many years will the investment be valued at $0?



3 The distance travelled by a walker is described by this graph.

a What is the total distance walked?

b How long was the person actually walking?

c How far had the person walked after:

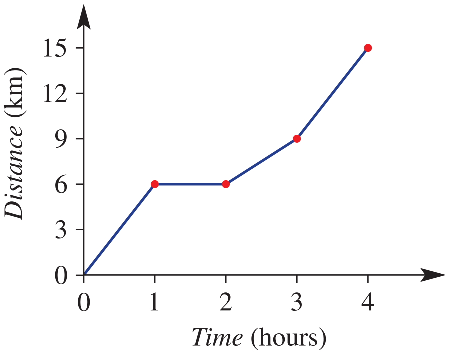
i 1 hour?

ii 2 hours?

iii 3 hours?

iv 4 hours?

d How long did it take to walk a distance of 12 km?



4 Sketch a graph to show a journey described by:

- a total distance of 60 metres in 15 seconds
- 30 metres covered in the first 6 seconds
- a 5-second rest after the first 6 seconds

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5 Francene delivers take-away orders for a restaurant. She is paid \$10 a shift plus \$5 per delivery.

a Complete the table of values.

No. of deliveries (d)	0	5	10	15	20
Payment (P)					

b Plot a graph of amount paid against number of deliveries.

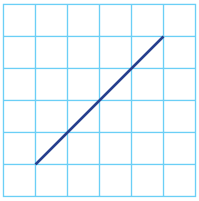
c Use the graph to determine:

i the amount of pay for 12 deliveries

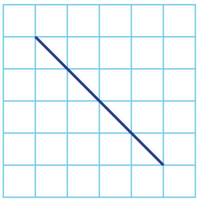
ii the number of deliveries made if Francene is paid \$95

6 Find the gradient of the following lines.

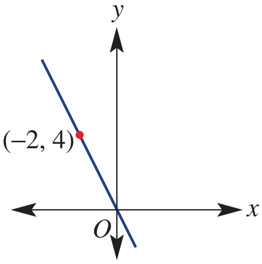
a



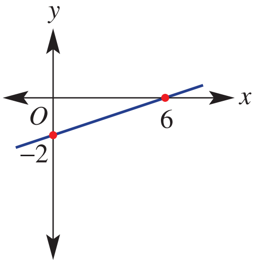
b



c

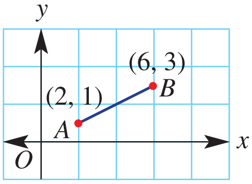


d



7 Find the midpoint of each line segment.

a

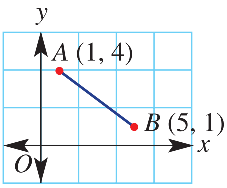


b $P(5, 7)$ to $Q(-1, -2)$

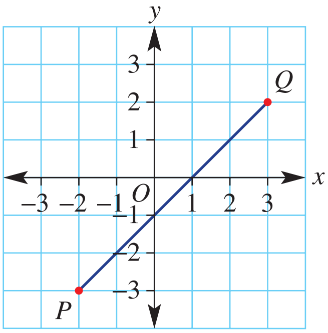
c $G(-3, 8)$ to $H(6, -10)$

8 Find the length of each line segment.

a



b



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9 State the gradient and y-intercept of the following lines.

a $y = 3x + 4$ **b** $y = -2x$

10 Sketch the following lines by considering the y-intercept and the gradient.

a $y = 2x + 3$ **b** $y = -4x$ **c** $y = 2$ **d** $x = -1$

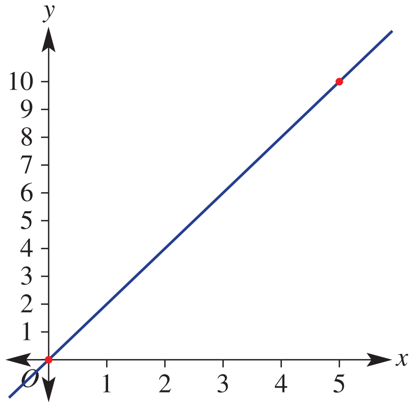
11 Sketch the following lines by considering the x- and y-intercepts.

a $3x + 4y = 12$ **b** $2x - y = 6$ **c** $y = 3x - 9$

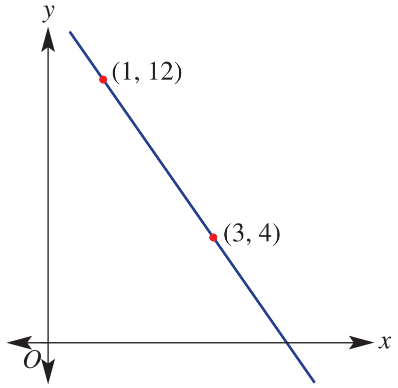
12 For each of the straight lines shown:

- **i** Determine its gradient.
- **ii** Find the y-intercept.
- **iii** Write the equation of the line.

a



b

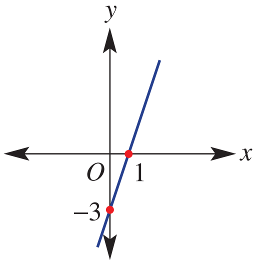


13 Match each of the linear equations (**a**–**f**) to the sketches shown (**A**–**F**).

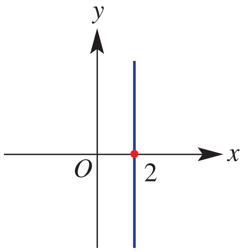
a $y = 3x - 3$ **b** $y = 5x$ **c** $5x + 4y = 20$

d $x = 2$ **e** $-2x + 5y = 10$ **f** $y = -4$

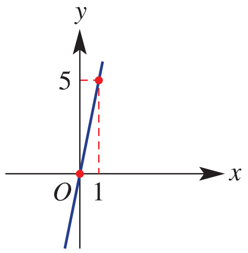
A



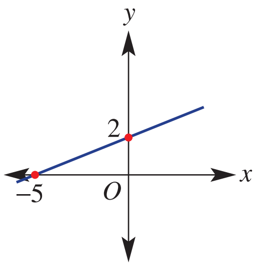
B



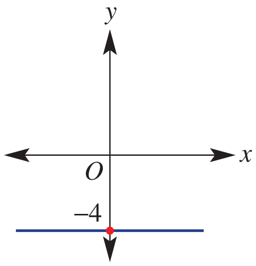
C



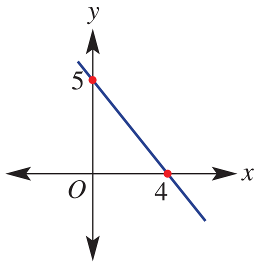
D



E



F



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14 A fruit picker earns \$50 plus \$20 per bin of fruit picked. If the picker earns \$$E$ for n bins picked, complete the following.

a Write a rule for E in terms of n.

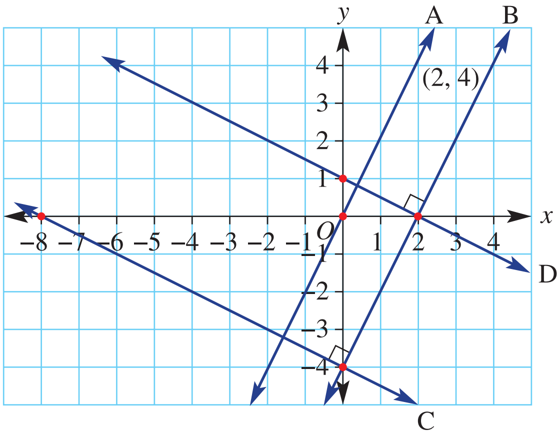
b Sketch a graph for n between 0 and 6.

c Use your rule to find:

  i the amount earned after picking four bins of fruit

  ii the number of bins of fruit picked if \$160 is earned.

15 Use the grid given to find the equations of the lines A, B, C and D.



16 Find the equation of the lines with the given description.

a A line passes through (0, 3) and is parallel to another line with gradient 2.

b A line passes through (0, −1) and is parallel to another line with gradient $\frac{1}{2}$.

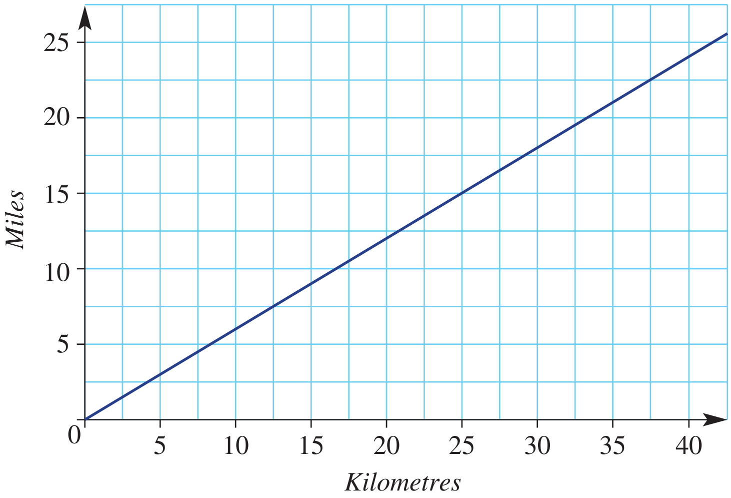
c A line passes through (0, 2) and is perpendicular to another line with gradient 1.

d A line passes through (0, −7) and is perpendicular to another line with gradient $\frac{3}{4}$.

e A line passes through (1, 2) and is parallel to another line with gradient −4.

f A line passes through (−2, 5) and is perpendicular to another line with gradient 2.

17 This graph shows the direct proportional relationship between miles and kilometres.



- **a** Use the graph to convert 5 miles to kilometres.
- **b** Use the graph to convert 35 kilometres to miles.
- **c** Given that 15 miles is 24.14 km, find the gradient, to 3 decimal places.
- **d** State the conversion rate in miles/km, to 3 decimal places.
- **e** Determine the constant of proportionality, k, to 3 decimal places.
- **f** Write the direct proportion equation between miles (y) and kilometres (x).
- **g** Use this equation to find the number of miles in 100 km.
- **h** Use this equation to find the number of kilometres in 100 miles.

18 State whether these variables are in direct or indirect proportion and give a reason why.

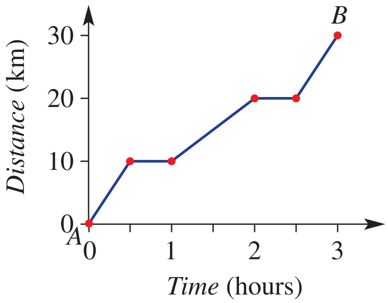
- **a** Cost of buying cricket balls and the number of balls.
- **b** Cost per person of renting a beach house for a week and the number of people sharing it.

19 Convert these units to the given units.

- **a** \$18/h (cents/min)
- **b** 5 m/s to km/h
- **c** 720 km/h to m/s
- **d** 36 L/h (mL/s)

Extended-response questions

1 A courier van picks up goods from two different houses, A and B, as shown on the graph.



- **a** Between houses A and B, find:
  - **i** the distance travelled
  - **ii** the average speed (not including stops)
- **b** How fast was the courier van driving during:
  - **i** the first $\frac{1}{2}$ hour?
  - **ii** the second $\frac{1}{2}$ hour?
  - **iii** the final $\frac{1}{2}$ hour?

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2 David and Kaylene travel from Melton to Moorbank army base to watch their son's march-out parade. The total distance for the trip is 720 km, and they travel an average of 90 km per hour.

a Complete the table of values below from 0 to 8 hours.

Time in hours (t)	0	2	4	6	8
Km from Moorbank	720				

b Plot a graph of the number of kilometres from Moorbank army base against time.

c David and Kaylene start their trip at 6 a.m. If they decide to stop for breakfast at Albury and Albury is 270 km from Melton, what time would they stop for breakfast?

d If the car they are driving needs refilling every 630 km, how long could they drive for before refilling the car?

e What would be the total driving time if they didn't stop at all?

f If the total number of breaks, including food and petrol stops, is 2 hours, when would they arrive at the army base?

3 A young maths whiz in the back of a car is counting down the distance to the nearest town, which is initially 520 km away. The car is travelling at an average speed of 80 km per hour.

a Find the distance to the town after:

- **i** 1 hour
- **ii** 3 hours

b If D km is the distance to the town after t hours:

- **i** Write a rule for D in terms of t.
- **ii** Sketch a graph for t between 0 and 6.5.

c Use your rule to find:

- **i** the distance to the town after 4.5 hours
- **ii** the time it takes for the distance to the town to be 340 km

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Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
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7

Properties of geometrical figures

What you will learn

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Cambridge University Press

NSW syllabus

STRAND: MEASUREMENT AND GEOMETRY

SUBSTRAND: PROPERTIES OF GEOMETRICAL FIGURES

Outcomes

A student describes and applies the properties of similar figures and scale drawings.
(MA5.1–11MG)

A student calculates the angle sum of any polygon and uses minimum conditions to prove triangles are congruent or similar.
(MA5.2–14MG)

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Opera House geometry

The geometry of the Sydney Opera House is based on triangles drawn on a sphere. To understand how this was achieved, imagine an orange sliced into wedges and then each wedge is cut into two pieces in a slanting line across the wedge. The orange skin of each wedge portion is a 3D triangle and illustrates the shape of one side of an Opera House sail. One full sail has two congruent curved triangular sides joined, each a reflection of the other. The edges of the sails form arcs of circles. All the curved sides of the 14 Opera House sails could be joined to form one very large, whole sphere.

The Danish architect Jørn Utzon and engineer Ove Arup chose a radius of 75 m for the virtual sphere from which to design the curved triangular sails. The calculations required high level mathematical modelling, including the applications of circle and spherical geometry. Designed in the 1950s and 1960s, it was one of the first ever projects to use CAD (computer assisted drawing).

Overall the Opera House is 120 m wide, 85 m long and 67 m high (20 storeys above the water level). The sails are covered with about 1 million tiles and it is visited by over 8 million people each year.

Pre-test

1 Write the missing word or number.

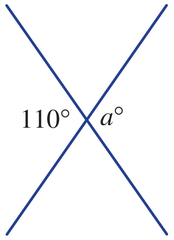
- **a** _________ angles are between 0° and 90°.
- **b** A right angle is ________.
- **c** An obtuse angle is between 90° and ________.
- **d** A 180° angle is called a ________ angle.
- **e** A _________ angle is between 180° and 360°.
- **f** A revolution is _______.
- **g** Complementary angles sum to ________.
- **h** ___________ angles sum to 180°.

2 Name the type of triangle with the given properties.

- **a** all sides of different length
- **b** two sides the same length
- **c** one right angle
- **d** one obtuse angle
- **e** three sides of equal length
- **f** all angles acute

3 Find the values of the pronumerals.

a



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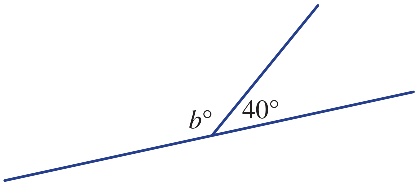

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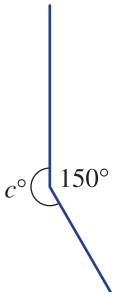

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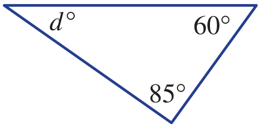

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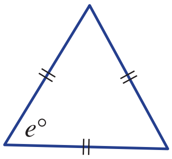

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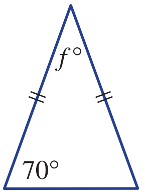
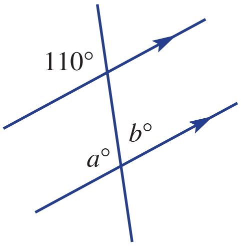


4 Find the value of the pronumerals in these sets of parallel lines.

a



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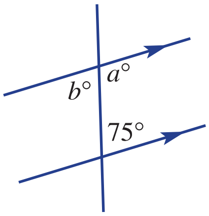

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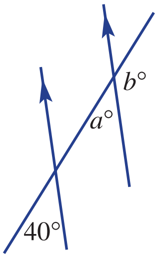

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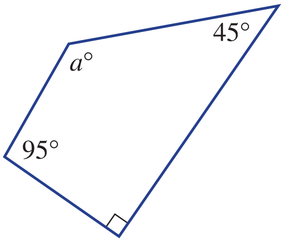
5 Name the quadrilaterals with these properties.

- **a** all sides equal and all angles 90°
- **b** two pairs of parallel sides
- **c** two pairs of parallel sides and all angles 90°
- **d** two pairs of parallel sides and all sides equal
- **e** one pair of parallel sides
- **f** two pairs of equal length sides and no sides parallel

6 Use the angle sum formula, $S = (n - 2) \times 180$, to find the angle sum of these polygons and the value of the pronumeral.

a



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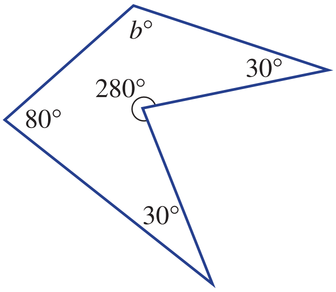

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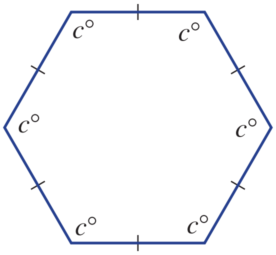
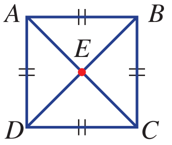


7 In each diagram below, is ΔABC definitely congruent to ΔCDE?

a



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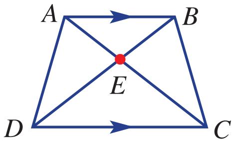

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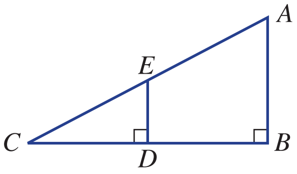

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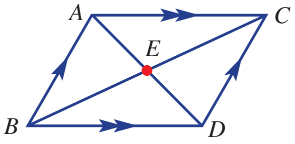

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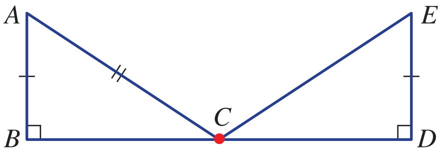

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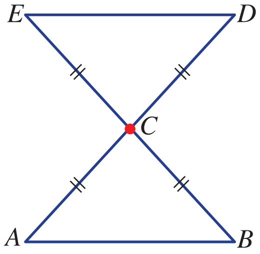

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7A Parallel lines REVISION

Parallel lines are everywhere: in buildings, in nature and on clothing patterns. Sections of straight railway lines are an example.

Parallel lines are always the same distance apart and never meet. In diagrams, arrows are used to show that lines are parallel.

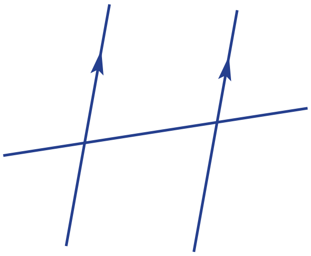
Wheel tracks from farm machinery in a paddock will be parallel.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

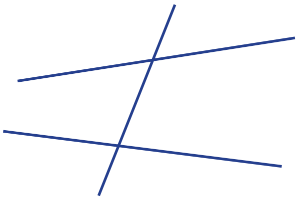
Let's start: 2, 4 or 8 different angles

Diagram **A** and diagram **B** show a pair of lines crossed by a transversal. One pair is parallel and the other is not.

A



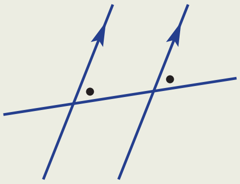
B



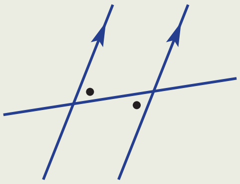
- How many angles of different size are in set A?
- How many angles of different size are in set B?
- If only one angle is known in set A, can you determine all the other angles? Give reasons.

Key ideas

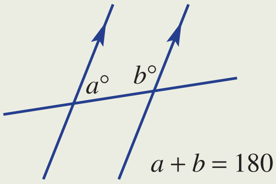
- A **transversal** is a line cutting two or more other lines.
- For parallel lines:
  - corresponding angles are equal



  - alternate angles are equal



  - co-interior angles are supplementary



Transversal A line that cuts two or more lines

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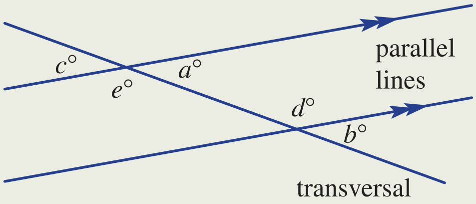
Key ideas



$a = b$	Corresponding angles on parallel lines.
$a = c$	Vertically opposite angles.
$d = e$	Alternate angles on parallel lines.
$a + e = 180$	Angles on a straight line.
$a + d = 180$	Co-interior angles on parallel lines.

Exercise 7A REVISION

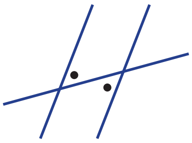
UNDERSTANDING AND FLUENCY	1–5	2–5

1 Write the missing word or number.

- **a** Supplementary angles add to ________.
- **b** Vertically opposite angles are _________.
- **c** If two lines are parallel and are crossed by a transversal, then:
  - **i** corresponding angles are _______.
  - **ii** alternate angles are _______.
  - **iii** co-interior angles are _________________.

2 For the diagrams below, decide whether the given pair of marked angles are corresponding, alternate, co-interior or vertically opposite.

a



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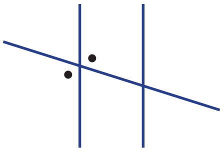

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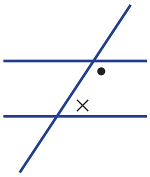

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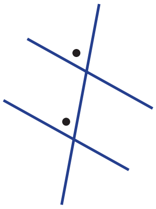
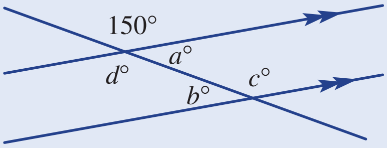


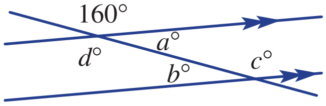
Example 1 Finding angles in parallel lines

Find the values of the pronumerals in this diagram.
Write down the reason in each case.

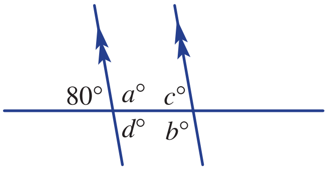


SOLUTION		EXPLANATION
$a + 150 = 180$	(angles on a straight line)	Two angles on a straight line add to 180°.
$a = 30$		
$b = a = 30$	(alternate angles in parallel lines)	$a°$ and $b°$ are alternate angles in parallel lines.
$a + c = 180$	(co-interior angles in parallel lines)	$a°$ and $c°$ are co-interior angles in parallel lines.
$30 + c = 180$		
$c = 150$		
$d = 150$	(vertically opposite angles)	Vertically opposite angles are equal.

3 Find the values of the pronumerals in this diagram. Write down the reason in each case.

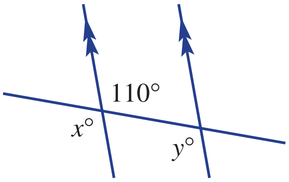


4 Find the values of the pronumerals in this diagram. Write down the reason in each case.



5 Find the value of x and y in these diagrams.

a



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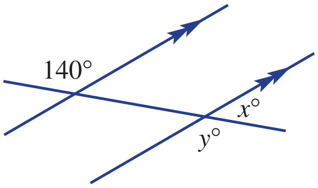

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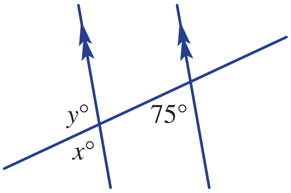

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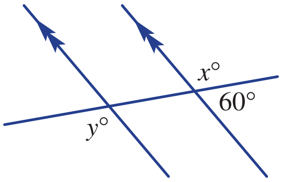

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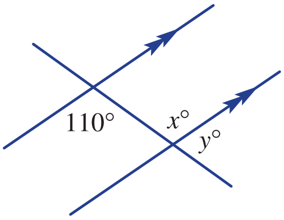

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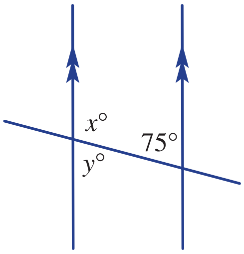


For parallel lines:
Corresponding angles are equal.

Alternate angles are equal.

Co-interior angles add to 180°.

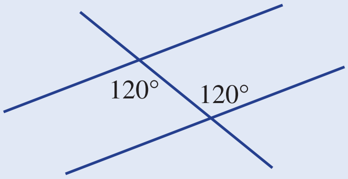
Vertically opposite angles are equal.

PROBLEM-SOLVING AND REASONING 6–8(½) 6–8(½), 9, 10(½)

Example 2 Proving that two lines are parallel

Decide, with reasons, whether the given pairs of lines are parallel.

a



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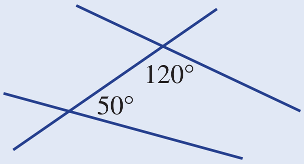
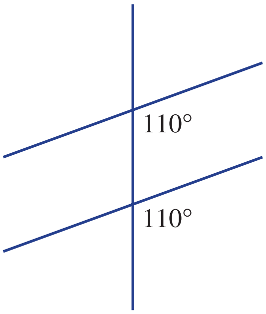


SOLUTION	EXPLANATION
a Yes, alternate angles are equal.	If alternate angles are equal, then lines are parallel.
b No, co-interior angles are not supplementary.	If lines are parallel, then co-interior angles should add to 180°, but 120° + 50° = 170°.

6 Decide, with reasons, whether the given pairs of lines are parallel.

a



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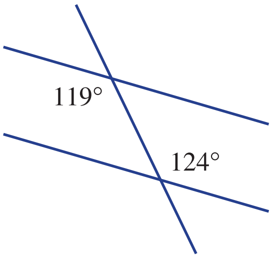

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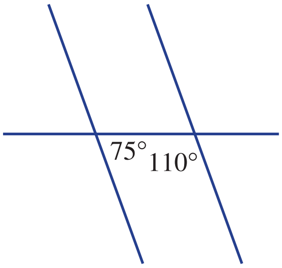

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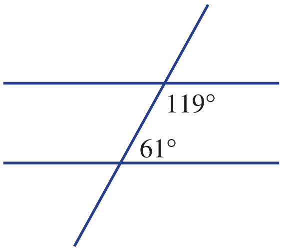

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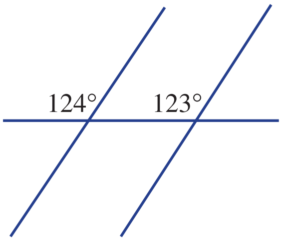

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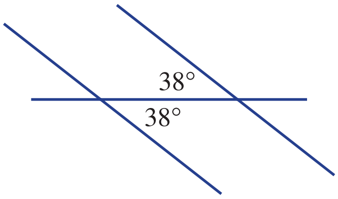
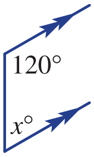


7 These diagrams have a pair of parallel lines. Find the unknown value of x.

a



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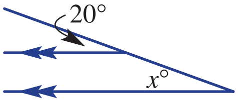

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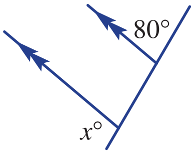

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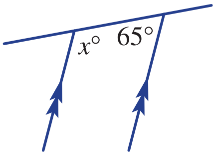

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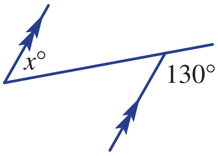

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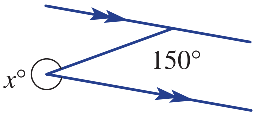
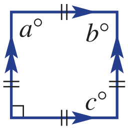


8 These common shapes consist of parallel lines. One internal angle is given. Find the values of the pronumerals.

a



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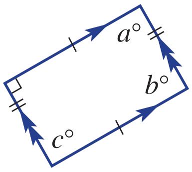

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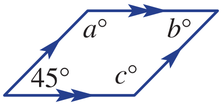

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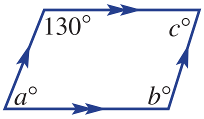

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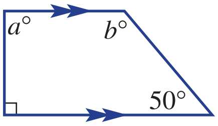

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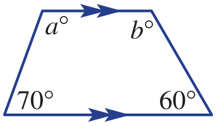

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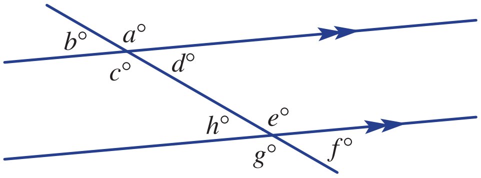
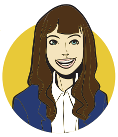
9 For this diagram, list all pairs of angles that are:



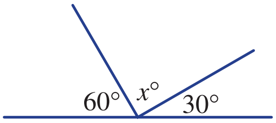
One example for part **a** is (a, e).



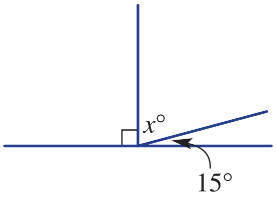
a corresponding
b alternate
c co-interior
d vertically opposite

10 Find the unknown value of x in each of these cases.

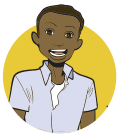
a



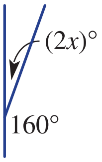
b



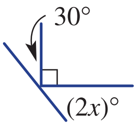
Angles on a straight line add to 180°.



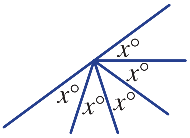
c



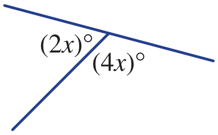
d



e



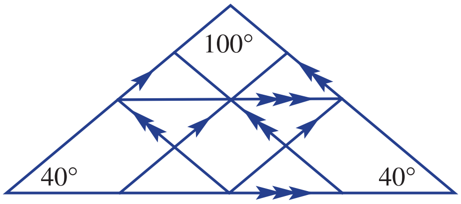
f



ENRICHMENT	–	11

The roof truss

11 This diagram is of a roof truss with three groups of parallel supports.



How many of the angles are:

a 100° in size?
b 40° in size?
c 140° in size?

7B Triangles REVISION

Interactive

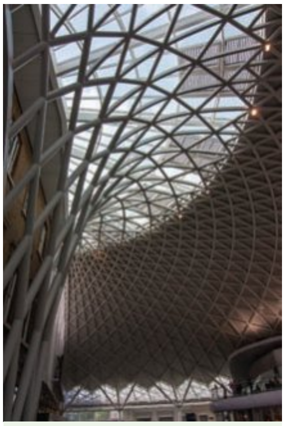
Widgets

HOTsheets

Walkthrough

The triangle is at the foundation of geometry, and its properties are used to work with more complex geometry.

One of the best known and most useful properties of triangles is the internal angle sum (180°). You can check this by measuring and adding up the three internal angles of any triangle.



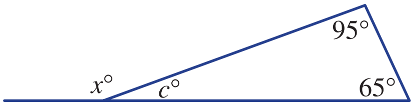
Triangles are everywhere in modern architecture, like the roof of King's Cross Station in London.

Stage

- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

Let's start: Exterior angle proof

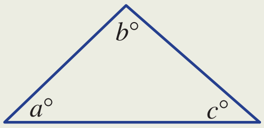
Consider this triangle with exterior angle $x°$.



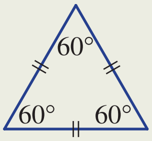
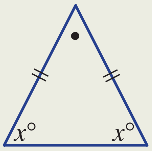
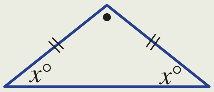
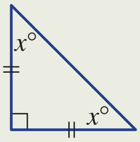
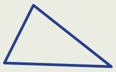
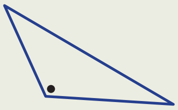
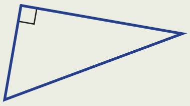
- Use the angle sum of a triangle to find the value of c.
- Now find the value of x.
- What do you notice about $x°$ and the two given angles? Is this true for other triangles? Give examples and reasons.

Key ideas

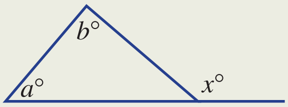
- The sum of all three internal angles of a triangle is 180°.
- Triangles can be classified by their side lengths or their internal angles.



$a + b + c = 180$

		Classified by internal angles		
		Acute-angled triangles (all angles acute, < 90°)	Obtuse-angled triangles (one angle obtuse, > 90°)	Right-angled triangles (one right angle, 90°)
Classified by side lengths	Equilateral triangles (three equal side lengths)		Not possible	Not possible
	Isosceles triangles (two equal side lengths)			
	Scalene triangles (no equal side lengths)			

- The **exterior angle theorem**: The exterior angle is equal to the sum of the two opposite interior angles.



$x = a + b$

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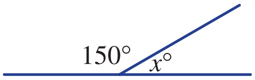
Exercise 7B REVISION

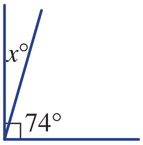
UNDERSTANDING AND FLUENCY 1–3, 4–6(½) 3, 4–6(½)

1 Give the value of x in these diagrams.

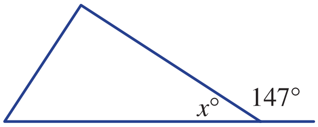
a



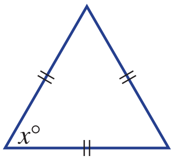
b



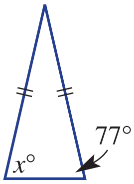
c



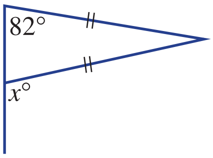
d



e



f

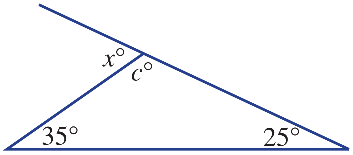


2 The two given interior angles for this triangle are 25° and 35°.

a Use the angle sum (180°) to find the value of c.

b Hence, find the value of x.

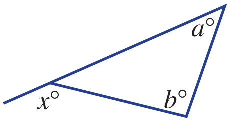
c What do you notice about the value of x and the two given interior angles?



3 Choose the correct expression for this exterior angle.

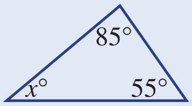
A $a = x + b$ **B** $b = x + a$ **C** $x = a + b$

D $a + b = 180$ **E** $2a + b = 2x$



Example 3 Using the angle sum of a triangle

Find the value of the unknown angle (x) in this triangle.



SOLUTION

$$x + 85 + 55 = 180$$
$$x + 140 = 180$$
$$x = 40$$

∴ The unknown angle is 40°.

EXPLANATION

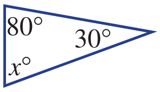
The sum of the three internal angles in a triangle is 180°.

Simplify before solving for x.

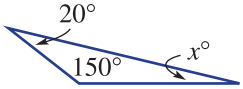
Solve for x by subtracting 140 from both sides of the equals sign.

4 Find the value of the unknown angle (x) in these triangles.

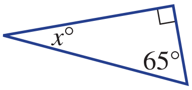
a



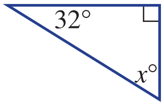
b



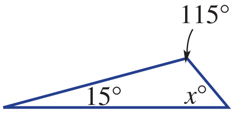
c



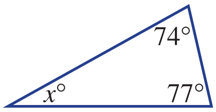
d

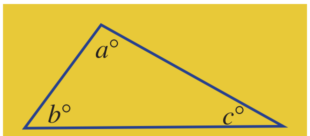


e



f





$a + b + c = 180$

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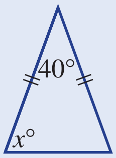
Example 4 Working with an isosceles triangle

Find the value of x in this isosceles triangle.



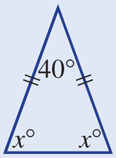
SOLUTION

$$x + x + 40 = 180$$
$$2x + 40 = 180$$
$$2x = 140$$
$$x = 70$$

∴ The unknown angle is 70°.

EXPLANATION

The triangle is isosceles and therefore the two base angles are equal.



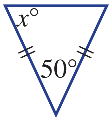
Collect like terms.

Subtract 40 from both sides.

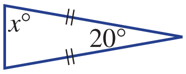
Divide both sides by 2.

5 Find the value of the unknown angle (x) in these triangles.

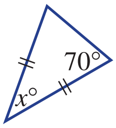
a



b



c



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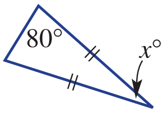
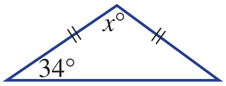
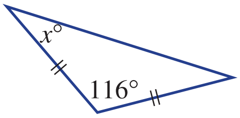


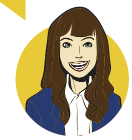
e



f



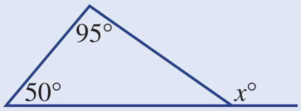
Label the third angle first.



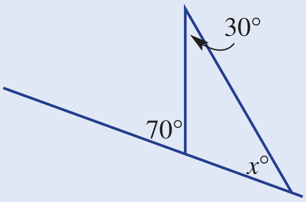
Example 5 Using the exterior angle theorem

Use the exterior angle theorem to find the value of x.

a



b



SOLUTION

a $x = 95 + 50$
$= 145$

b $x + 30 = 70$
$x = 40$

EXPLANATION

The exterior angle $x°$ is the sum of the two opposite interior angles.

The two opposite interior angles are $x°$ and 30°, and 70° is the exterior angle.

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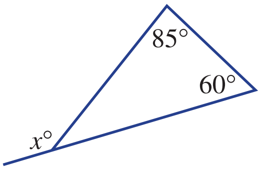
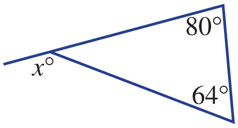
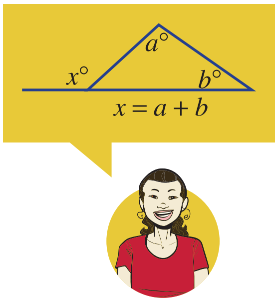
6 Use the exterior angle theorem to find the value of x.

a



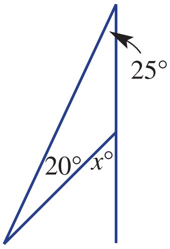
b





$x = a + b$

c



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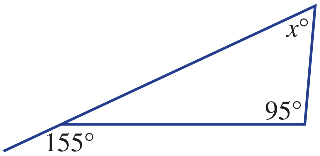

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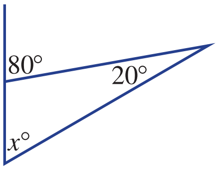

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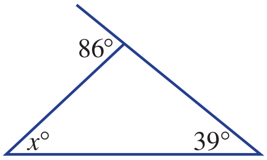


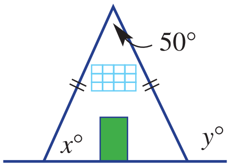
PROBLEM-SOLVING AND REASONING 7, 8 7, 9(½), 10

7 Decide whether the following are possible. If so, make a drawing.

a acute scalene triangle
b acute isosceles triangle
c obtuse equilateral triangle
d acute equilateral triangle
e obtuse isosceles triangle
f obtuse scalene triangle
g right equilateral triangle
h right isosceles triangle
i right scalene triangle

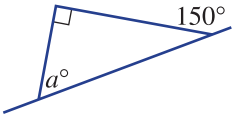
8 An architect draws the cross-section of a new ski lodge, which includes a very steep roof, as shown. The angle at the top is 50°. Find:

a the acute angle that the roof makes with the floor ($x°$)
b the obtuse angle that the roof makes with the floor ($y°$)

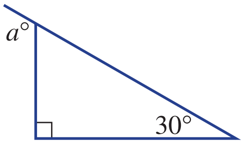


9 Use your knowledge of parallel lines and triangles to find out the value of the pronumerals in these diagrams.

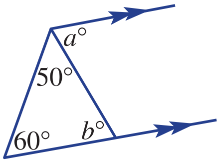
a



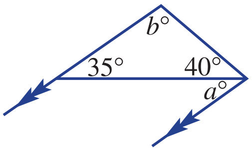
b



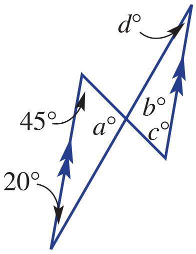
c



d



e



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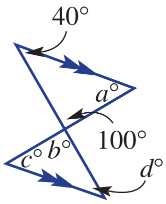

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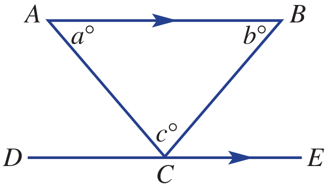
10 For this diagram, *AB* is parallel to *DE*.



a What is the size of $\angle ACD$? Use a pronumeral and give a reason.

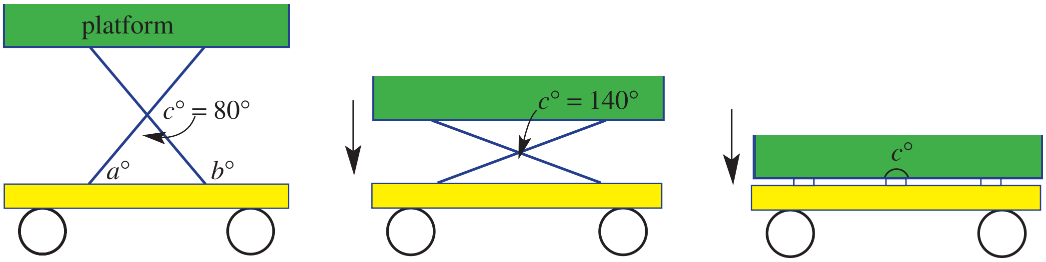
b What is the size of $\angle BCE$? Use a pronumeral and give a reason.

c Since $\angle DCE = 180°$, what does this tell us about a, b and c?

ENRICHMENT	–	11

The hydraulic platform

11 A hydraulic platform includes a moveable ‘X’-shaped support system, as shown. When the platform is at its highest point, the angle at the centre ($c°$) of the ‘X’ is 80°, as shown.



a When the platform is at its highest position, find:
  - **i** the acute angle that the ‘X’ makes with the platform ($a°$)
  - **ii** the obtuse angle that the ‘X’ makes with the platform ($b°$)

b The platform now moves down so that the angle at the centre ($c°$) of the ‘X’ changes from 80° to 140° At this platform position, find the values of:
  - **i** the acute angle that the ‘X’ makes with the platform ($a°$)
  - **ii** the obtuse angle that the ‘X’ makes with the platform ($b°$)

c The platform now moves down to the base so that the angle at the centre ($c°$) of the ‘X’ is now 180°. Find:
  - **i** the acute angle that the ‘X’ makes with the platform ($a°$)
  - **ii** the obtuse angle that the ‘X’ makes with the platform ($b°$)

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7C Quadrilaterals REVISION

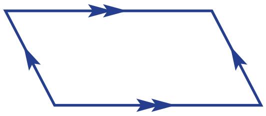
Quadrilaterals are shapes that have four straight sides with a special angle sum of 360°. There are six special quadrilaterals, each with their own special set of properties. If you look around any old or modern building, you will see examples of these shapes.

Mosaics are made up of quadrilaterals along with many other polygons.

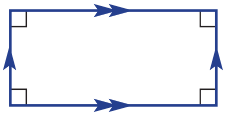
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Why is a rectangle a parallelogram?

By definition, a parallelogram is a quadrilateral with two pairs of parallel sides.



Parallelogram

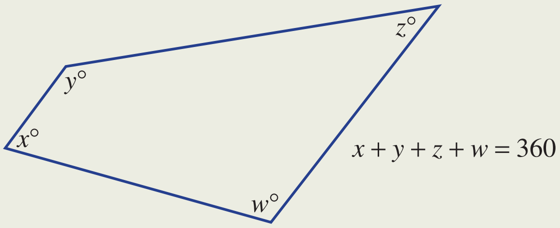


Rectangle

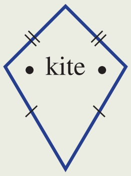
- Using this definition, do you think that a rectangle is also a parallelogram? Why?
- What properties does a rectangle have that a general parallelogram does not?
- What other special shapes are parallelograms? What are their properties?

Key ideas

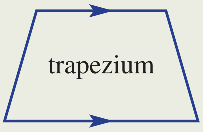
- The sum of the interior angles of any quadrilateral is 360°.



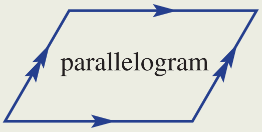
- Formal definitions:
  - A kite is a quadrilateral with two pairs of adjacent sides that are equal and one pair of opposite equal angles.



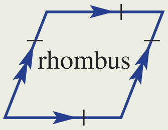
  - A trapezium is a quadrilateral with at least one pair of opposite sides that are parallel.



  - A parallelogram is a quadrilateral with both pairs of opposite sides that are parallel.



  - A rhombus is a parallelogram with two adjacent sides that are equal in length.



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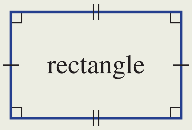
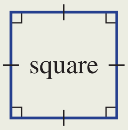
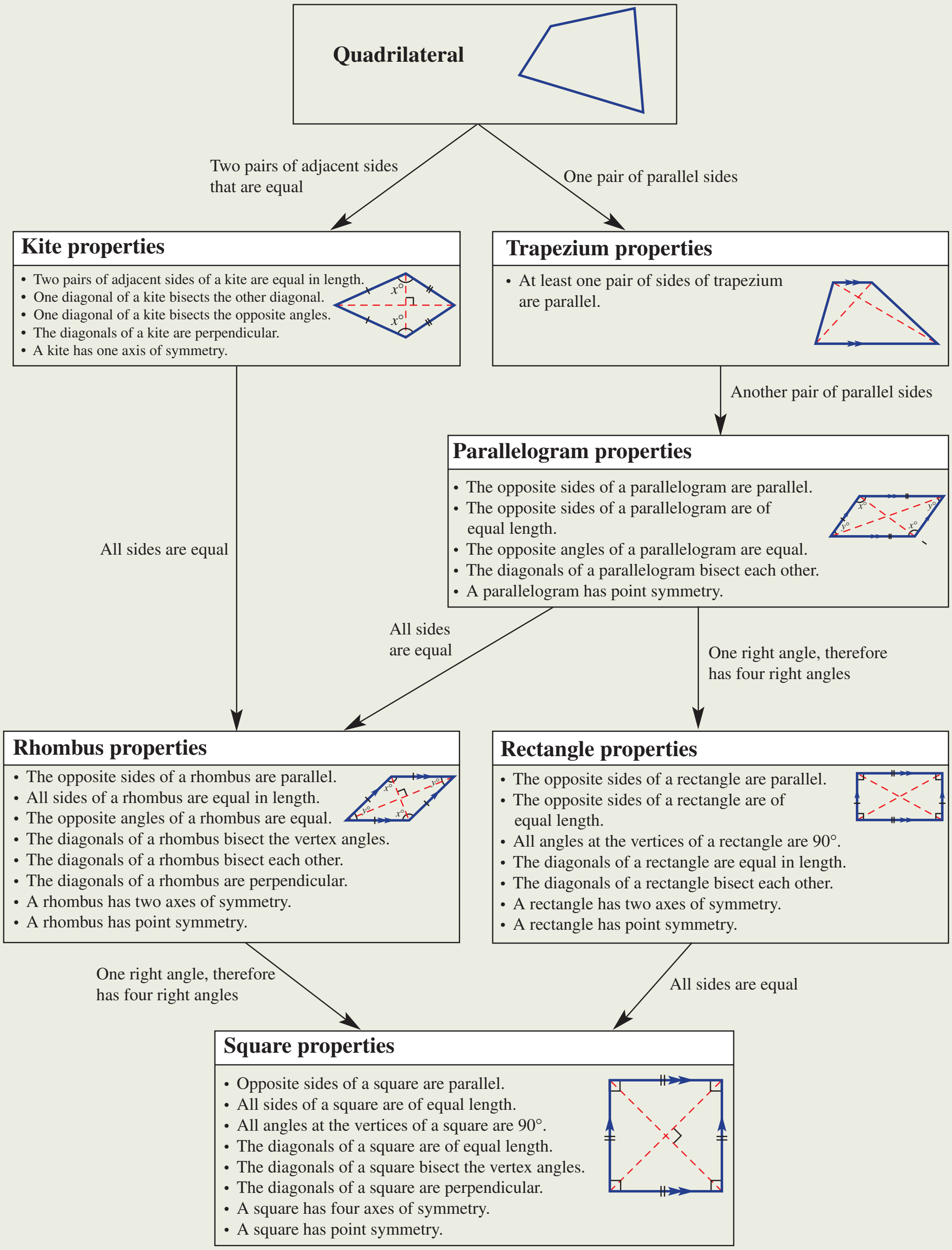
- A rectangle is a paralleogram with one angle that is a right angle.



- A square is a rectangle with two adjacent sides that are equal.





Quadrilateral

Two pairs of adjacent sides that are equal

One pair of parallel sides

Kite properties

- Two pairs of adjacent sides of a kite are equal in length.
- One diagonal of a kite bisects the other diagonal.
- One diagonal of a kite bisects the opposite angles.
- The diagonals of a kite are perpendicular.
- A kite has one axis of symmetry.

Trapezium properties

- At least one pair of sides of trapezium are parallel.

Another pair of parallel sides

Parallelogram properties

- The opposite sides of a parallelogram are parallel.
- The opposite sides of a parallelogram are of equal length.
- The opposite angles of a parallelogram are equal.
- The diagonals of a parallelogram bisect each other.
- A parallelogram has point symmetry.

All sides are equal

All sides are equal

One right angle, therefore has four right angles

Rhombus properties

- The opposite sides of a rhombus are parallel.
- All sides of a rhombus are equal in length.
- The opposite angles of a rhombus are equal.
- The diagonals of a rhombus bisect the vertex angles.
- The diagonals of a rhombus bisect each other.
- The diagonals of a rhombus are perpendicular.
- A rhombus has two axes of symmetry.
- A rhombus has point symmetry.

Rectangle properties

- The opposite sides of a rectangle are parallel.
- The opposite sides of a rectangle are of equal length.
- All angles at the vertices of a rectangle are 90°.
- The diagonals of a rectangle are equal in length.
- The diagonals of a rectangle bisect each other.
- A rectangle has two axes of symmetry.
- A rectangle has point symmetry.

One right angle, therefore has four right angles

All sides are equal

Square properties

- Opposite sides of a square are parallel.
- All sides of a square are of equal length.
- All angles at the vertices of a square are 90°.
- The diagonals of a square are of equal length.
- The diagonals of a square bisect the vertex angles.
- The diagonals of a square are perpendicular.
- A square has four axes of symmetry.
- A square has point symmetry.

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Exercise 7C REVISION

UNDERSTANDING AND FLUENCY

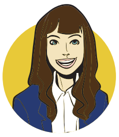
1–3, 4–5(½)	3, 4–5(½)

1 Which special quadrilaterals are parallelograms?

2 List all the quadrilaterals that have the following properties.

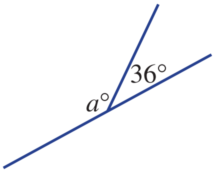
a two pairs of parallel sides
b two pairs of equal length sides
c equal opposite angles
d one pair of parallel sides
e one pair of equal angles
f all angles 90°
g equal length diagonals
h diagonals intersecting at right angles

Refer to the Key ideas for help.



3 Find the value of the pronumerals.

a



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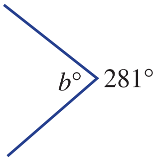

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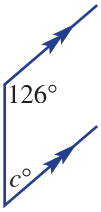
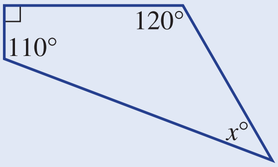


Example 6 Using the angle sum of a quadrilateral

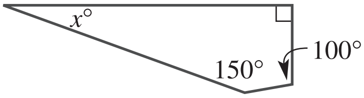
Find the unknown angle in this quadrilateral.



SOLUTION	EXPLANATION
$x + 110 + 120 + 90 = 360$	The sum of the interior angles is 360° in a quadrilateral.
$x + 320 = 360$	Simplify.
$x = 40$	Subtract 320 from both sides.
∴ The unknown angle is 40°.	

4 Find the unknown angles in these quadrilaterals.

a



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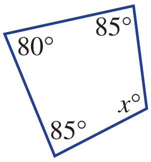
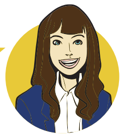


The angle sum of a quadrilateral is 360°.



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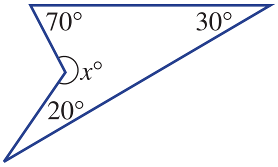

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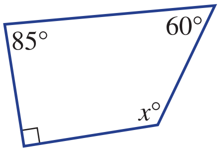

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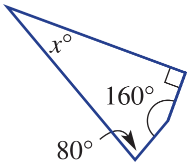

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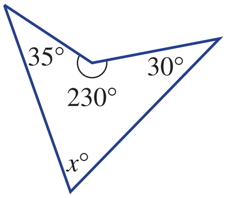

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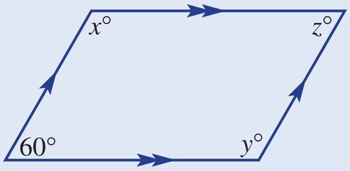
Example 7 Finding angles in special quadrilaterals

Find the value of the pronumerals in these special quadrilaterals, giving reasons.

a



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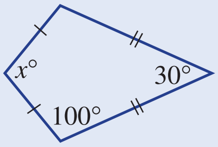
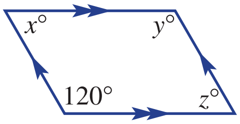


SOLUTION	EXPLANATION
a $x + 60 = 180$ (co-interior angles in parallel lines) $x = 120$	$x°$ and $60°$ are co-interior angles and sum to $180°$. Subtract 60 from both sides.
$\therefore y = 120$ (opposite angles in a parallelogram)	$y°$ is opposite and equal to $x°$.
$\therefore z = 60$ (opposite angles in a parallelogram)	$z°$ is opposite and equal to $60°$.
b $x + 100 + 100 + 30 = 360$ (angle sum of a quadrilateral) $x + 230 = 360$ $x = 130$	A kite has a pair of equal, opposite angles, so there are two $100°$ angles. The total sum is still $360°$.

5 Find the value of the pronumerals in these special quadrilaterals, giving reasons.

a



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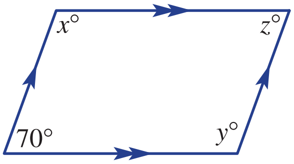
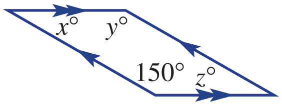


Refer to the properties of special quadrilaterals for help.

c



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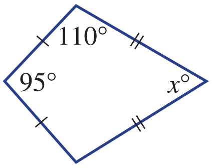

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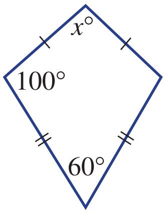

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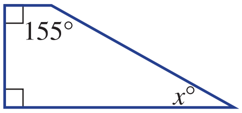

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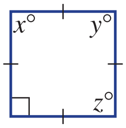

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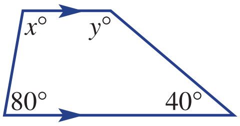

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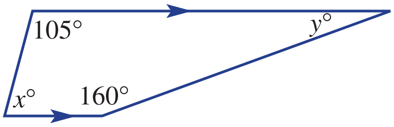

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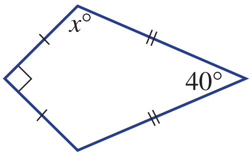
PROBLEM-SOLVING AND REASONING	6(½), 7	6(½), 7–9

6 Find the value of the pronumerals in these shapes.

a



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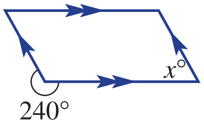

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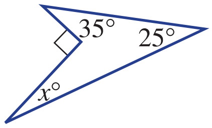

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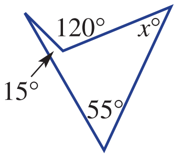

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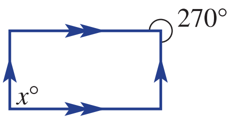

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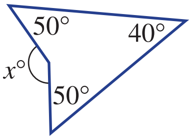
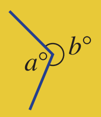
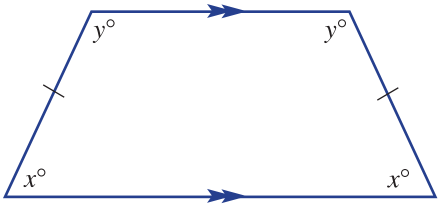


Angles in a revolution add to 360°.



$a + b = 360$

7 This shape is called an isosceles trapezium.



a Why do you think it is called an isosceles trapezium?

b **i** If $x = 60$, find the value of y.

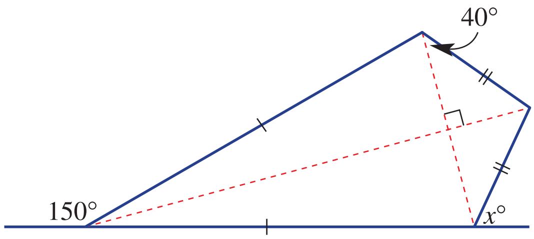
ii If $y = 140$, find the value of x.

c List the properties of an isosceles trapezium.

8 A modern hotel is in the shape of a kite. Some angles are given in the diagram.

a Draw a copy of just the kite shape, including the diagonals.

b Find the angle that the right-hand wall makes with the ground ($x°$).



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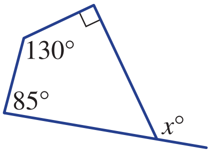
9 These quadrilaterals also include exterior angles. Find the value of *x*.

a



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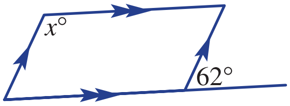

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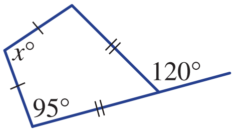


Recall:

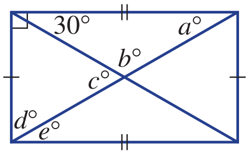
$a + b = 180$

ENRICHMENT – 10(½)

Quadrilaterals and triangles

10 The following shapes combine quadrilaterals with triangles. Find the values of the pronumerals.

a



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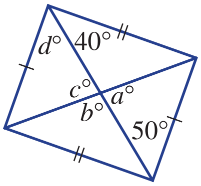

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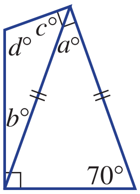

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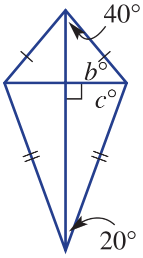

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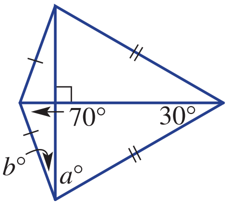

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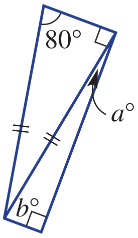
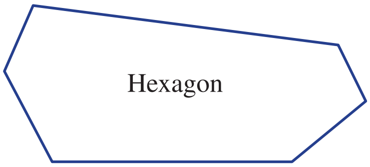


7D Polygons

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

A closed shape with all straight sides is called a polygon. Like triangles and quadrilaterals (which are both polygons), they all have a special angle sum.



The Pentagon building in Washington, D.C.

Let's start: Remember the names

From previous years you should remember some of the names for polygons.

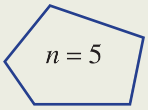
See if you can remember them by completing this table.

Number of sides	Name
3	
4	
5	
6	
7	heptagon

Number of sides	Name
8	
9	
10	
11	undecagon
12	

Key ideas

- A **polygon** is a shape with straight sides.
  - They are named by their number of sides.
- The sum of internal angles (S) of a polygon is given by the rule:
  $S = (n - 2) \times 180$
  where n is the number of sides

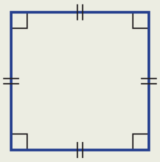


For example:

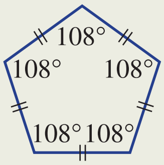
$$S = (n - 2) \times 180$$
$$S = (5 - 2) \times 180$$
$$= 180^\circ \times 3$$
$$= 540^\circ$$

A **regular polygon** has equal angles and sides of equal length.

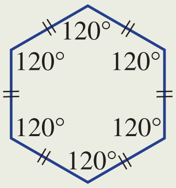
regular quadrilateral (square) (four sides)



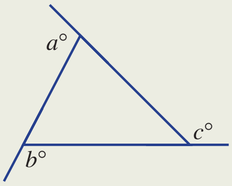
regular pentagon (five sides)



regular hexagon (six sides)



- This diagram shows the exterior angles of a triangle.
  In every polygon, the sum of the exterior angles is 360°.
  $a + b + c = 360$



Polygon A two-dimensional shape where three or more straight lines are joined together to form a closed figure

Regular polygon A polygon with all sides of equal length and all angles equal

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Exercise 7D

UNDERSTANDING AND FLUENCY

1–3, 4(½), 5

3, 4(½), 5, 6

1 How many sides do these shapes have?

a quadrilateral **b** octagon **c** decagon **d** heptagon
e nonagon **f** hexagon **g** pentagon **h** dodecagon

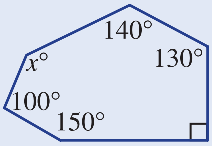
2 Use the angle sum rule, $S = (n - 2) \times 180$, to find the angle sum of these polygons.

a pentagon ($n = 5$) **b** hexagon ($n = 6$) **c** heptagon ($n = 7$)
d octagon ($n = 8$) **e** nonagon ($n = 9$) **f** decagon ($n = 10$)

3 What is always true about a polygon that is regular?

Example 8 Finding and using the angle sum of a polygon

For this polygon, find the angle sum and then the value of x.



SOLUTION

$$\begin{aligned} S &= (n - 2) \times 180 \\ &= (6 - 2) \times 180 \\ &= 720° \end{aligned}$$

$$\begin{aligned} x + 100 + 150 + 90 + 130 + 140 &= 720 \\ x + 610 &= 720 \\ x &= 110 \end{aligned}$$

EXPLANATION

Use the angle sum rule first, with $n = 6$ because there are 6 sides.

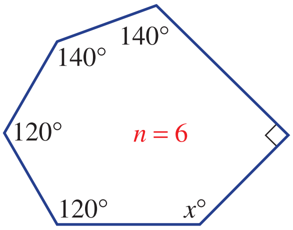
Find the angle sum.

Use the total angle sum to find the value of x.

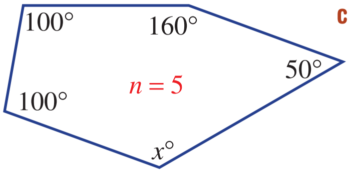
Solve for the value of x.

4 For these polygons, find the angle sum and then find the value of x.

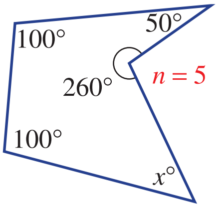
a



b



c



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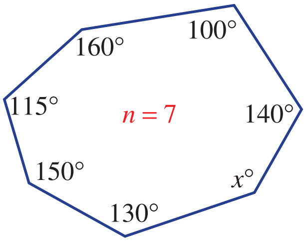

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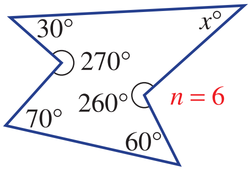
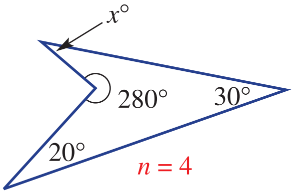


f



First use
$S = (n - 2) \times 180$

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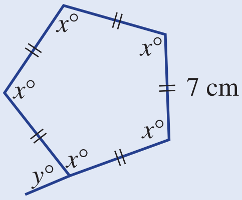
Example 9 Working with regular polygons

Shown here is a regular pentagon with straight edge side lengths of 7 cm.

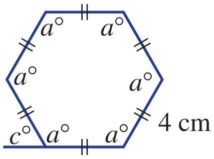
a Find the perimeter of the pentagon.
b Find the total internal angle sum (S).
c Find the size of each interior angle $x°$.
d Find the size of each exterior angle $y°$.



SOLUTION	EXPLANATION
a 35 cm	There are five sides of length 7 cm each.
b $S = (n - 2) \times 180$	Write the general rule for the sum of internal angles for a polygon.
$= (5 - 2) \times 180$	$n = 5$ because there are five sides.
$= 180° \times 3$ $= 540°$	Simplify and evaluate.
c $540° \div 5 = 108°$ $\therefore x = 108$	There are five equally sized angles since it is a regular pentagon.
d $y = 180 - 108$ $y = 72$	The interior and exterior angle form a straight angle.
or $360 \div 5 = 72$ $\therefore y = 72$ The exterior angles are 72° each.	Alternatively, the sum of the five exterior angles is 360°.

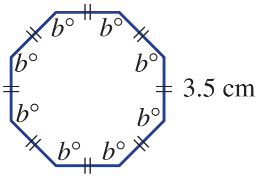
5 Shown here is a regular hexagon with straight edge side lengths of 4 cm.

a Find the perimeter of the hexagon.
b Find the total internal angle sum (S).
c Find the size of each interior angle $a°$.
d Find the size of each exterior angle $c°$.



6 Shown here is a regular octagon with straight edge side lengths of 3.5 cm.

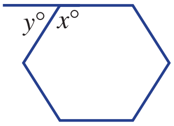
a Find the perimeter of the octagon.
b Find the total internal angle sum (S).
c Find the size of each interior angle $b°$.



PROBLEM-SOLVING AND REASONING 7–9 9–12

7 The cross-section of a pencil is a regular hexagon.

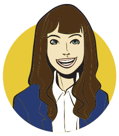
a Find the interior angle ($x°$).
b Find the exterior angle ($y°$).



8 Find the total internal angle sum for a polygon with:

a 11 sides **b** 20 sides

Remember:
$S = (n - 2) \times 180$



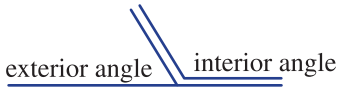
9 Find the size of a single interior angle for a regular polygon with:

a 10 sides **b** 25 sides

10 A castle turret is in the shape of a regular hexagon. At each of the six corners find:

a the interior angle

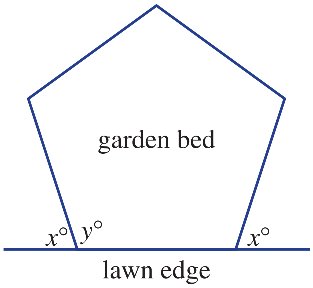
b the exterior angle



11 A garden bed is to be designed in the shape of a regular pentagon and sits adjacent to a lawn edge, as shown.

a Find the angle the lawn edge makes with the garden bed ($x°$).

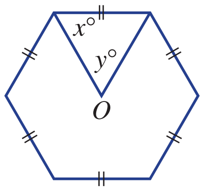
b Find the interior angle for each corner ($y°$).



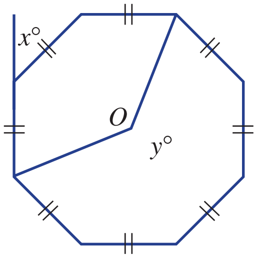
Sum of exterior angles in all polygons is 360°

12 For these diagrams, find the values of the unknowns. The shapes are regular.

a



b

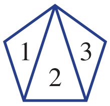


The point O is the centre.

ENRICHMENT	–	13

Develop the angle sum rule

13 **a** Copy and complete this table. For the diagram, use diagonals to divide the shape into triangles, as shown for the pentagon.

Regular polygon	Number of sides	Diagram	Number of triangles	Interior angle sum (S)	Single interior angle (A)	Exterior angle sum (S)	Single exterior angle (E)
triangle							
quadrilateral							
pentagon	5		3	$3 \times 180° = 540°$	$540° \div 5 = 108°$		
hexagon							
…							
n-gon	n						

b Complete these sentences by writing the rule.

i For a polygon with n sides, the interior angle sum, S, is given by $S =$ _____.

ii For a regular polygon with n sides, a single interior angle, A, is given by $A =$ _____.

iii For a polygon with n sides, the exterior angle sum is _____ degrees.

iv For a regular polygon with n sides, a single exterior angle, E, is given by $E =$ _____.

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7E Congruent triangles

When solving problems or when building structures, for example, it is important to know whether or not two expressions or objects are identical. The mathematical word used to describe identical objects is **congruence**.

For congruent triangles there are four important tests that can be used to prove congruence.

At the same height, the cross sections of the Petronas Twin Towers in Kuala Lumpur will be congruent.

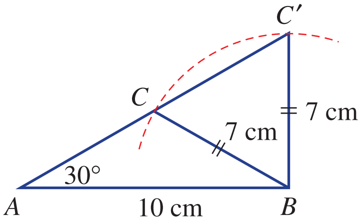
Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Why are AAA and ASS not tests for congruence?

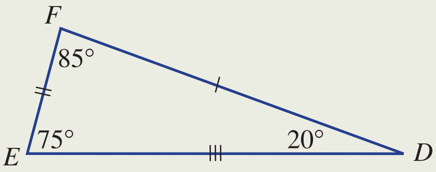
AAA and ASS are not tests for the congruence of triangles.

- For AAA, can you draw two different triangles using the same three angles? Why does this mean that AAA is not a test for congruence?
- Look at the diagram opposite, showing triangle *ABC* and triangle *ABC*′. Both triangles have a 30° angle and two sides of length 10 cm and 7 cm. Explain how this diagram shows that ASS is not a test for congruence of triangles.

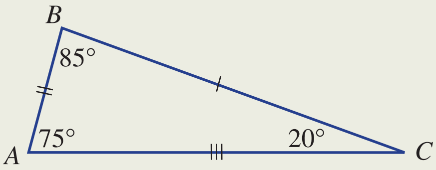


Key ideas

- Two triangles are said to be **congruent** if they are exactly the same *size* and *shape*. Corresponding sides and angles will be of the same size, as shown in these triangles.

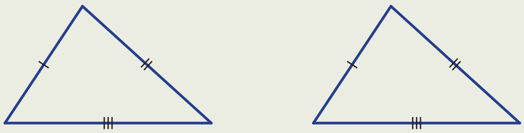


- If triangle *ABC* is congruent to triangle *EFD*, we write $\Delta ABC \equiv \Delta EFD$.
  - This is called a congruence statement.
  - Letters are written in matching order.

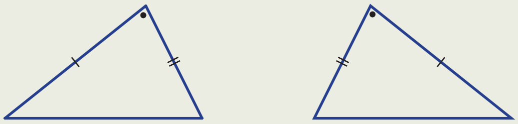


Key ideas

- Two triangles can be tested for congruence by considering the following necessary conditions.
  1. Three pairs of sides are equal (SSS).



  2. Two corresponding sides and the angle between them are equal (SAS).



  3. Two angles and any corresponding side are equal (AAS).

  4. A right angle, the hypotenuse and one other pair of corresponding sides are equal (RHS).

- A congruence proof

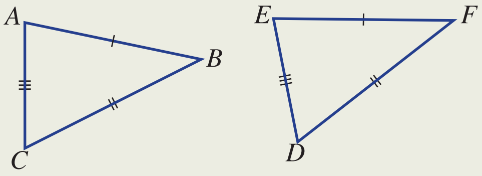
In ΔABC and ΔEFD:

$AB = EF$ (given)

$BC = FD$ (given)

$AC = ED$ (given)

$\therefore \Delta ABC \equiv \Delta EFD$ (SSS)



Exercise 7E

UNDERSTANDING AND FLUENCY 1–3, 4–5(½) 3, 4–5(½)

1 True or false?

a SSA is a test for the congruence of triangles.

b AAA is a test for the congruence of triangles.

c Two congruent triangles are the same shape and size.

d If $\Delta ABC \equiv \Delta DEF$, then triangle ABC is congruent to triangle DEF.

2 Write the four tests for congruence, using their abbreviated names.

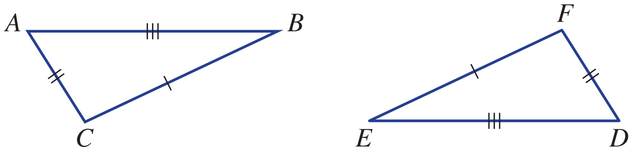
SAS is one of the answers.

3 Here is a pair of congruent triangles.

a Which point on ΔDEF corresponds to point B on ΔABC?

b Which side on ΔABC corresponds to side DF on ΔDEF?

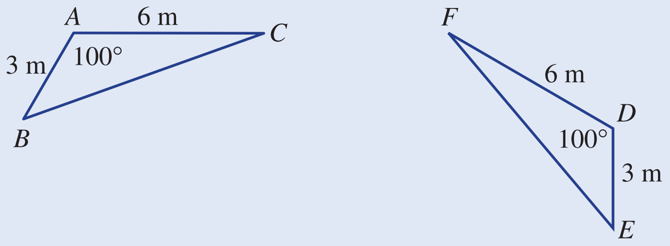
c Which angle on ΔDEF corresponds to $\angle BAC$ on ΔABC?



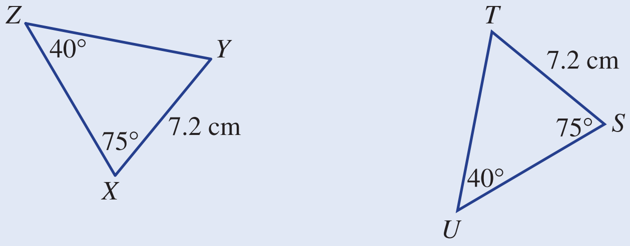
Example 10 Choosing a test for congruence

Write a congruence statement and the test to prove congruence for these pairs of triangles.

a



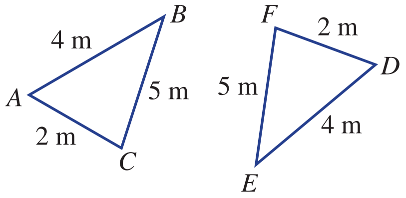
b



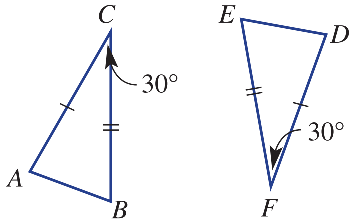
SOLUTION	EXPLANATION
a $\Delta ABC \equiv \Delta DEF$ (SAS)	Write letters in corresponding (matching) order. Two pairs of sides are equal, as well as the angle between.
b $\Delta XYZ \equiv \Delta STU$ (AAS)	X matches S, Y matches T and Z matches U. Two angles and one pair of matching sides are equal.

4 Write a congruence statement and the test to prove congruence for these pairs of triangles.

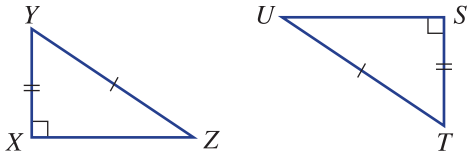
a



b



c



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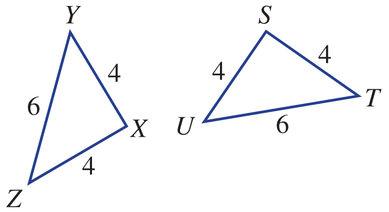
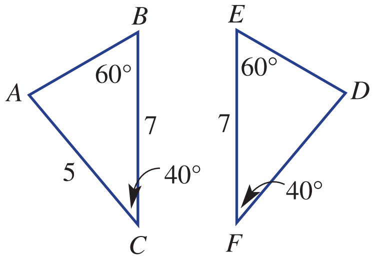
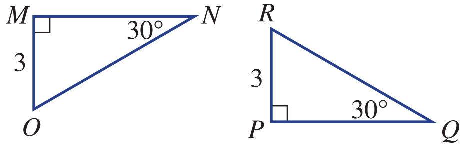


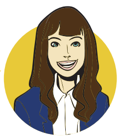
e



f



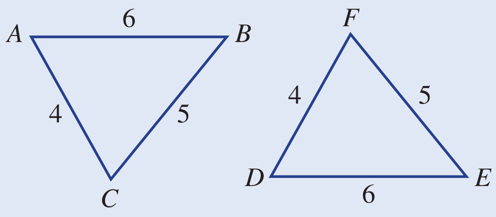
$\Delta ABC \equiv \Delta DEF$ is a congruence statement.
Choose one of the tests SSS, SAS, AAS or RHS.



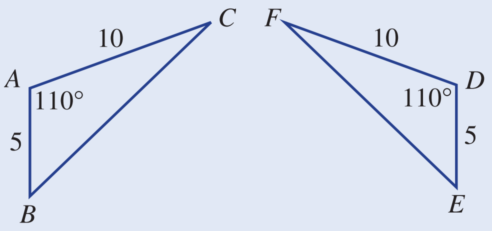
Example 11 Proving that a pair of triangles are congruent

Prove that the following pairs of triangles are congruent.

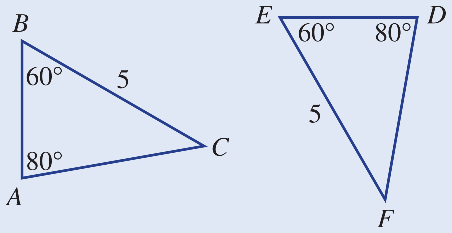
a



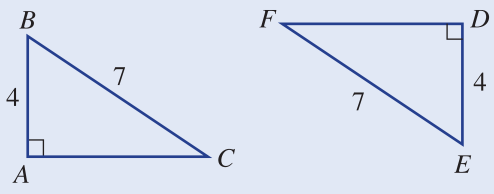
b



c



d



SOLUTION		EXPLANATION
a $AB = DE$ (given)	(S)	First choose all the corresponding side lengths.
$AC = DF$ (given)	(S)	Corresponding side lengths will have the same length.
$BC = EF$ (given)	(S)	
$\therefore\ \Delta ABC \equiv \Delta DEF$	(SSS)	Write the congruence statement and the abbreviated reason.
b $AB = DE$ (given)	(S)	Note that two corresponding side lengths are equal and the included angles are equal.
$\angle BAC = \angle EDF$ (given)	(A)	
$AC = DF$ (given)	(S)	
$\therefore\ \Delta ABC \equiv \Delta DEF$	(SAS)	Write the congruence statement and the abbreviated reason.
c $\angle ABC = \angle DEF$ (given)	(A)	Two of the angles are equal and one of the corresponding sides is equal.
$\angle BAC = \angle EDF$ (given)	(A)	
$BC = EF$ (given)	(S)	
$\therefore\ \Delta ABC \equiv \Delta DEF$	(AAS)	Write the congruence statement and the abbreviated reason.
d $\angle BAC = \angle EDF = 90^\circ$ (given)	(R)	Note that both triangles are right-angled, the hypotenuse of each triangle is of the same length and another corresponding side is of the same length.
$BC = EF$ (given)	(H)	
$AB = DE$ (given)	(S)	
$\therefore\ \Delta ABC \equiv \Delta DEF$	(RHS)	Write the congruence statement and the abbreviated reason.

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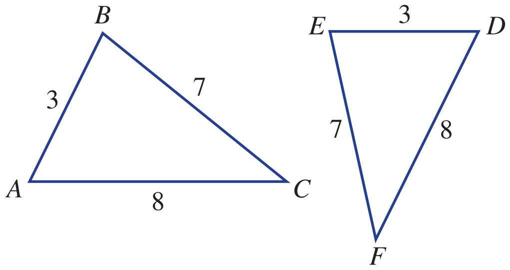
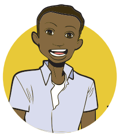
5 Prove that the following pairs of triangles are congruent.

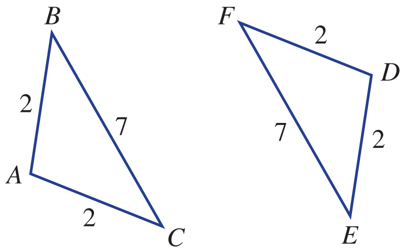
a



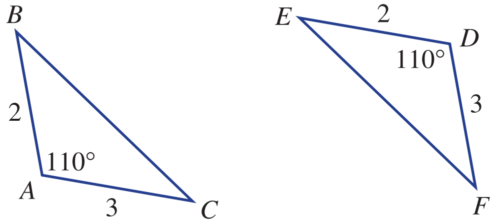
List reasons, as done in the examples, to establish SSS, SAS, AAS or RHS.



b



c



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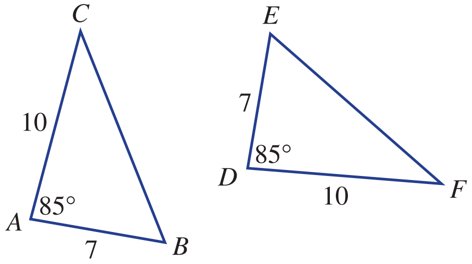

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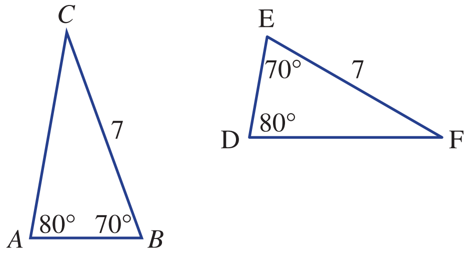

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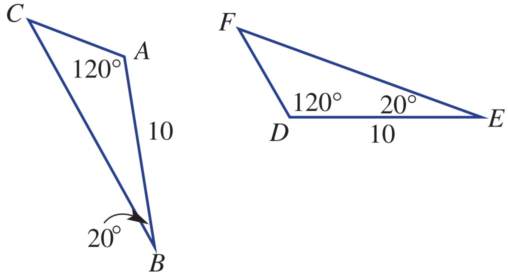

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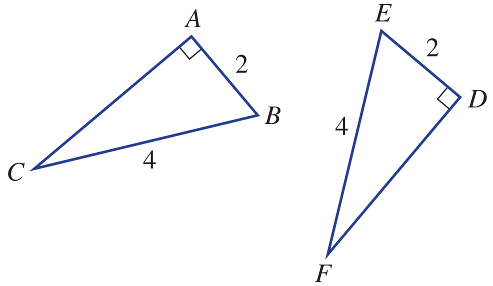

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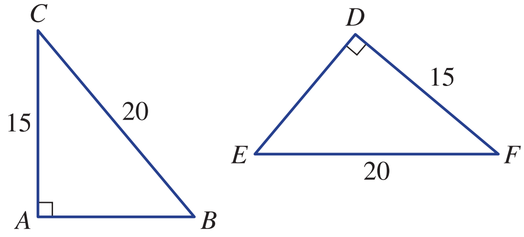

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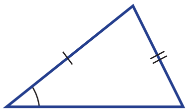
PROBLEM-SOLVING AND REASONING

6, 7 | 6, 7, 8(½), 9

6 Identify the pairs of congruent triangles from those below.

A



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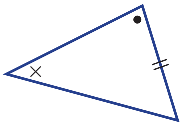

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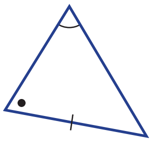

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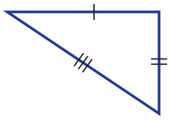

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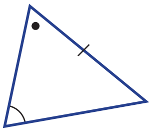

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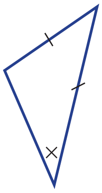

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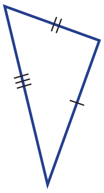

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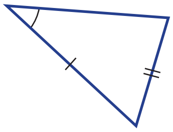
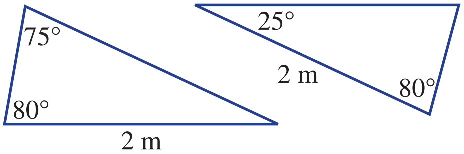


Sides with the same markings and angles with the same mark are equal.

7 Two triangular windows have the given dimensions.

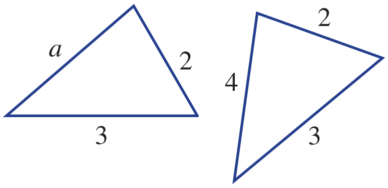
a Find the missing angle in each triangle.

b Are the two triangles congruent? Give a reason.



8 For the pairs of congruent triangles, find the values of the pronumerals.

a



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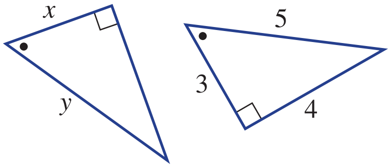

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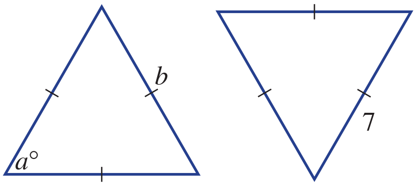

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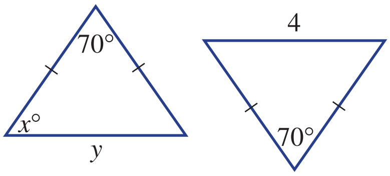

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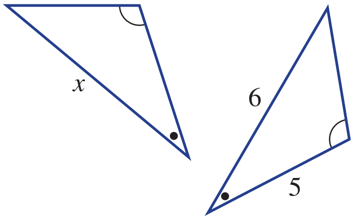

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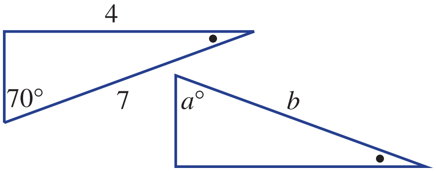

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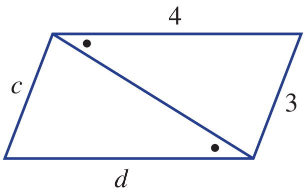

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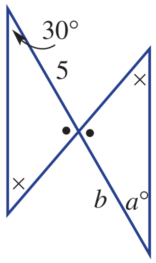
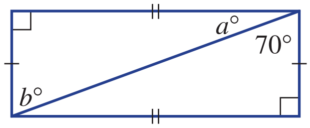


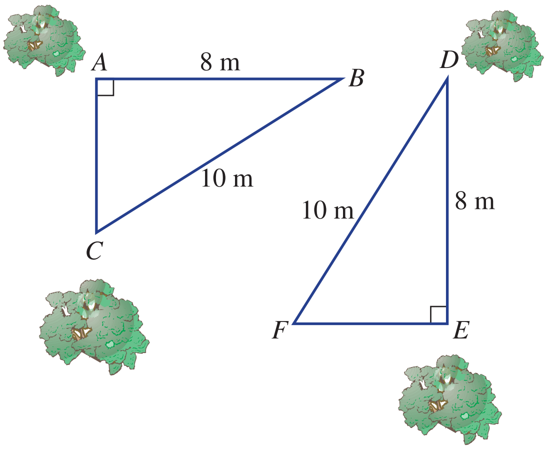
i



Given that these triangles are congruent, corresponding sides are equal, as are corresponding angles.

9 A new garden design includes two triangular lawn areas, as shown.

- **a** Prove that the two triangular lawn areas are congruent.
- **b** If the length of AC is 6 m, find the length of EF.
- **c** If the angle $ABC = 37°$, find these angles.
  - **i** $\angle EDF$
  - **ii** $\angle DFE$



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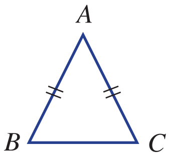
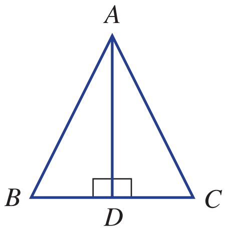
ENRICHMENT – 10–13

More challenging proofs

10 In ΔABC, $AB = AC$.



Complete the following proof to show that $\angle B = \angle C$.



Construct $AD \perp BC$.

In ΔABD and ΔACD,

$AB =$ ____ (given) (H)

$\angle ADB = \angle$____ $= 90°$ ($AD \perp BC$) (R)

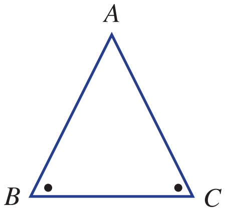
AD is common (S)

$\therefore \Delta$____ $\equiv \Delta$____ (RHS)

$\therefore \angle B = \angle C$ (matching angles in congruent triangles)

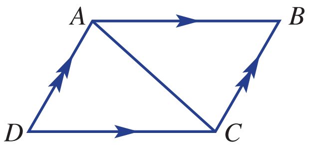
This proves that when two sides of an isosceles triangle are equal, then the angles opposite the equal sides are also equal.

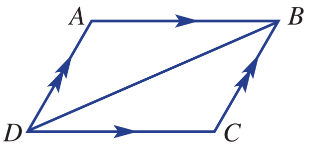
11 In ΔABC, $\angle ABC = \angle ACB$. Use congruent triangles to prove that $AB = AC$.



12 In ΔABC, $AB = AC = BC$. Prove that each angle in ΔABC is 60°.

13 Use these diagrams to prove that the opposite angles in a parallelogram are equal.





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7F Similar triangles

Interactive
Widgets
HOTsheets
Walkthrough

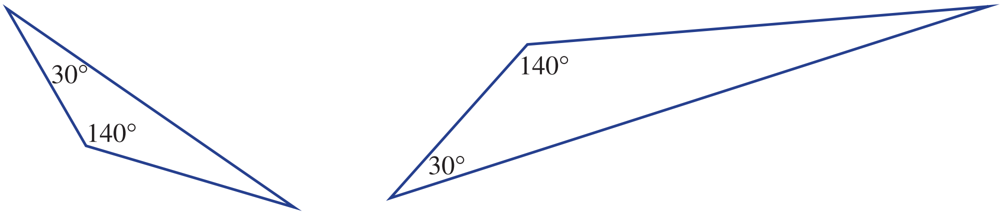
When two objects are similar, they are the same shape but of different size. For example, in the television department of an electronics store, the same image will often be shown on televisions with screens of many different sizes. The images on the screens are said to be similar figures.

Images that are reproduced on different sized screens are said to be similar figures because they are the same in all aspects except size.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Two pairs of matching angles

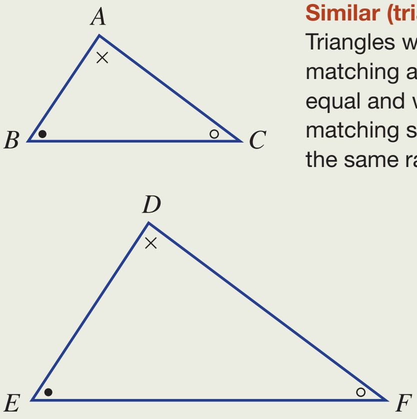
Look at these two triangles.



- What is the missing angle in each triangle?
- Do you think the triangles are similar? Why?
- When working with similar triangles, is it sufficient to have two pairs of matching angles?

Key ideas

- Two triangles are said to be **similar** if they are the same shape but not necessarily the same size. Matching angles will be equal and matching side lengths will be in the same ratio.
- If ΔABC is similar to ΔDEF, then we write $\Delta ABC \,|||\, \Delta DEF$.
- In congruence, abbreviations like SSS are acceptable. In similarity, these are generally not used.



Similar (triangles) Triangles whose matching angles are equal and whose matching sides are in the same ratio

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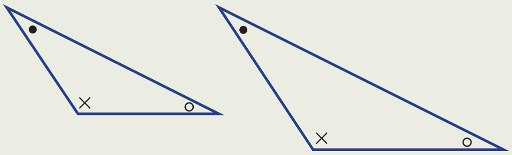
Key ideas

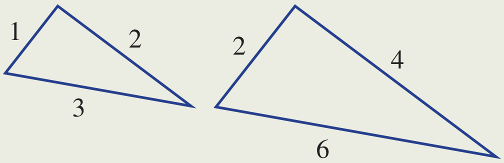
- Two triangles can be tested for similarity by considering the following necessary conditions.

  1 Two angles of a triangle are equal to two angles of another triangle.



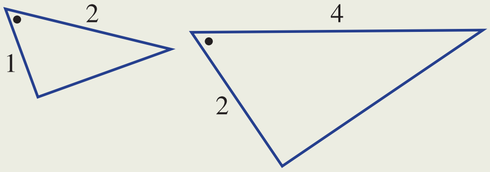
  2 Three sides of a triangle are proportional to three sides of another triangle.

  $$\frac{6}{3}=\frac{4}{2}=\frac{2}{1}=2$$



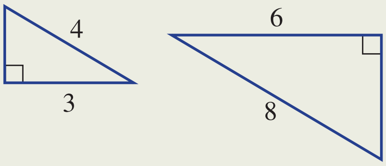
  3 Two sides of a triangle are proportional to two sides of another triangle and the included angles are equal.

  $$\frac{4}{2}=\frac{2}{1}=2$$



  4 The hypotenuse and a second side of a right-angled triangle are proportional to the hypotenuse and a second side of another right-angled triangle.

  $$\frac{8}{4}=\frac{6}{3}=2$$



- The **scale factor** is calculated using a pair of corresponding sides. In the three examples above (conditions **2**–**4**), the scale factor is 2.

Scale factor The number you multiply each side length by to enlarge or reduce a shape

Exercise 7F

UNDERSTANDING AND FLUENCY

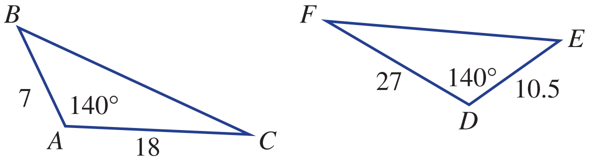
1–3, 4–5(½)

3, 4–5(½)

1 How many tests for similarity are there?

2 In the first test for similarity, why are only two pairs of equal angles needed? Why aren't all three angles needed?

3 Consider this pair of triangles.



a Work out $\frac{DE}{AB}$.

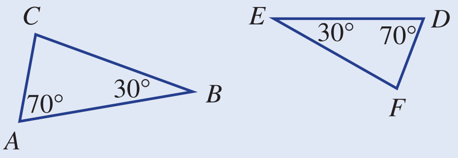
b Work out $\frac{DF}{AC}$. What do you notice?

c What is the scale factor?

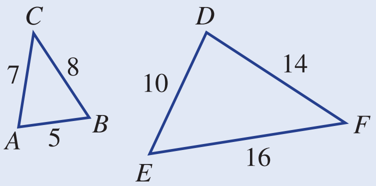
Example 12 Proving triangles are similar

Prove that the pairs of triangles are similar.

a



b



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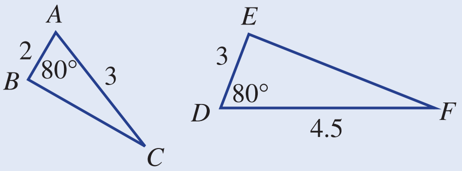

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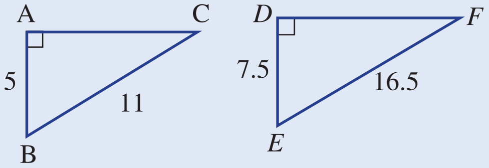


SOLUTION

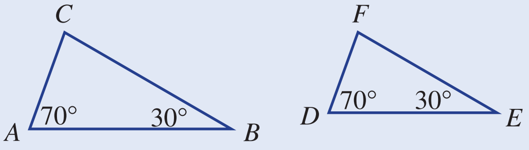
a $\angle BAC = \angle EDF$ (given)

$\angle ABC = \angle DEF$ (given)

$\therefore\ \Delta ABC \mathbin{|||} \Delta DEF$ (matching angles are equal)

EXPLANATION

Two angles of one triangle are equal to two angles of another triangle.



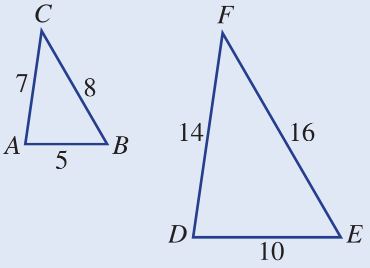
b $\dfrac{DE}{AB} = \dfrac{10}{5} = 2$

$\dfrac{EF}{BC} = \dfrac{16}{8} = 2$

$\dfrac{DF}{AC} = \dfrac{14}{7} = 2$

$\therefore\ \Delta ABC \mathbin{|||} \Delta DEF$ (matching sides are in proportion)

Three sides of one triangle are proportional to three sides of another triangle.



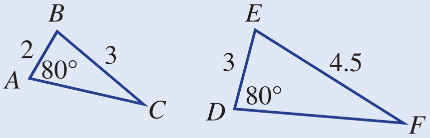
c $\dfrac{DE}{AB} = \dfrac{3}{2} = 1.5$

$\angle BAC = \angle EDF$ (given)

$\dfrac{DF}{AC} = \dfrac{4.5}{3} = 1.5$

$\therefore\ \Delta ABC \mathbin{|||} \Delta DEF$ (sides about equal angles are in proportion)

Two sides of one triangle are proportional to two sides of another and the included angles are equal.



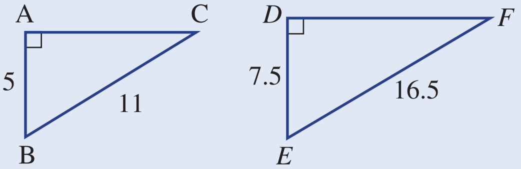
d $\angle BAC = \angle EDF = 90°$ (given)

$\dfrac{EF}{BC} = \dfrac{16.5}{11} = 1.5$

$\dfrac{DE}{AB} = \dfrac{7.5}{5} = 1.5$

$\therefore\ \Delta ABC \mathbin{|||} \Delta DEF$ (hypotenuse and a second side are in proportion)

The hypotenuse and a second side of one right-angled triangle are proportional to the hypotenuse and a second side of another right-angled triangle.



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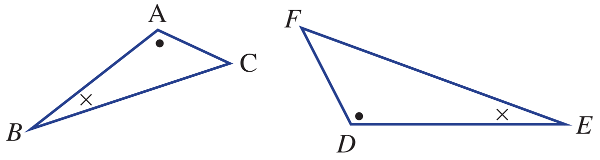
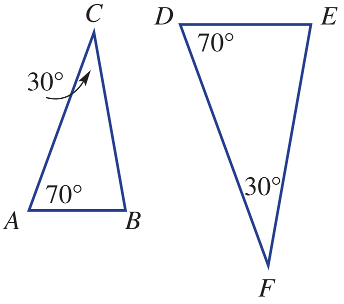
4 Decide whether the pairs of triangles are similar. For those that are, explain why.

a



List all the equal angles and corresponding pairs of sides, as in Example 12.

b



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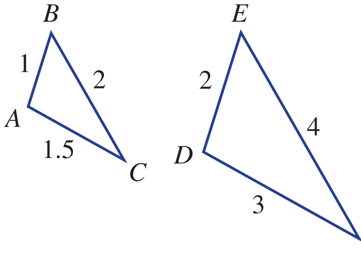

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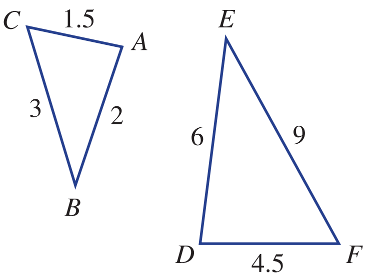

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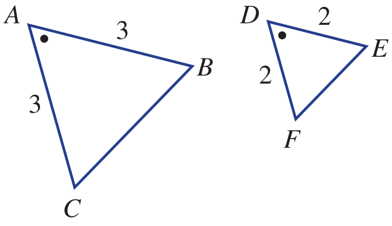

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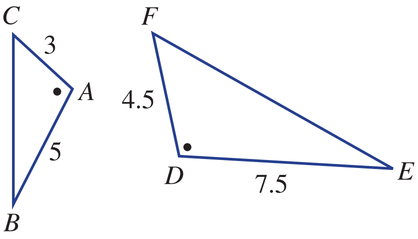

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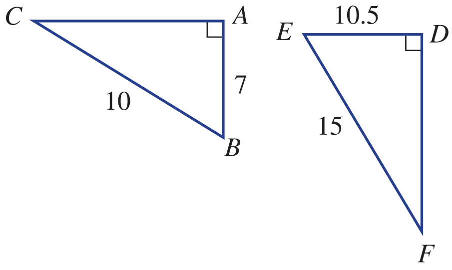

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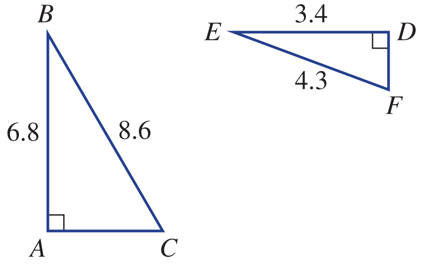

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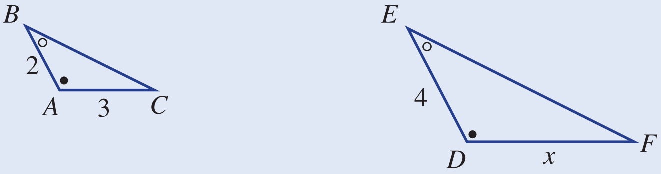
Example 13 Using similarity to find unknown values

If the given triangles are known to be similar, find the value of x.



SOLUTION

Scale factor $= \dfrac{DE}{AB} = \dfrac{4}{2} = 2$

$\therefore x = 3 \times 2$

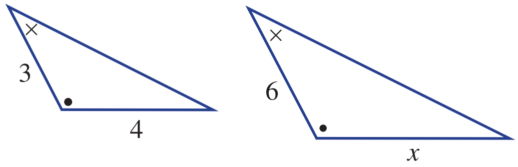
$= 6$

EXPLANATION

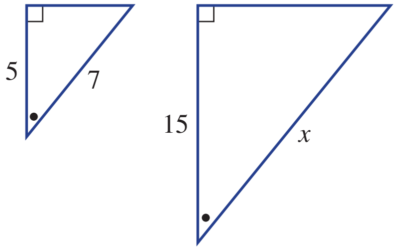
First, find the scale factor using a pair of corresponding sides.
Divide the larger number by the smaller number.
Multiply the corresponding length of the smaller triangle using the scale factor.

5 If the given pairs of triangles are known to be similar, find the value of x.

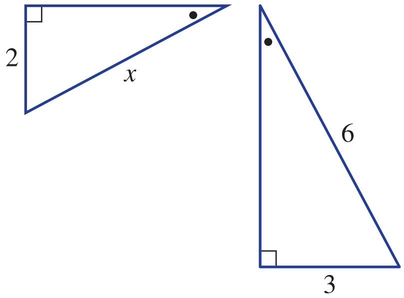
a



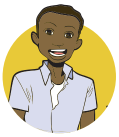
b



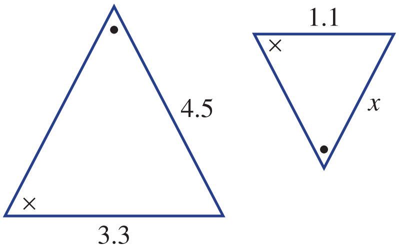
c



For parts **c** and **d**, use division to find x.



d



PROBLEM-SOLVING AND REASONING

6 | 6, 7

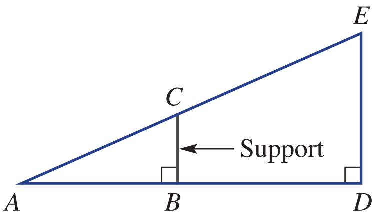
6 A ski ramp has a vertical support, as shown.

a List the two triangles that are similar.

b Why are the two triangles similar?

c If $AB = 4$ m and $AD = 10$ m, find the scale factor.

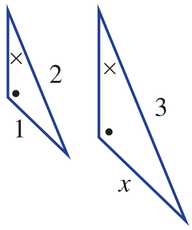
d If $BC = 1.5$ m, find the height of the ramp DE.



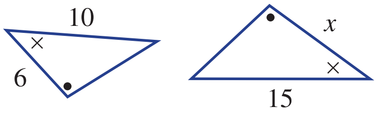
List triangles like this: ΔSTU.

7 The pairs of triangles are similar. Determine the value of x in each case.

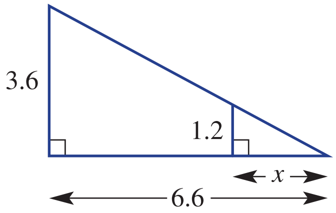
a



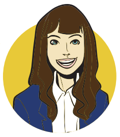
b



c



They all have the same reason.



ENRICHMENT

– | 8

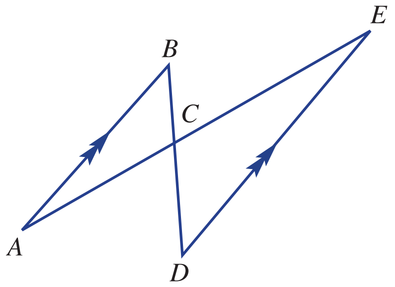
Triangles in parallel lines

8 In the given diagram, AB is parallel to DE.

a List the three pairs of angles that are equal and give a reason.

b If $AB = 8$ cm and $DE = 12$ cm, find:

- **i** DC if $BC = 4$ cm
- **ii** AC if $EC = 9$ cm



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7G Applying similar triangles

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Once it is established that two triangles for a particular situation are similar, the ratio or scale factor between side lengths can be used to find unknown side lengths.

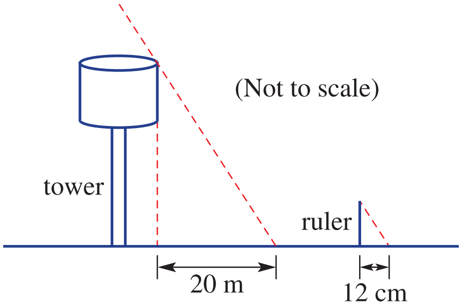
Similar triangles have many applications in the real world. One application is finding an inaccessible distance, like the height of a tall object or the distance across a deep gorge.

The distance across this gorge can be found without having to actually measure it physically.

Let's start: The tower and the ruler

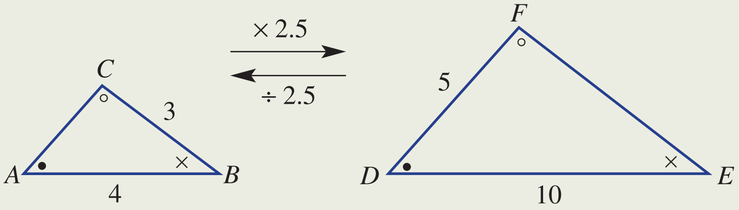
Franklin wants to know how tall a water tower is in his town. At a particular time of day, he measures its shadow to be 20 m long. At the same time, he stands a 30 cm ruler near the tower, which gives a 12 cm shadow.

- Explain why the two formed triangles are similar.
- What is the scale factor?
- What is the height of the tower?



Key ideas

- For two similar triangles, the ratio of the corresponding side lengths written as a single number is called the **scale factor**.
- Once the scale factor is known, it can be used to find unknown side lengths.
  For example:



$$\frac{DE}{AB} = \frac{10}{4} = \frac{5}{2} = 2.5$$

$\therefore$ Scale factor is 2.5.

$\therefore EF = 3 \times 2.5 = 7.5$

$AC = 5 \div 2.5 = 2$

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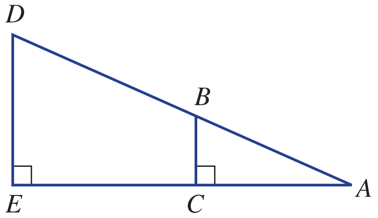
Exercise 7G

UNDERSTANDING AND FLUENCY

1–4 2–5

1 Give reasons why the pairs of triangles in each diagram are similar.

a



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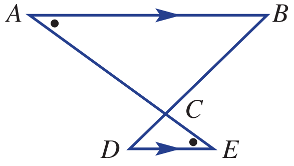
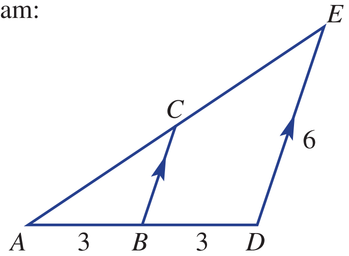
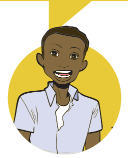


2 For the pair of triangles in the given diagram:
- **a** Explain why they are similar.
- **b** Find the scale factor.
- **c** Find the length *BC*.

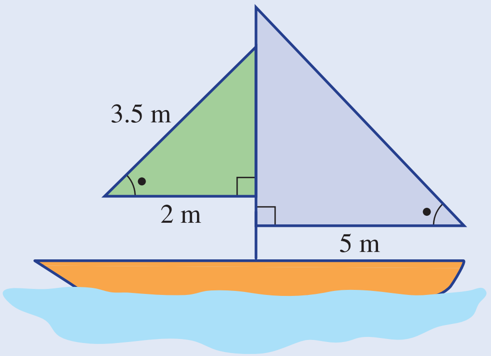


Compare *AB* and *AD* for the scale factor.



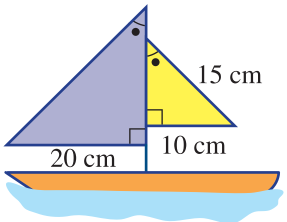
Example 14 Applying similar triangles

A homemade raft consists of two sails with measurements and angles as shown in this diagram.
- **a** Explain why the two sails are similar in shape.
- **b** Find the scale factor for the side lengths of the sails.
- **c** Find the length of the longest side of the large sail.



SOLUTION	EXPLANATION
a Two pairs of angles are equal.	Two of the three angles are clearly equal, so the third must be equal.
b $\text{Scale factor} = \frac{5}{2} = 2.5$	Choose two corresponding sides with known lengths and divide the larger by the smaller.
c $\text{Longest side} = 3.5 \times 2.5$ $= 8.75 \text{ m}$	Multiply the corresponding side on the smaller triangle by the scale factor.

3 A toy yacht consists of two sails with measurements and angles as shown in this diagram.
- **a** Explain why the two sails are similar in shape.
- **b** Find the scale factor for the side lengths of the sails.
- **c** Find the length of the longest side of the large sail.



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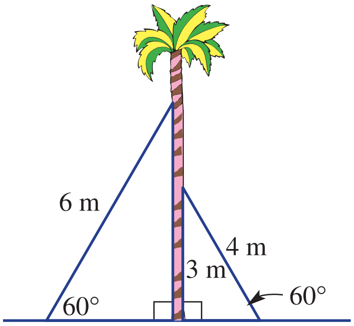
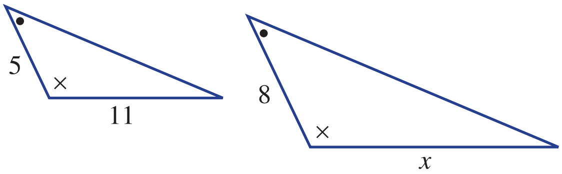
4 A tall palm tree is held in place with two cables of length 6 m and 4 m, as shown.



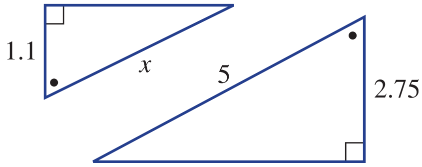
a Explain why the two triangles created by the cables are similar in shape.
b Find the scale factor for the side lengths of the cables.
c Find the height of the point above the ground where the longer cable is attached to the palm tree.

5 These pairs of triangles are known to be similar. By finding the scale factor, find the value of x.

a



b

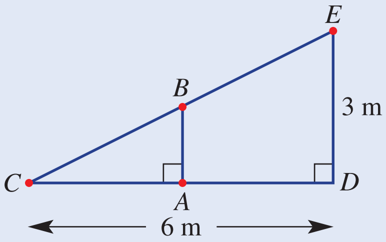


PROBLEM-SOLVING AND REASONING	6–8	7–10

Example 15 Working with combined triangles

A ramp is supported by a vertical stud, AB, where A is at the centre of CD. It is known that $CD = 6$ m and that the ramp is 3 m high.

a Using the letters given, name the two triangles that are similar and explain why.
b Find the length of the stud AB.



SOLUTION	EXPLANATION
a ΔABC and ΔDEC $\angle C$ is common and $\angle CAB = \angle CDE$	The angle at C is common to both triangles and they both have a right angle.
b $AC = 3$ m	Since A is in the centre of CD, then AC is half of CD.
$\text{Scale factor} = \frac{6}{3} = 2$	$CD = 6$ m and $AC = 3$ m
$\therefore AB = 3 \div 2$ $= 1.5$ m	Divide the larger side length, DE, by the scale factor.

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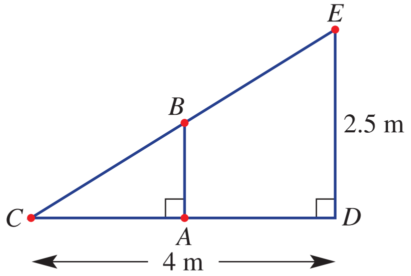
6 A ramp is supported by a vertical stud AB, where A is at the centre of CD. It is known that $CD = 4$ m and that the ramp is 2.5 m high.

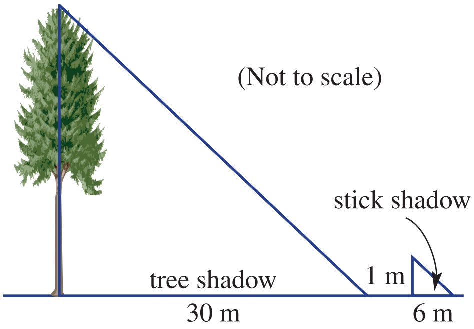


a Using the letters given, name the two triangles that are similar and explain why.
b Find the length of the stud AB.

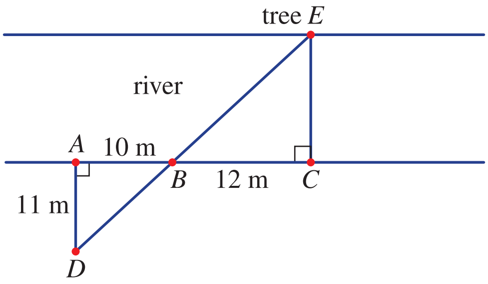
7 A 1 m vertical stick and a tree cast their shadows at a particular time in the day. The shadow lengths are shown in this diagram.

a Explain why the two triangles shown are similar in shape.
b Find the scale factor for the side lengths of the triangles.
c Find the height of the tree.

At the same time of day, the angle that the light makes with the ground will be the same.



8 From a place on the river (C), a tree (E) is spotted on the opposite bank. The distances between selected trees A, B, C and D are measured as shown.



AB corresponds to *CB* and *AD* corresponds to *CE*.

a List two similar triangles and explain why they are similar.
b Find the scale factor.
c Find the width of the river.

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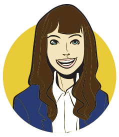
9 At a particular time of day, Aaron casts a shadow 1.3 m long whereas Jack, who is 1.75 m tall, casts a shadow 1.2 m long. Find the height of Aaron, to 2 decimal places.

Draw a diagram to find the scale factor.



10 Try this activity with a partner but ensure that at least one person knows their height.

a Go out into the sun and measure the length of each person's shadow.

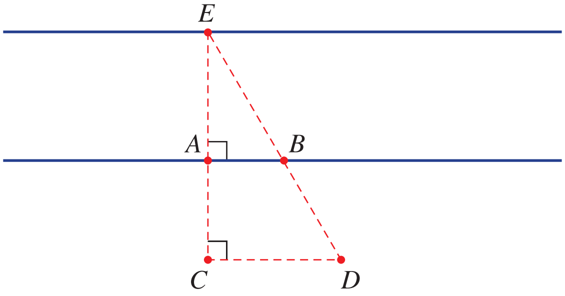
b Use these measurements plus the known height of one person to find the height of the other person.

ENRICHMENT		–	11

Gorge challenge

11 Mandy sets up a series of rocks alongside a straight section of a deep gorge. She places rocks A, B, C and D as shown. Rock E sits naturally on the other side of the gorge. She then measures the following distances.

- $AB = 10$ m
- $AC = 10$ m
- $CD = 15$ m



a Explain why $\Delta ABE \parallel\!\mid \Delta CDE$.

b What is the scale factor?

c Use trial and error to find the distance across the gorge from rocks A to E.

d Can you instead find the length AE by setting up an equation?

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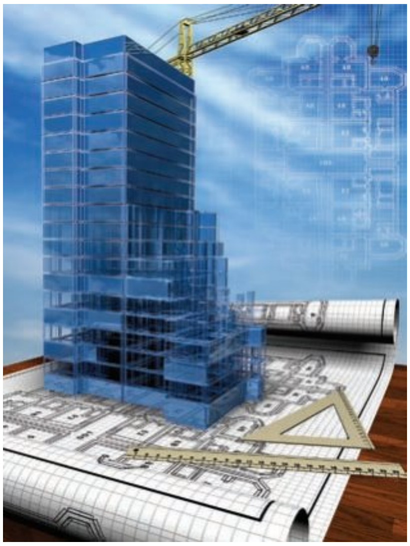
7H Applications of similarity in measurement EXTENSION

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

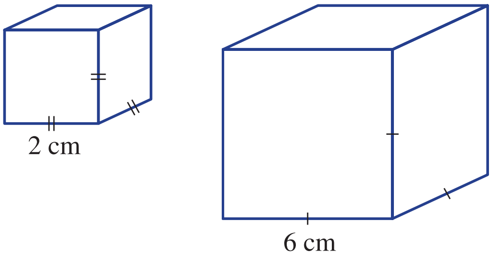
Shapes or objects that are similar have a distinct length, area and volume ratio relationship.

For example, if the lengths on a model of a building are one-hundredth of the actual structure, then the length ratio is 1 : 100. From this, the surface area and volume ratios are $1^2 : 100^2$ (1 : 10 000) and $1^3 : 100^3$ (1 : 1 000 000), respectively. These ratios can be used to calculate the amount of material that is needed for the construction of the building.



Let's start: Cube analysis

These two cubes have side lengths of 2 cm and 6 cm, respectively.



- What is the side length ratio when comparing the two cubes?
- What are the surface areas of the two cubes?
- What is the surface area ratio? What do you notice?
- What are the volumes of the two cubes?
- What is the volume ratio? What do you notice?

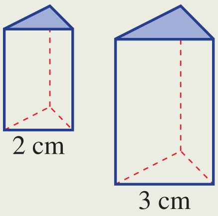
Key ideas

■ If two objects are similar and have a length ratio of $a : b$, then:

- Length ratio $= a : b$ Scale factor $= \frac{b}{a}$
- Area ratio $= a^2 : b^2$ Scale factor $= \frac{b^2}{a^2}$
- Volume ratio $= a^3 : b^3$ Scale factor $= \frac{b^3}{a^3}$

For example:

- One dimension: length ratio $= 2^1 : 3^1 = 2 : 3$
- Two dimensions: area ratio $= 2^2 : 3^2 = 4 : 9$
- Three dimensions: volume ratio $= 2^3 : 3^3 = 8 : 27$



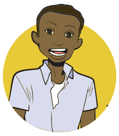
Exercise 7H EXTENSION

UNDERSTANDING AND FLUENCY	1–3, 5, 7	2–6, 8

1 The length ratio for two objects is 2 : 3.

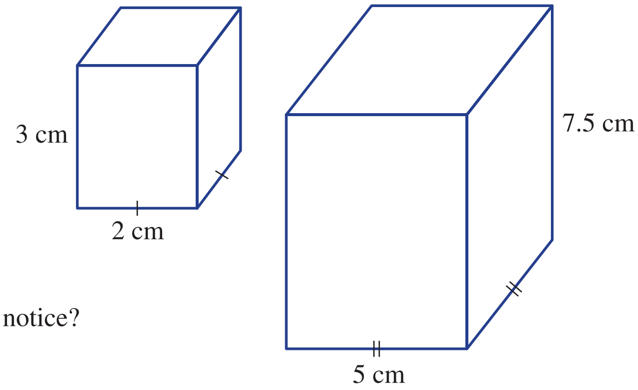
- **a** What would be the area ratio?
- **b** What would be the volume ratio?

Length ratio = $a : b$
Area ratio = $a^2 : b^2$
Volume ratio = $a^3 : b^3$



2 These two rectangular prisms are similar.

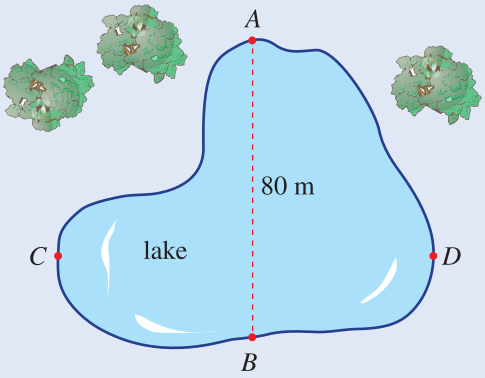
- **a** What is the side length ratio?
- **b** What is the surface area of the two prisms?
- **c** What is the surface area ratio? What do you notice?
- **d** What are the volumes of the two prisms?
- **e** What is the volume ratio? What do you notice?



Example 16 Measuring to find actual lengths

The given diagram is a simple map of a park lake.

- **a** Use a ruler to measure the distance across the lake (AB). (Answer in cm.)
- **b** Find the scale factor between the map and ground distance.
- **c** Use a ruler to measure the map distance across the lake (CD). (Answer in cm.)
- **d** Use your scale factor to find the real distance across the lake (CD). (Answer in m.)



SOLUTION	EXPLANATION
a 4 cm	Check with your ruler.
b $\frac{8000}{4} = 2000$	Using the same units, divide the real distance (80 m = 8000 cm) by the measured distance (4 cm).
c 5 cm	Check with your ruler.
d $5 \times 2000 = 10\,000 \text{ cm} = 100 \text{ m}$	Multiply the measured distance by the scale factor and convert to metres by dividing by 100.

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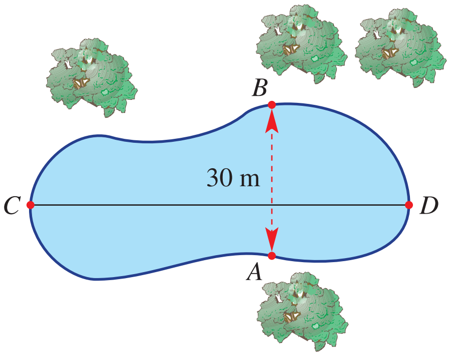
3 The given diagram is a simple map of a park lake.

a Use a ruler to measure the distance across the lake (*AB*). (Answer in cm.)

b Find the scale factor between the map and ground distance.

c Use a ruler to find the map distance across the lake (*CD*). (Answer in cm.)

d Use your scale factor to find the real distance across the lake (*CD*). (Answer in m.)



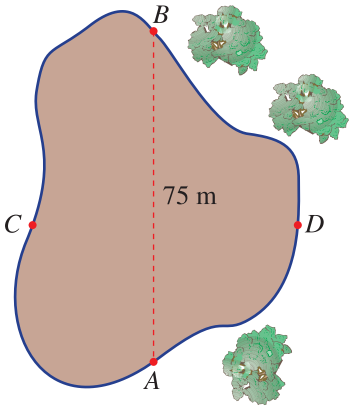
4 The given diagram is a simple map of a children's play area.

a Use a ruler to measure the distance across the children's play area (*AB*). (Answer in cm.)

b Find the scale factor between the map and ground distance.

c Use a ruler to find the map distance across the children's play area (*CD*). (Answer in cm.)

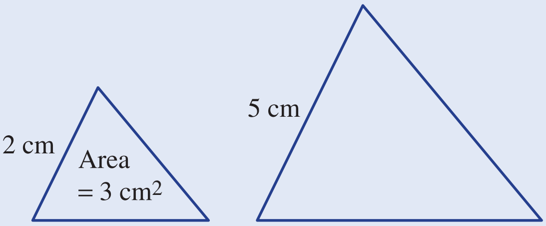
d Use your scale factor to find the real distance across the children's play area (*CD*). (Answer in m.)



Use the measured distance *AB* and the actual distance *AB* to find the scale factor.

Example 17 Using similarity to find areas

The two given triangles are known to be similar.
Find the area of the larger triangle.



SOLUTION

Length ratio $= 2^1 : 5^1 = 2 : 5$

Area ratio $= 2^2 : 5^2 = 4 : 25$

Area scale factor $= \dfrac{25}{4} = 6.25$

$\therefore$ Area of larger triangle $= 3 \times 6.25$
$= 18.75 \text{ cm}^2$

EXPLANATION

First, write the length ratio.

Square each number in the length ratio to get the area ratio.

Divide the two numbers in the area ratio to get the scale factor.

Multiply the area of the smaller triangle by the scale factor.

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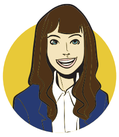
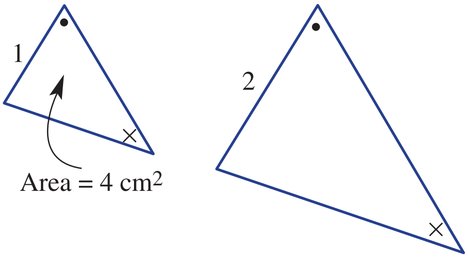
5 The two given triangles are known to be similar. Find the area of the larger triangle.

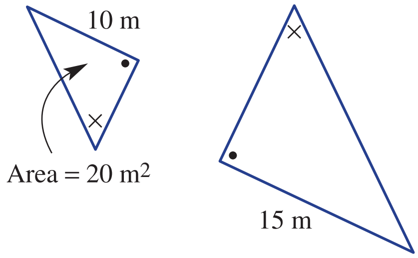
Length ratio $= a : b$
Area ratio $= a^2 : b^2$
Area scale factor $= \frac{b^2}{a^2}$



a



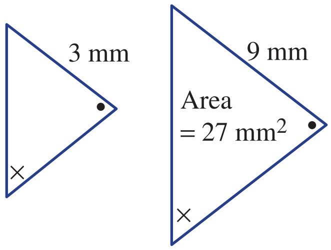
b



6 The two given triangles are known to be similar. Find the area of the smaller triangle.

You will need to divide the larger area by the area scale factor.

a



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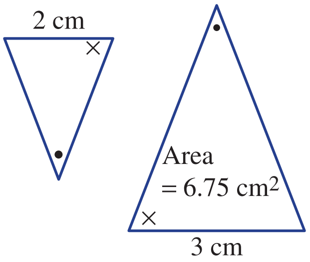
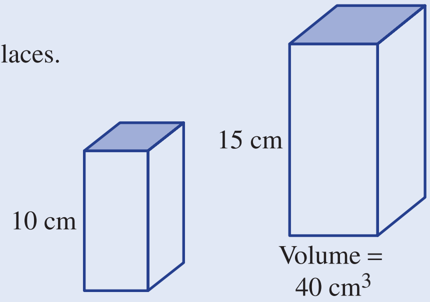


Example 18 Using similarity to find volume

The two given prisms are known to be similar.
Find the volume of the smaller prism, correct to 2 decimal places.



SOLUTION	EXPLANATION
Length ratio $= 10^1 : 15^1 = 2 : 3$	First, write the length ratio and simplify.
Volume ratio $= 2^3 : 3^3 = 8 : 27$	Cube each number in the length ratio to get the volume ratio.
Volume scale factor $= \frac{27}{8} = 3.375$	Divide the two numbers in the volume ratio to get the scale factor.
$\therefore$ Volume of smaller prism $= 40 \div 3.375$ $= 11.85$ cm^3	Divide the volume of the larger prism by the scale factor and round as required.

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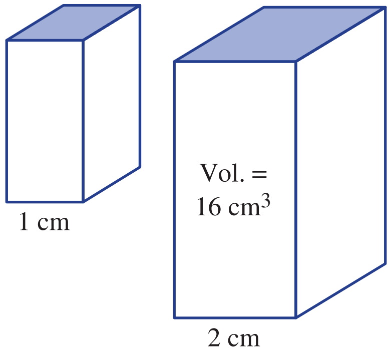
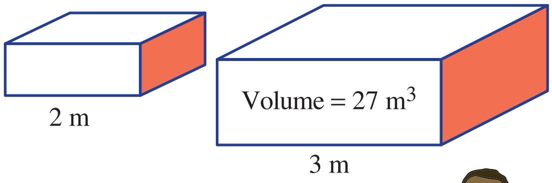
7 The two given prisms are known to be similar. Find the volume of the smaller prism, correct to 2 decimal places.

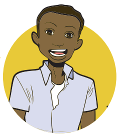
a



b

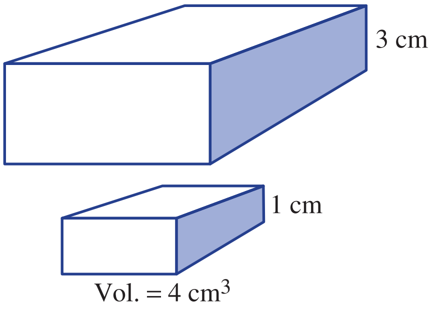


Volume scale factor = $\frac{b^3}{a^3}$ if the length ratio is $a : b$.

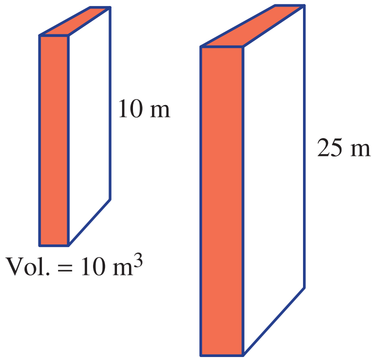


8 The two given prisms are known to be similar. Find the volume of the larger prism.

a



b



PROBLEM-SOLVING AND REASONING		9, 10	10–12

9 The given map has a scale factor of 50000 (ratio 1 : 50000).

a How far on the ground, in km, is represented by these map distances?

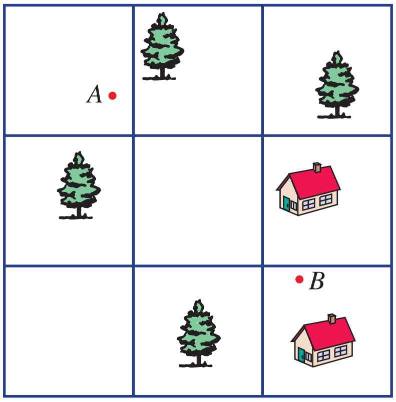
- **i** 2 cm
- **ii** 6 cm

b How far on the map, in cm, is represented by these ground distances?

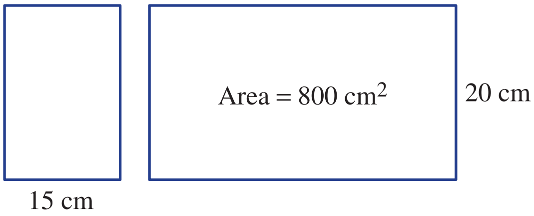
- **i** 5 km
- **ii** 0.5 km

c What is the actual ground distance between the two points A and B? Use your ruler to measure first the distance between A and B.

1 m = 100 cm
1 km = 1000 m



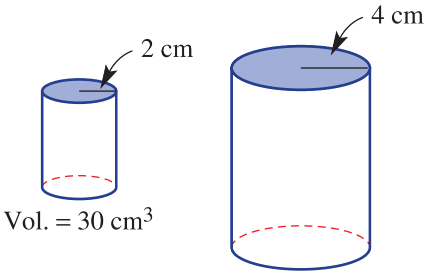
10 Two pieces of paper are similar in shape, as shown.



a What is:
  i the length ratio?
  ii the area ratio?

b Find the area of the smaller piece of paper.

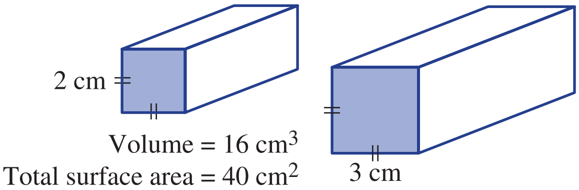
11 Two cylinders are similar in shape, as shown.



a Find the volume ratio.

b Find the volume of the larger cylinder.

12 Two rectangular prisms are known to be similar.



a Find the following ratios.
  i length
  ii area
  iii volume

b Find the total surface area of the larger prism.

c Find the volume of the larger prism.

ENRICHMENT	–	13

Skyscraper model

13 A scale model of a skyscraper is 1 m tall and the volume is 2 m^3. The actual height of the skyscraper is 300 m tall.

a Find the volume ratio between the model and actual skyscraper.

b Find the volume of the actual skyscraper.

c If the area of a window on the model is 1 cm^2, find the area of the actual window in m^2.

$$1\text{m}^2 = 100 \times 100$$
$$= 10000 \text{ cm}^2$$

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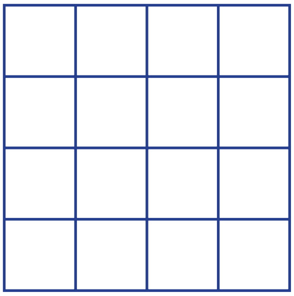
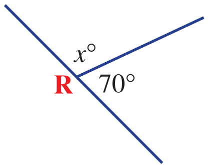
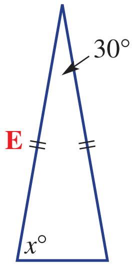
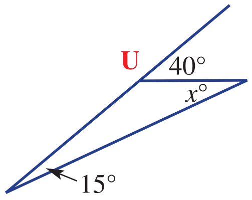
1 How many squares can you see in this diagram?

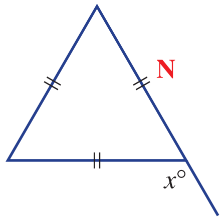


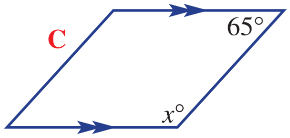
2 'I think of this when I look in the mirror.' Find the value of x in each diagram, then match the letters beside the diagrams to the answers below.

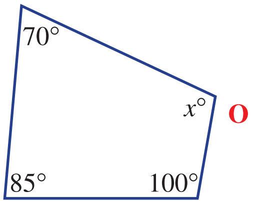


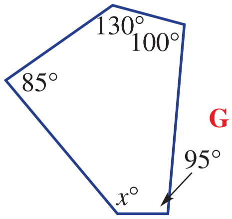






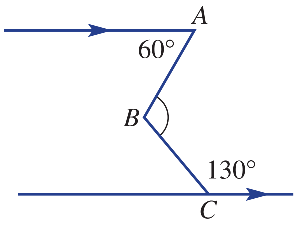






115 105 120 130 110 25 75 120 115 75

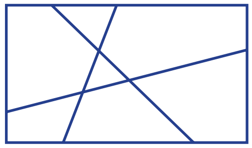
3 What is the size of the acute angle $\angle ABC$ in this diagram?



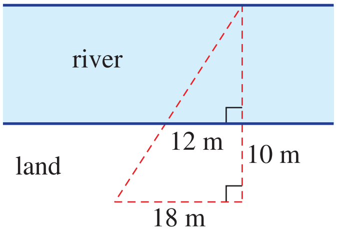
4 This rectangle is subdivided by three straight lines.

a How many regions are formed?

b What is the maximum number of regions formed if four lines are used instead of three?



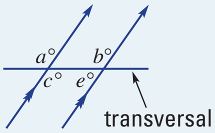
5 Find the distance across the river.



Chapter summary

Properties of geometrical figures

Parallel lines



$a = b$ corresponding
$b = c$ alternate
$c + e = 180$ co-interior
$a = c$ vertically opposite

Congruent triangles

Equal in size and shape

Tests: SSS, SAS, AAS, RHS

A congruence statement:
$\Delta ABC \equiv \Delta DEF$

Similar triangles

Equal in shape and sides are in proportion

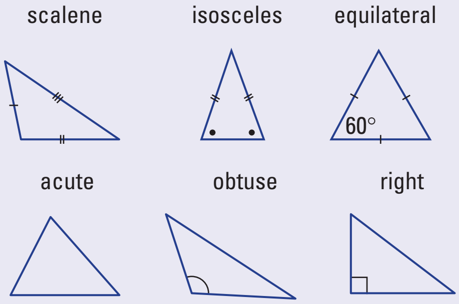
There are four tests of similarity.

1 Two angles of a triangle equal two angles in another triangle.
2 Three sides of a triangle are proportional to three sides of another triangle.
3 Two sides of a triangle are proportional to two sides of another triangle and the included angles are equal.
4 The hypotenuse and another side of a right-angled triangle are proportional to the hypotenuse and a second side of another right-angled triangle.

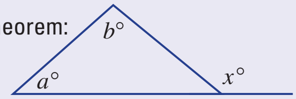
A similarity statement:
$\Delta ABC \mathbin{|||} \Delta DEF$

Triangles

Angle sum = 180°



Exterior angle theorem:
$x = a + b$



Quadrilaterals

Angle sum = 360°

Special types include:
- parallelogram
- square
- rectangle
- rhombus
- kite
- trapezium

Polygons

Interior angle sum $S = (n - 2) \times 180$
Exterior angle sum = 360°

Regular polygons have:
- equal side lengths
- equal angles

Applications of similarity

If $\Delta ABC \mathbin{|||} \Delta DEF$ then:
- Scale factor $= \frac{DE}{AB}$ or $\frac{DF}{AC}$ or $\frac{EF}{BC}$
- Length ratio $a : b$, Scale factor $= \frac{b}{a}$
- Area ratio $a^2 : b^2$, Scale factor $= \frac{b^2}{a^2}$
- Volume ratio $a^3 : b^3$, Scale factor $= \frac{b^3}{a^3}$

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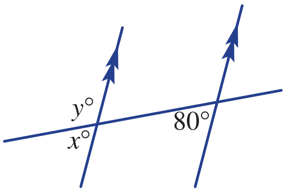
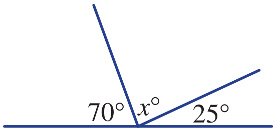
Multiple-choice questions

1 The values of x and y in the diagram are:



A 100, 100 **B** 80, 100 **C** 80, 80 **D** 60, 120 **E** 80, 60

2 The unknown value x in this diagram is:

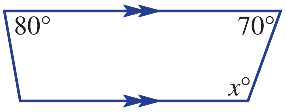


A 85 **B** 105 **C** 75 **D** 80 **E** 90

3 A triangle has one angle of 60° and another angle of 70°. The third angle is:

A 60° **B** 30° **C** 40° **D** 50° **E** 70°

4 The value of x in this quadrilateral is:



A 130 **B** 90 **C** 100 **D** 120 **E** 110

5 The sum of the interior angles of a hexagon is:

A 180° **B** 900° **C** 360° **D** 540° **E** 720°

6 Which abbreviated reason is not relevant for proving congruent triangles?

A AAS **B** RHS **C** SSS **D** AAA **E** SAS

7 Two similar triangles have a length ratio of 2 : 3. If one side on the smaller triangle is 5 cm, the length of the corresponding side on the larger triangle is:

A 3 cm **B** 7.5 cm **C** 9 cm **D** 8 cm **E** 6 cm

8 A stick of length 2 metres and a tree of unknown height stand vertically in the sun. The shadow lengths cast by each are 1.5 m and 30 m, respectively. The height of the tree is:

A 40 m **B** 30 m **C** 15 m **D** 20 m **E** 60 m

9 Two similar triangles have a length ratio of 1 : 3 and the area of the large triangle is 27 cm^2. The area of the smaller triangle is:

A 12 cm^2 **B** 1 cm^2 **C** 3 cm^2 **D** 9 cm^2 **E** 27 cm^2

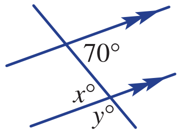
10 Two similar prisms have a length ratio of 2 : 3. The volume ratio is:

A 4 : 9 **B** 8 : 27 **C** 2 : 27 **D** 2 : 9 **E** 4 : 27

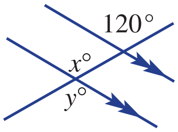
Short-answer questions

1 Find the value of x and y in these diagrams.

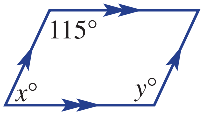
a



b



c



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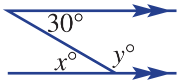
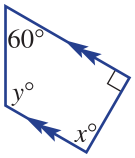


e



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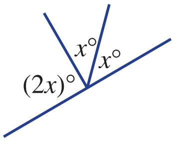
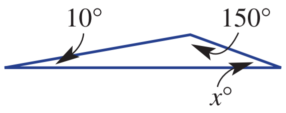


2 Find the value of x in these triangles.

a



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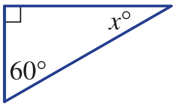

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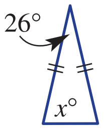

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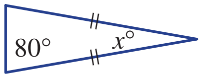

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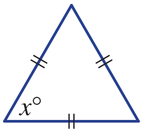

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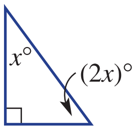

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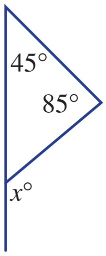

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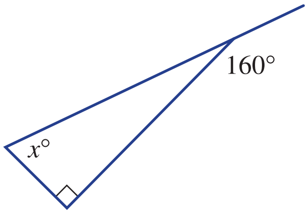

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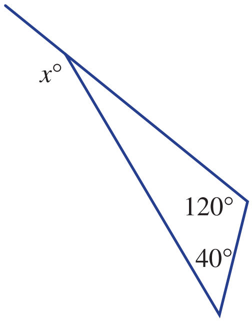


3 Which of the special quadrilaterals have:

a two pairs of parallel lines?

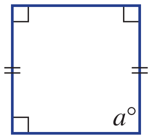
b opposite angles equal?

c one pair of equal angles?

d diagonals intersecting at right angles?

4 Find the values of the pronumerals in these quadrilaterals.

a



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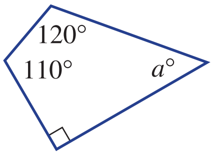
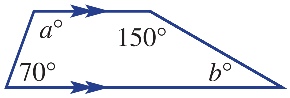


c



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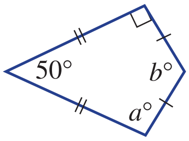

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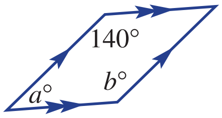

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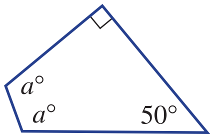
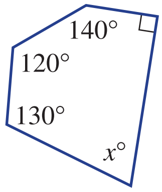


5 Find the value of x by first finding the angle sum. Use $S = (n - 2) \times 180$.

a



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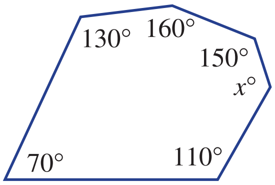

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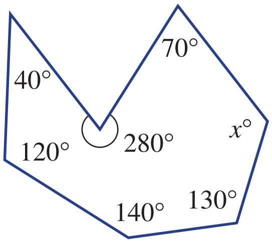
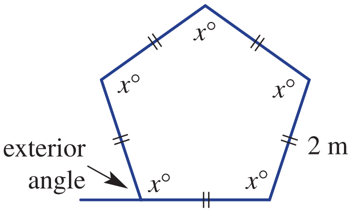


6 Shown here is an example of a regular pentagon with side lengths of 2 m. Find:



a the perimeter of the pentagon

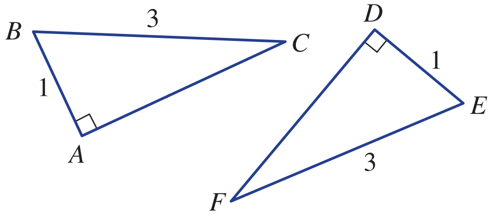
b the total interior angle sum (S)

c the size of each interior angle ($x°$)

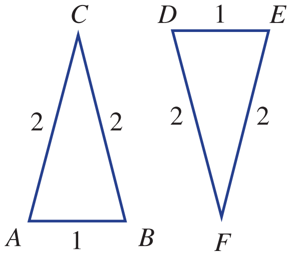
d the size of each exterior angle

7 Prove that the following pairs of triangles are congruent.

a



b



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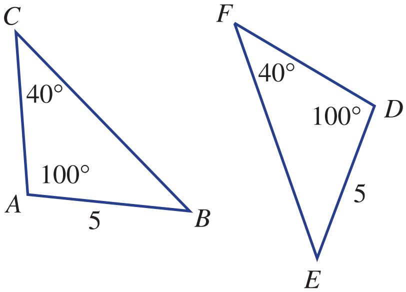

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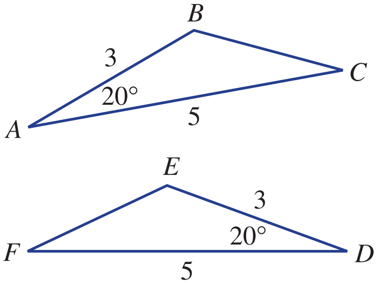
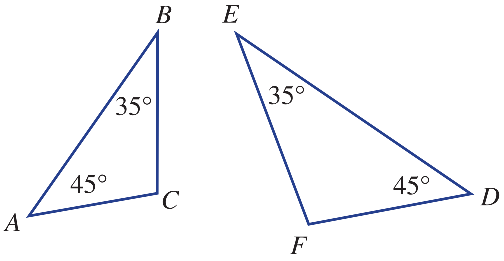


8 Show that the given pairs of triangles are similar.

a



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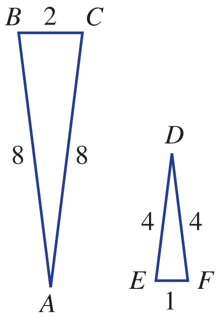

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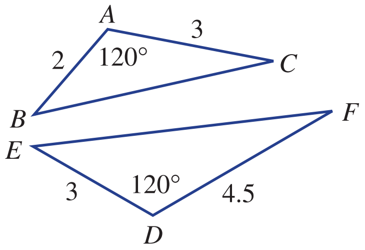
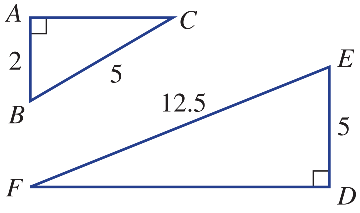


d



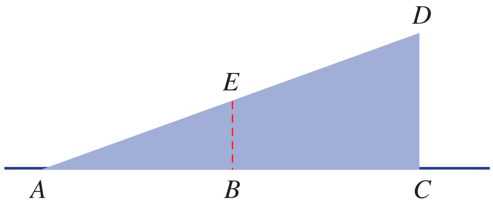
9 A skateboard ramp is supported by two vertical struts, *BE* (2 m) and *CD* (5 m).

a Name two triangles that are similar, using the letters *A*, *B*, *C*, *D* and *E*.

b Explain why the triangles are similar.

c Find the scale factor from the smallest to the largest triangle.

d If the length *AB* is 3 m, find the horizontal length of the ramp *AC*.

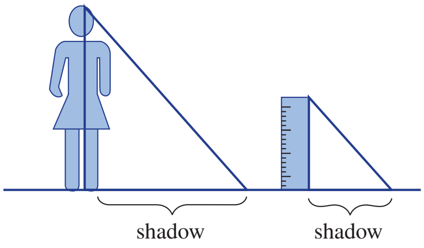


10 The shadow of Mei standing in the sun is 1.5 m long, and the shadow of a 30 cm ruler is 24 cm.

a Explain why the two created triangles are similar.

b Find the scale factor between the two triangles.

c How tall is Mei?



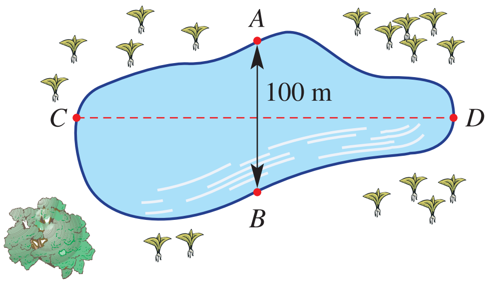
11 The given diagram is a simple map of a swamp in bushland.

a Use a ruler to measure the distance across the swamp (*AB*). (Answer in cm.)

b Find the scale factor between the map and ground distance.

c Use a ruler to find the map distance across the swamp (*CD*). (Answer in cm.)

d Use your scale factor to find the real distance across the lake (*CD*). (Answer in m.)



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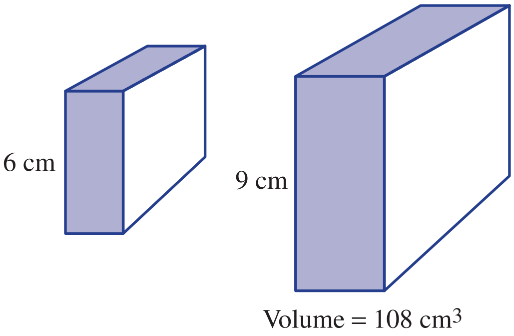
12 Two rectangular prisms are known to be similar.

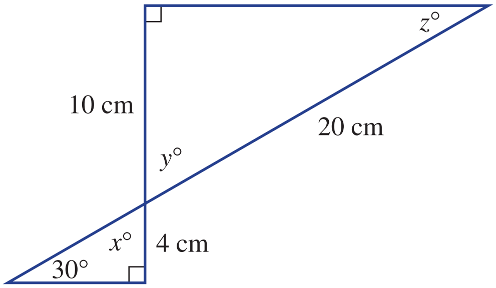
- **a** Find the:
  - **i** length ratio
  - **ii** area ratio
  - **iii** volume ratio
- **b** Find the volume of the smaller prism.



Extended-response questions

1 A company logo contains two triangles, as shown.

- **a** Write down the value of x, y and z.
- **b** Explain why the two triangles are similar.
- **c** Write down the scale factor for length.
- **d** Find the length of the longest side of the smaller triangle.
- **e** Write down the area ratio of the two triangles.
- **f** Write down the area scale factor of the two triangles.



2 A toy model of a car is 8 cm long and the actual car is 5 m long.

- **a** Write down the length ratio of the toy car to the actual car.
- **b** If the toy car is 4.5 cm wide, what is the width of the actual car?
- **c** What is the surface area ratio?
- **d** If the actual car needs 5 litres of paint, what amount of paint would be needed for the toy car?

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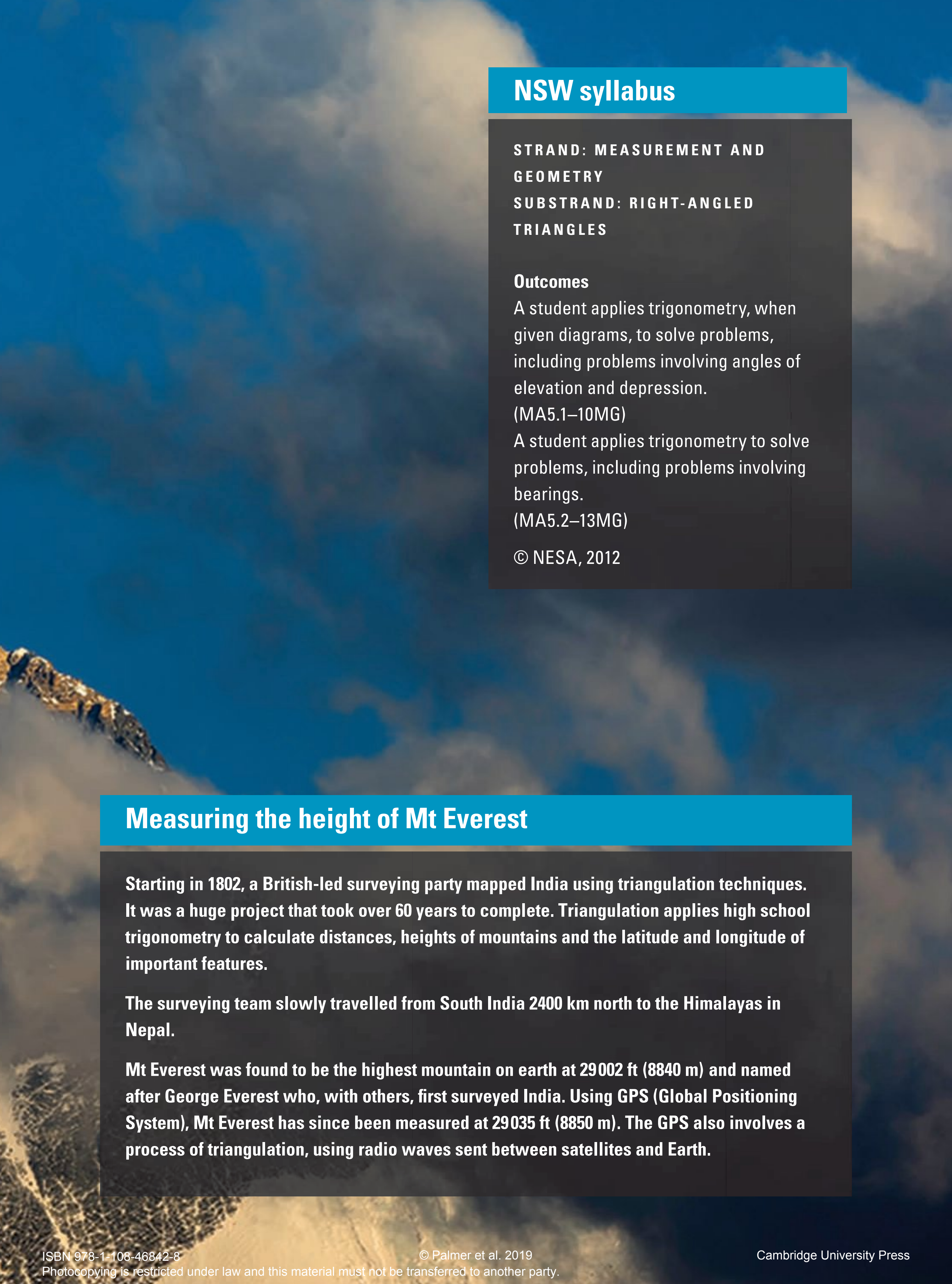
Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

8 Right-angled triangles

What you will learn



NSW syllabus

STRAND: MEASUREMENT AND GEOMETRY

SUBSTRAND: RIGHT-ANGLED TRIANGLES

Outcomes

A student applies trigonometry, when given diagrams, to solve problems, including problems involving angles of elevation and depression.
(MA5.1–10MG)

A student applies trigonometry to solve problems, including problems involving bearings.
(MA5.2–13MG)

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Measuring the height of Mt Everest

Starting in 1802, a British-led surveying party mapped India using triangulation techniques. It was a huge project that took over 60 years to complete. Triangulation applies high school trigonometry to calculate distances, heights of mountains and the latitude and longitude of important features.

The surveying team slowly travelled from South India 2400 km north to the Himalayas in Nepal.

Mt Everest was found to be the highest mountain on earth at 29 002 ft (8840 m) and named after George Everest who, with others, first surveyed India. Using GPS (Global Positioning System), Mt Everest has since been measured at 29 035 ft (8850 m). The GPS also involves a process of triangulation, using radio waves sent between satellites and Earth.

Pre-test

1 Round the following decimals, correct to 2 decimal places.

a 15.84312 **b** 164.8731 **c** 0.86602 **d** 0.57735

e 0.173648 **f** 0.7071 **g** 12.99038 **h** 14.301

2 Find the value of each of the following.

a 5^2 **b** 6.8^2 **c** 19^2 **d** $9^2 + 12^2$

e $3.1^2 + 5.8^2$ **f** $41^2 - 40^2$

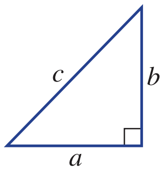
3 Find the following, correct to 1 decimal place.

a $\sqrt{8}$ **b** $\sqrt{7}$ **c** $\sqrt{15}$ **d** $\sqrt{10}$

e $\sqrt{12.9}$ **f** $\sqrt{8.915}$ **g** $\sqrt{3.8}$ **h** $\sqrt{200}$

4 Write down the name of the hypotenuse (i.e. the side opposite the right angle) on the following triangles.

a



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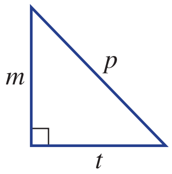
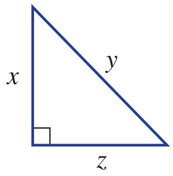


c



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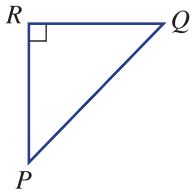
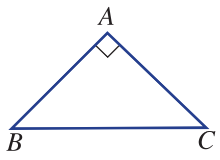
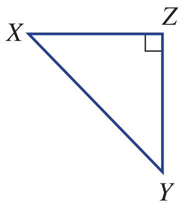


e



f



5 Solve for x.

a $3x = 9$ **b** $4x = 16$

c $5x = 60$ **d** $\frac{x}{5} = 7$

e $\frac{x}{12} = 9$ **f** $\frac{2x}{3} = 6$

6 Solve for m.

a $7m = 25.55$ **b** $9m = 10.8$

c $1.5m = 6.6$ **d** $\frac{m}{1.3} = 4$

e $\frac{m}{5.89} = 3.2$ **f** $\frac{m}{5.4} = 1.06$

7 Solve each of the following equations, correct to 1 decimal place.

a $\frac{3}{x} = 5$

b $\frac{4}{x} = 17$

c $\frac{32}{x} = 15$

d $\frac{3.8}{x} = 9.2$

e $\frac{15}{x} = 6.2$

f $\frac{29.3}{x} = 3.2$

8 If x is a positive integer, solve:

a $x^2 = 16$

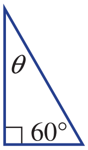
b $x^2 = 400$

c $x^2 = 5^2 + 12^2$

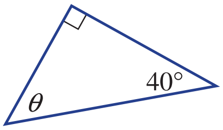
d $x^2 + 3^2 = 5^2$

9 Find the size of the angle θ in the following diagrams.

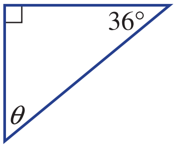
a



b



c



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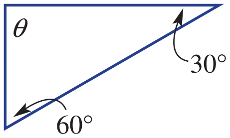
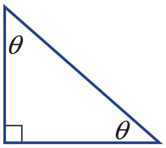
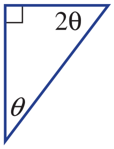


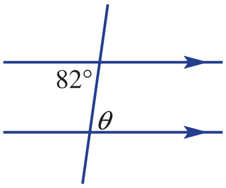
e



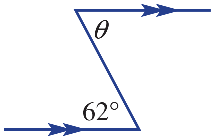
f



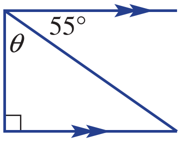
g



h



i



8A Reviewing Pythagoras’ theorem REVISION

Interactive
Widgets
HOTsheets
Walkthrough

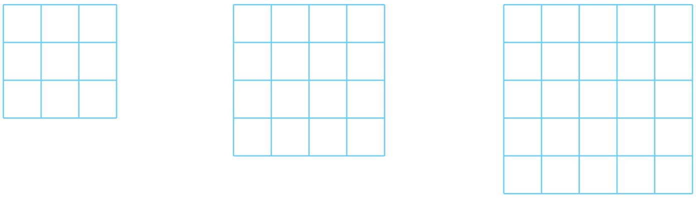
The ancient Egyptians knew of the relationship between the numbers 3, 4 and 5 and how they could be used to form a right-angled triangle.

Greek philosopher and mathematician Pythagoras expanded on this idea and the theorem we use today is named after him.

An engraving depicting Pythagoras discussing ideas with Egyptian priests during one of his visits to Egypt.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let’s start: Three, four and five

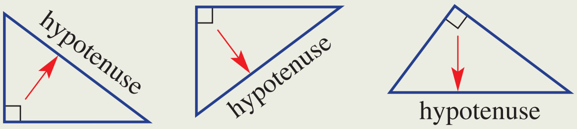


- On square grid paper, construct three squares, as shown above.
- Cut them out and place the middle-sized square on top of the largest square. Then cut the smallest square into nine smaller squares and also place them on the largest square to finish covering it.
- What does this show about the numbers 3, 4 and 5?

Key ideas

- A right-angled triangle has its longest side opposite the right angle. This side is called the **hypotenuse**.

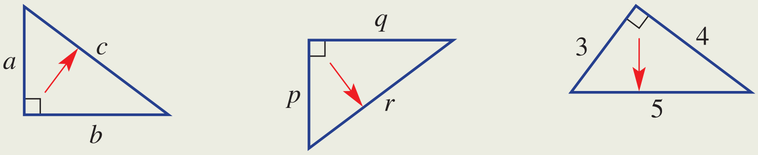
  For example:



Hypotenuse
The longest side of a right-angled triangle (i.e. the side opposite the right angle)

- **Pythagoras’ theorem** states:
  The square of the hypotenuse is equal to the sum of the squares on the other two sides.

  For example:



$c^2 = a^2 + b^2$
hypotenuse

$r^2 = p^2 + q^2$
hypotenuse

$5^2 = 3^2 + 4^2$
hypotenuse

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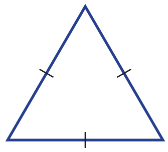
Exercise 8A REVISION

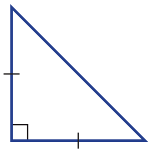
UNDERSTANDING AND FLUENCY 1–4, 5–6(½) 4, 5–7(½)

1 Which of the following triangles contain a side known as the hypotenuse?

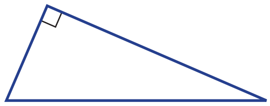
A



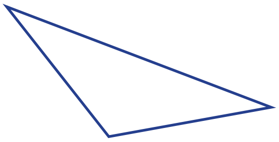
B



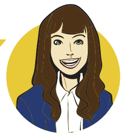
C



D

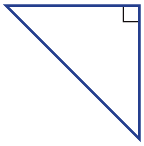


Only right-angled triangles have a hypotenuse.



2 Copy these triangles into your workbook and label the hypotenuse.

a



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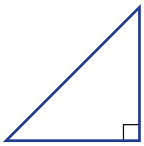

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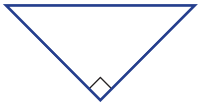
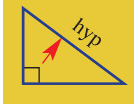
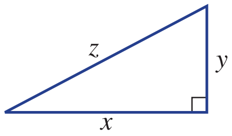


Draw an arrow across from the right angle to find the hypotenuse (hyp).



3 Write the relationship between the sides of these triangles.

a



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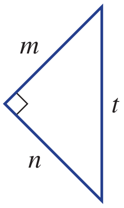

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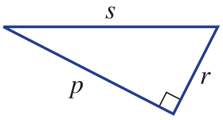
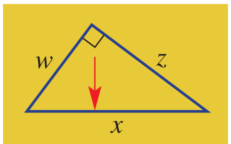




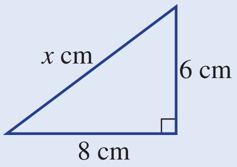
$x^2 = w^2 + z^2$

4 Find the value of $a^2 + b^2$ if:

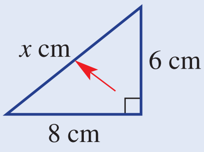
a $a = 3$ and $b = 4$ **b** $a = 3$ and $b = 5$ **c** $a = 3$ and $b = 6$

Example 1 Finding the length of the hypotenuse

Find the length of the hypotenuse of the triangle shown.



SOLUTION	EXPLANATION
$x^2 = 6^2 + 8^2$ $= 36 + 64$ $= 100$	Write the relationship for the given triangle using Pythagoras' theorem.
$x = \sqrt{100}$ $= 10$	Take the square root to find x.
∴ Hypotenuse length = 10 cm.	Write your answer.



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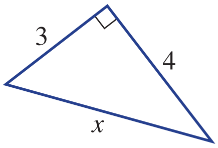
5 Find the length of the hypotenuse in these right-angled triangles.

a



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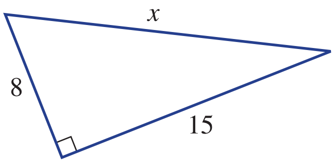

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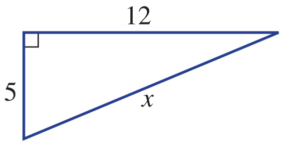

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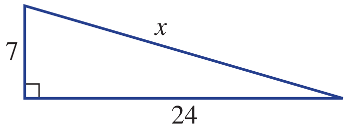

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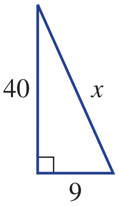

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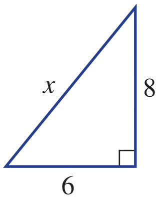
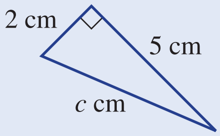
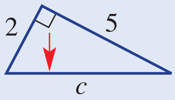


Example 2 Finding the length of the hypotenuse as a decimal

Find the length of the hypotenuse in this triangle, correct to 1 decimal place.

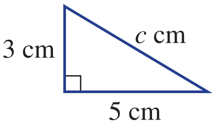


SOLUTION	EXPLANATION
$c^2 = 5^2 + 2^2$ $= 25 + 4$ $= 29$	Write the relationship for this triangle, where c is the length of the hypotenuse.
$c = \sqrt{29}$	Simplify.
$c = 5.38516\ldots$	Take the square root to find c.
$c = 5.4$ (to 1 d.p.) $\therefore$ Hypotenuse length = 5.4 cm.	Round 5.3⑧516 … to 1 decimal place.

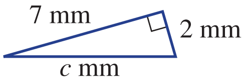


6 Find the length of the hypotenuse in these triangles, correct to 1 decimal place.

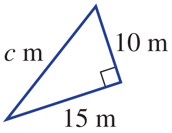
a



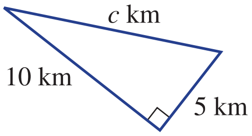
b



c



d



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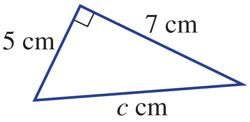

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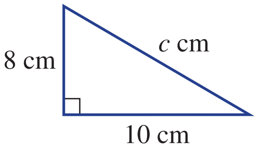
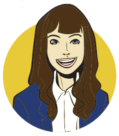


If $c^2 = 34$, then $c = \sqrt{34}$. Use a calculator to find the decimal.



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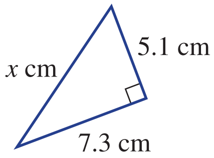
7 Find the value of the hypotenuse in these triangles, correct to 2 decimal places.

a



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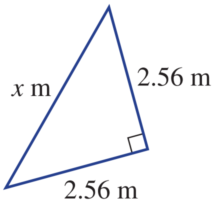

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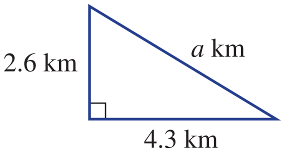

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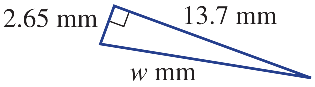

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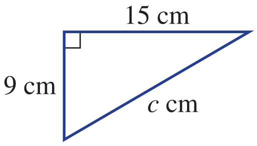

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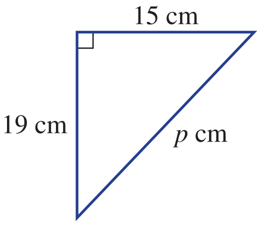
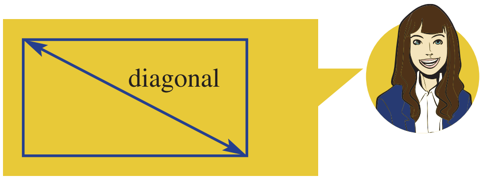


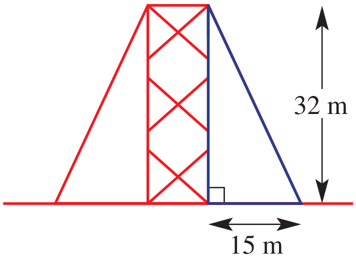
PROBLEM-SOLVING AND REASONING 8–11 11–13, 14(½)

8 A LCD plasma TV is 154 cm long and 96 cm high. Calculate the length of its diagonal, correct to 1 decimal place.

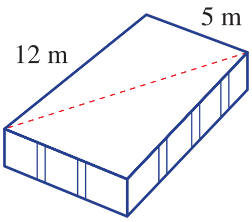


9 A 32 m tower is supported by cables from the top to a position on the ground 15 m from the base of the tower. Determine the length of each cable needed to support the tower, correct to 1 decimal place.

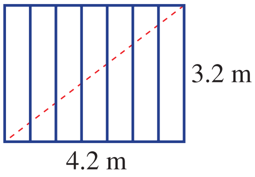
Set up and solve Pythagoras' theorem.



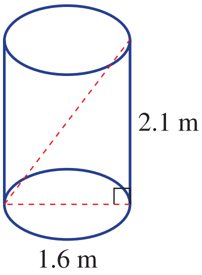
10 Boris the builder uses Pythagoras' theorem to check the corners of his concrete slab. What will be the length of the diagonal when the angle is 90°?



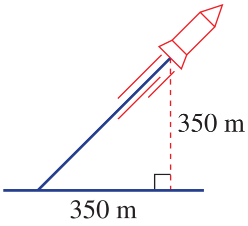
11 Find the length of the diagonal steel brace needed to support a gate of length 4.2 m and width 3.2 m, correct to 2 decimal places.



12 Find the length of the longest rod that will fit in a cylindrical container of height 2.1 m and diameter 1.6 m, correct to 2 decimal places.

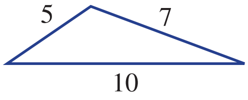


13 A rocket blasts off and after a few seconds it is 350 m above the ground. At this time it has covered a horizontal distance of 350 m. How far has the rocket travelled, correct to 2 decimal places?



14 Determine whether these triangles contain a right angle. Note: They may not be to scale.

a



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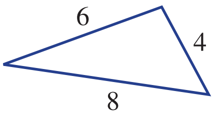

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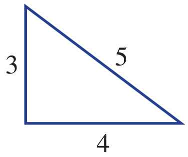

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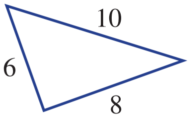

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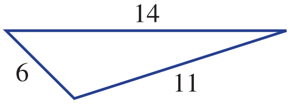

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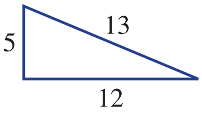
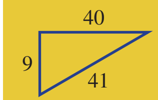


If Pythagoras' theorem works, then the triangle has a right angle.

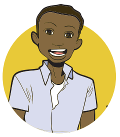
For example:



$41^2 = 1681$

$40^2 + 9^2 = 1681$

$\therefore 41^2 = 40^2 + 9^2$ and the triangle has a right angle, opposite the 41.



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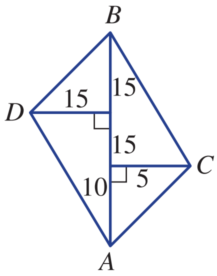
ENRICHMENT	–	15, 16

An offset survey

An offset survey measures distances perpendicular to the baseline offset. A notebook entry is made showing these distances and then perimeters and areas are calculated.

	B	
	40	
D 15	25	
	10	5 *C*
	0	
	A	

Notebook entry



Field diagram
(Not to scale)

15 **a** Using the diagrams above, find these lengths, correct to 1 decimal place.

- **i** *AC*
- **ii** *BC*
- **iii** *DB*
- **iv** *AD*

b Find the perimeter of the field *ACBD*, correct to the nearest metre.

c Find the area of the field.

16 Shown at below is a notebook entry. Draw the field diagram and find the perimeter of the field, to 1 decimal place.

	B	
	60	
	40	10 *E*
D 25	30	
C 15	10	
	0	
	A	

8B Finding the lengths of the shorter sides REVISION

Interactive
Widgets
HOTsheets
Walkthrough

Using Pythagoras' theorem, we can determine the length of the shorter sides of a right-angled triangle. The angled support beams on a rollercoaster ride, for example, create right-angled triangles with the ground. The vertical and horizontal distances are the shorter sides of the triangle.

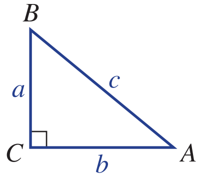
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Choosing the correct numbers

For the triangle *ABC*, Pythagoras' theorem is written as $c^2 = a^2 + b^2$.

Choose the three numbers from each group that work for $c^2 = a^2 + b^2$.

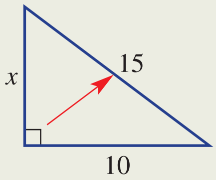
Group 1: 6, 7, 8, 9, 10
Group 2: 15, 16, 20, 25
Group 3: 9, 10, 12, 15
Group 4: 9, 20, 21, 40, 41



Key ideas

- We can use Pythagoras' theorem to determine the length of one of the shorter sides if we know the length of the hypotenuse and the other side.

For example:



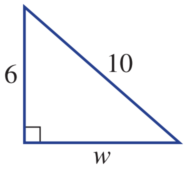
$$\begin{aligned} 15^2 &= x^2 + 10^2 \\ x^2 + 10^2 &= 15^2 \\ x^2 + 100 &= 225 \\ x^2 &= 125 \\ x &= \sqrt{125} \end{aligned}$$

Exercise 8B REVISION

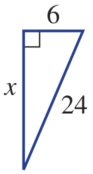
UNDERSTANDING AND FLUENCY	1–3, 4–5(½)	3, 4–6(½)

1 **a** What is the length of the hypotenuse in each of these triangles?

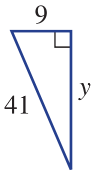
i



ii



iii



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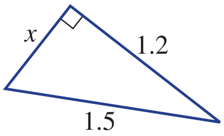

b Write a statement such as $15^2 = x^2 + 10^2$ for each triangle.

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2 Copy and complete the following.

a If $10^2 = 6^2 + w^2$, then $w^2 = 10^2 - \square$.

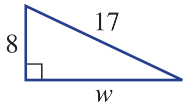
b If $13^2 = 5^2 + x^2$, then $x^2 = 13^2 - \square$.

c If $30^2 = p^2 + 18^2$, then $p^2 = \square - 18^2$.

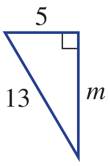
Follow a step as if you were solving an equation.

3 Write down Pythagoras' theorem for each of these triangles.

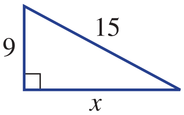
a



b

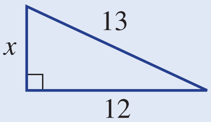


c



Example 3 Calculating a shorter side

Determine the value of x in the triangle shown, using Pythagoras' theorem.

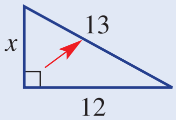


SOLUTION

$$\begin{aligned} 13^2 &= x^2 + 12^2 \\ x^2 + 12^2 &= 13^2 \\ x^2 &= 13^2 - 12^2 \\ &= 169 - 144 \\ &= 25 \\ x &= \sqrt{25} \\ \therefore x &= 5 \end{aligned}$$

EXPLANATION

Write the relationship for this triangle using Pythagoras' theorem with 13 as the hypotenuse.



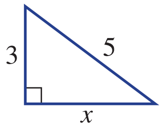
Rewrite the rule with the x^2 on the left-hand side.

Simplify.

Take the square root to find x.

4 Determine the value of x in these triangles, using Pythagoras' theorem.

a



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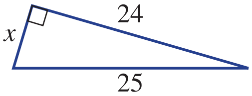

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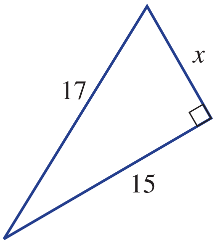

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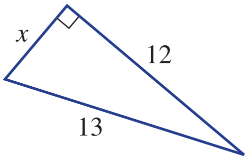

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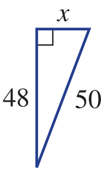

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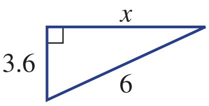
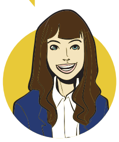


In $c^2 = a^2 + b^2$, c is always the hypotenuse.



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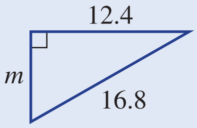
Example 4 Finding a shorter side length as a decimal value

Determine the value of m in the triangle, correct to 1 decimal place.

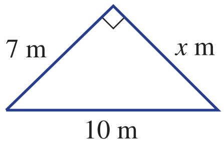


SOLUTION	EXPLANATION
$16.8^2 = m^2 + 12.4^2$	Write the relationship for this triangle.
$m^2 + 12.4^2 = 16.8^2$	
$m^2 = 16.8^2 - 12.4^2$	Make m^2 the subject by first swapping the LHS and RHS.
$= 128.48$	Simplify, using your calculator.
$m = \sqrt{128.48}$	Take the square root of both sides to find m.
$= 11.3349\ldots$	
$m = 11.3$ (to 1 d.p.)	Round your answer to 1 decimal place.

5 Determine the value of x in these triangles, using Pythagoras' theorem. Answer correct to 1 decimal place.

To round to one decimal place, look at the 2nd decimal place. If it is 5 or more, round up. If it is 4 or less, round down. For example, 7.1④14 … rounds to 7.1.

a



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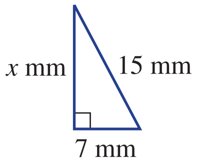

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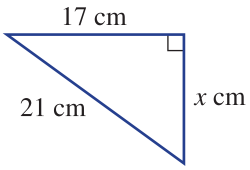

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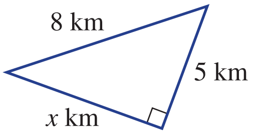

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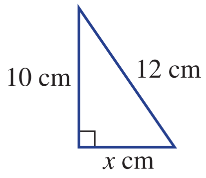

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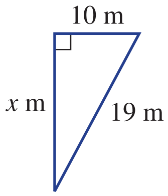
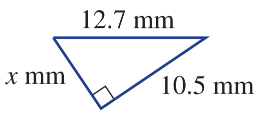


6 Determine the value of x in these triangles, using Pythagoras' theorem. Answer correct to 2 decimal places.

a



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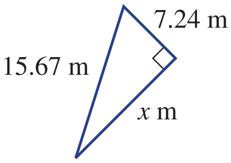

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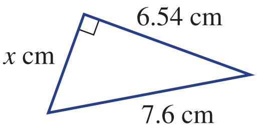

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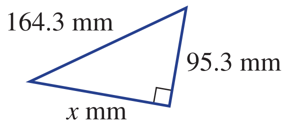

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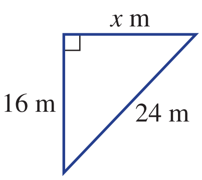

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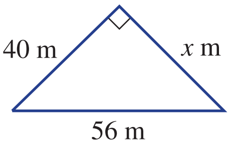

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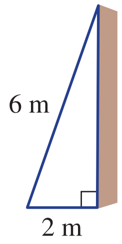
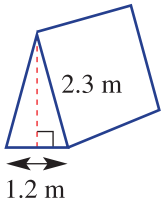
PROBLEM-SOLVING AND REASONING 7–9 8–11

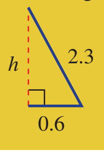
7 A 6 m ladder leans against a wall. If the base of the ladder is 2 m from the wall, determine how high the ladder is up the wall, correct to 2 decimal places.

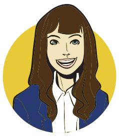


8 A tent has sloping sides of length 2.3 m and a base of 1.2 m. Determine the height of the tent pole, correct to 1 decimal place.

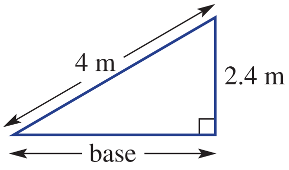


Identify the right-angled triangle.

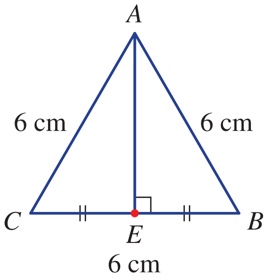




9 A city council wants to build a skateboard ramp measuring 4 m long and 2.4 m high. What would be the length of the base of the ramp?



10 Triangle *ABC* is equilateral. *AE* is an axis of symmetry.



An equilateral triangle has 3 equal sides.

Remember:
$A = \frac{1}{2}bh$ is the area of a triangle.

a Find the length of:
  i *EB*
  ii *AE*, to 1 decimal place

b Find the area of triangle *ABC*, to 1 decimal place.

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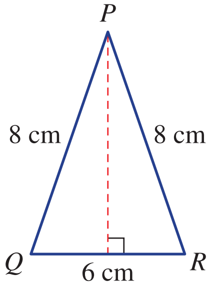
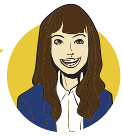
11 What is the height of this isosceles triangle, to 1 decimal place?



Pythagoras' theorem only applies to right-angled triangles.

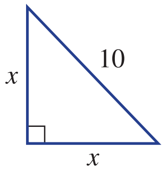


ENRICHMENT		–	12

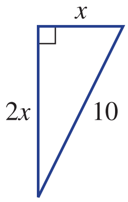
More than one pronumeral

12 Find the value of x in each of the following. Give your answer to 1 decimal place.

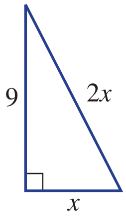
a



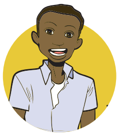
b



c



Remember to square the entire side.
The square of $2x$ is $(2x)^2$ or $4x^2$.
Also, $x^2 + x^2 = 2x^2$.



A statue of Pythagoras on the island of Samos in the Aegean sea.

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8C Applications of Pythagoras' theorem EXTENSION

Interactive
Widgets
HOTsheets
Walkthrough

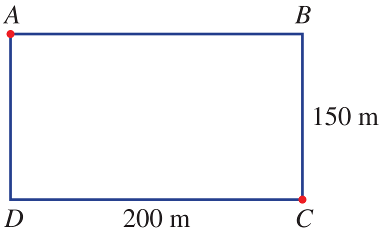
Pythagoras' theorem has many applications, some of which you may have noticed already in this chapter. Some areas in which Pythagoras' theorem is useful include drafting, building and navigation.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Finding the shortest path

A rectangular field is 200 m by 150 m.

Marco wishes to walk from the corner of the field marked *A* to the corner of the field marked *C*. How many metres are saved by walking along the diagonal *AC* rather than walking along *AB* then *BC*?



Key ideas

- When applying Pythagoras' theorem:
  - Identify and draw the right-angled triangle or triangles needed to solve the problem.
  - Label the triangle and place a pronumeral (letter) on the side length that is unknown.
  - Use Pythagoras' theorem to find the value of the pronumeral.
  - Answer the question. (Written questions should have written answers.)
  - Check that the answer is reasonable. (Remember that the hypotenuse is the longest side.)

Exercise 8C EXTENSION

UNDERSTANDING AND FLUENCY	1, 2, 3(½), 4, 5	4–8

1 Draw a diagram for each of the following questions. You don't need to answer the question.

a A 2.4 metre ladder is placed 1 metre from the foot of a building. How far up the building will the ladder reach?

b The diagonal of a rectangle with length 18 cm is 24 cm. How wide is the rectangle?

c Tom walks 5 km north, then 3 km west. How far is he from his starting point?

Each one involves a right-angled triangle.

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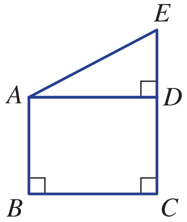
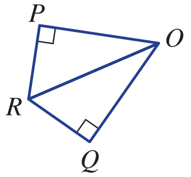
2 Name the right-angled triangles in each of the following diagrams.

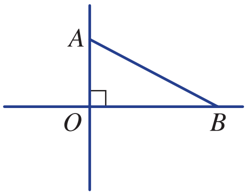
a



b

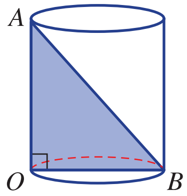


c

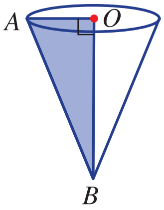


3 Name the hypotenuse in each of the shaded right-angled triangles found within these three-dimensional shapes.

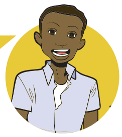
a



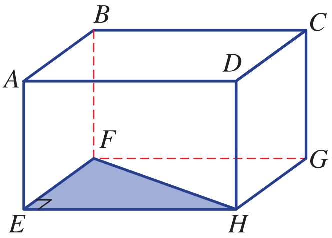
b



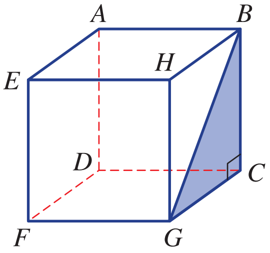
Use the given letters to name them; e.g. *AB*.



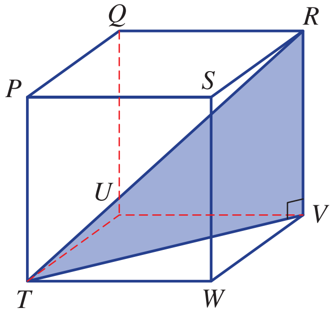
c



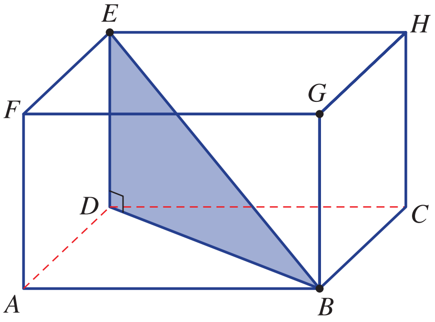
d



e

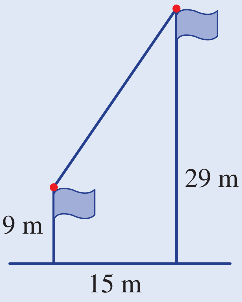


f



Example 5 Applying Pythagoras' theorem

Two flagpoles are 15 metres apart and a rope links the tops of both poles. Find the length of the rope if one flagpole is 9 m high and the other is 29 m high.



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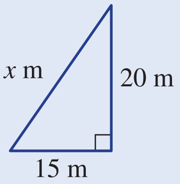
SOLUTION

Let x be the length of rope.

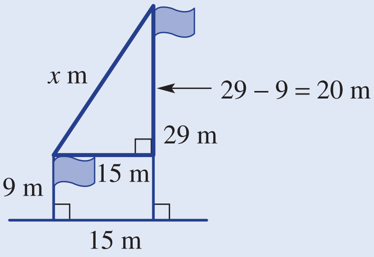


$$\begin{aligned} x^2 &= 15^2 + 20^2 \\ &= 225 + 400 \\ &= 625 \\ x &= \sqrt{625} \\ &= 25 \end{aligned}$$

The rope is 25 m long.

EXPLANATION

Locate and draw the right-angled triangle, showing all measurements.



Introduce a pronumeral for the missing side.

Write the relationship, using Pythagoras' theorem.

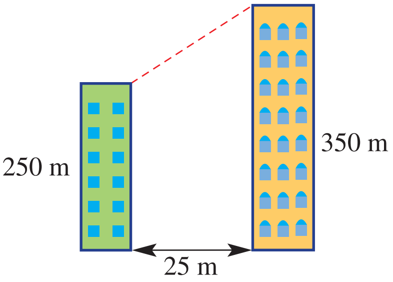
Simplify.

Take the square root to find x.

Answer the question.

4 Two skyscrapers are 25 m apart and a cable runs from the top of one building to the top of the other. One building is 350 m tall and the other is 250 m tall.

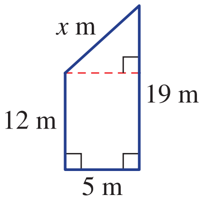
- **a** Determine the difference in the heights of the buildings.
- **b** Draw an appropriate right-angled triangle you could use to find the length of the cable.
- **c** Find the length of the cable, correct to 2 decimal places.



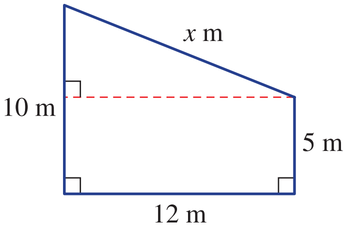
(Not to scale)

5 Find the value of x in each of the following, correct to 1 decimal place where necessary.

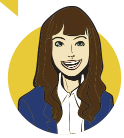
a



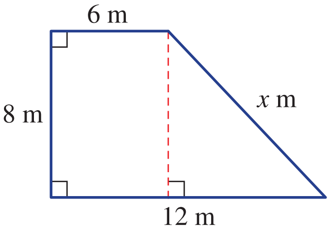
b



Label the two known lengths of each triangle first.



c



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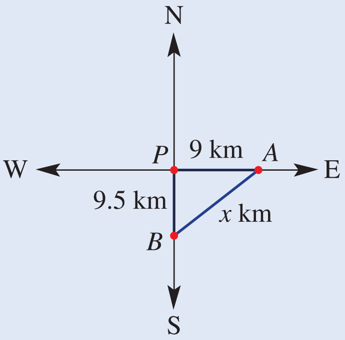
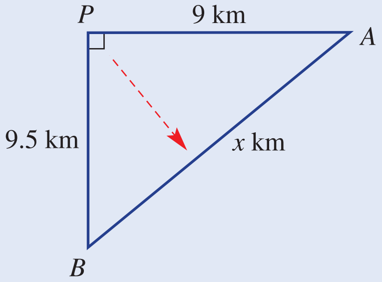
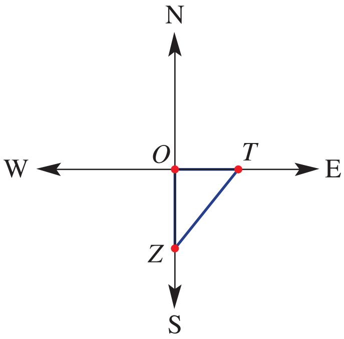
Example 6 Using direction with Pythagoras' theorem

Two hikers leave their camp (P) at the same time. One walks due east for 9 km; the other walks due south for 9.5 km. How far apart are the two hikers at this point? (Give your answer to 1 decimal place.)

SOLUTION	EXPLANATION
	Draw a diagram. Consider ΔPAB. 
$\therefore\ x^2 = 9^2 + 9.5^2$ $= 171.25$ $x = \sqrt{171.25}$ $= 13.08\dot{6}$	Write Pythagoras' theorem and evaluate. Take the square root to find x.
$= 13.1$ (to 1 d.p.)	Round to 1 decimal place.
∴ The hikers are 13.1 km apart.	Answer the question in words.

6 Tom (T) walks 4.5 km east while Zara (Z) walks 5.2 km south. How far from Tom is Zara? Answer to 1 decimal place.



7 Find the distance between Sui and Kevin if:

- **a** Sui walks 6 km north from camp O and Kevin walks 8 km west from camp O.
- **b** Sui walks 40 km east from point A and Kevin walks 9 km south from point A.
- **c** Kevin walks 15 km north-west from O and Sui walks 8 km south-west also from O.

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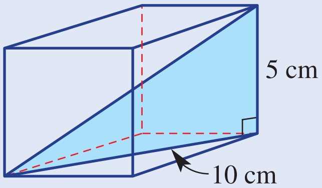
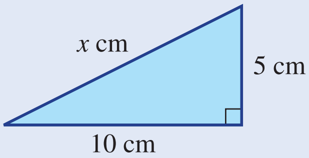
Example 7 Using Pythagoras' theorem in 3D

Find the distance from one corner of this rectangular prism to the opposite corner, correct to 2 decimal places.



SOLUTION



$x^2 = 5^2 + 10^2$

$\quad = 25 + 100$

$x = \sqrt{125}$

$\quad = 11.18$ (to 2 d.p.)

∴ The distance between the opposite corners is 11.18 cm.

EXPLANATION

Draw the triangle you need and mark the lengths.

Write the relationship for this triangle.

Simplify.

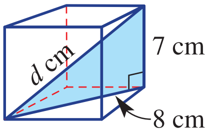
Take the square root to find x.

Round your answer to 2 decimal places.

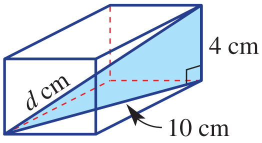
Write the answer.

8 For the following rectangular prisms, find the distance of d from one corner to the opposite corner, correct to 1 decimal place.

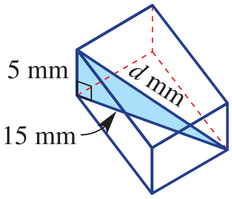
a



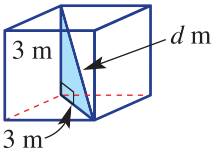
b



c



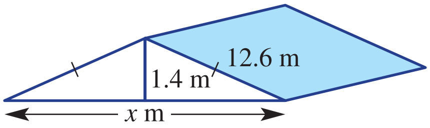
d



PROBLEM-SOLVING AND REASONING

9–11	11–14

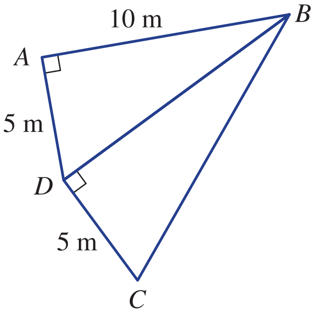
9 The height of a roof is 1.4 m. If the length of a gable (i.e. the diagonal) is to be 12.6 m, determine the length of the horizontal beam needed to support the roof, correct to 2 decimal places.



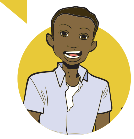
10 For the diagram, find the lengths of:

a BD, correct to 2 decimal places

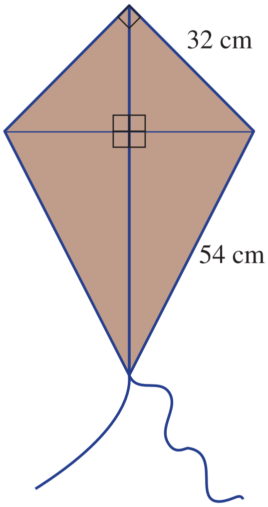
b BC, correct to 1 decimal place



In Question **9**, find the base length of the right-angled triangle first.



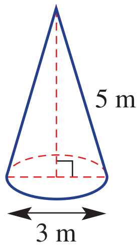
11 A kite is constructed with six pieces of wooden dowel and covered in fabric. The four pieces around the edge are two 32 cm rods and two 54 cm rods. If the top of the kite is right-angled, find the length of the horizontal and vertical rods, correct to 2 decimal places.



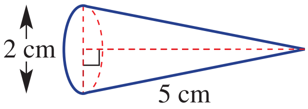
Find the length of the horizontal rod first. What type of triangle is the top of the kite? Find the length of the vertical rod using two calculations.

12 Find the height of the following cones, correct to 2 decimal places.

a



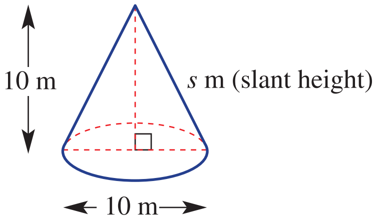
b



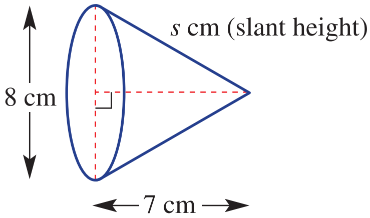
Use the radius of the base as one side of the right-angled triangle.

13 Find the slant height of the following, correct to 1 decimal place.

a



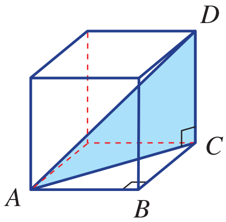
b



14 This cube has side lengths of 1 cm. Find, correct to 2 decimal places, the lengths of:

a AC

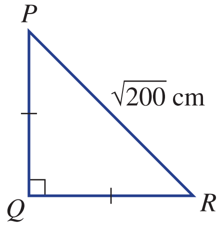
b AD



ENRICHMENT – 15

How much do you know?

15 Write down everything you know about ΔPQR.



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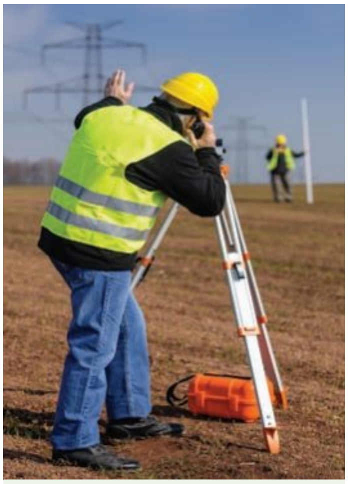
8D Trigonometric ratios

Trigonometry deals with the relationship between the sides and angles of triangles.

In right-angled triangles with an acute angle θ, there are three trigonometric ratios:

- the sine ratio ($\sin\theta$)
- the cosine ratio ($\cos\theta$)
- the tangent ratio ($\tan\theta$)

Using your calculator and knowing how to label the sides of right-angled triangles, you can use trigonometry to find missing sides and angles.



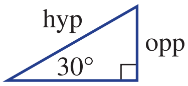
Surveyors use trigonometry to calculate accurate lengths.

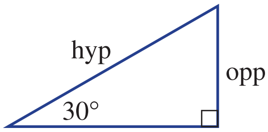
Stage

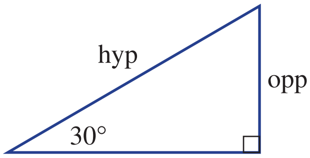
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: 30°

- Draw three different right-angled triangles that each have a 30° angle.



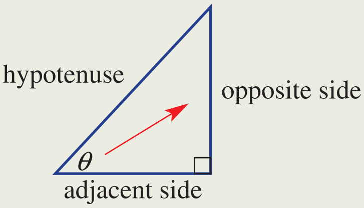


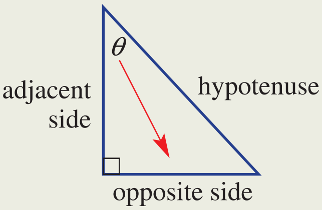


- Measure each side of each triangle, and add these measurements to your diagrams.
- The hypotenuse, as we know, is opposite the right angle. The side opposite the 30° is called the opposite side. For each of your three triangles, write down the ratio of the opposite side divided by the hypotenuse. What do you notice?
- Put your calculator in degree mode and enter $\boxed{\sin}$ $\boxed{3}$ $\boxed{0}$. What do you notice?

Key ideas

- Any right-angled triangle has three sides: the hypotenuse, adjacent and opposite.
  - The hypotenuse is always opposite the right angle.
  - The *adjacent* side is next to the **angle of reference** (θ).
  - The *opposite* side is opposite the angle of reference.





Angle of reference
The angle in a right-angled triangle that is used to determine the opposite side and the adjacent side

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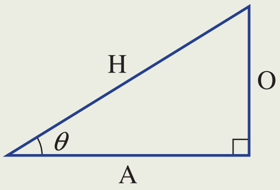
Key ideas

- For a right-angled triangle with a given angle θ (theta), the three trigonometric ratios of **sine (sin)**, **cosine (cos)** and **tangent (tan)** are given by:
  - sine of angle θ: $\sin\theta = \dfrac{\text{length of opposite side}}{\text{length of the hypotenuse}}$
  - cosine of angle θ: $\cos\theta = \dfrac{\text{length of adjacent side}}{\text{length of the hypotenuse}}$
  - tangent of angle θ: $\tan\theta = \dfrac{\text{length of opposite side}}{\text{length of adjacent side}}$
- When working with right-angled triangles, label each side of the triangle O (opposite), A (adjacent) and H (hypotenuse).



- The three trigonometric ratios are:

$$\sin\theta = \frac{O}{H} \quad \cos\theta = \frac{A}{H} \quad \tan\theta = \frac{O}{A}$$

We can remember this as **SOH CAH TOA**.

Sine (sin) The ratio of the length of the opposite side to the length of the hypotenuse in a right-angled triangle

Cosine (cos) The ratio of the length of the adjacent side to the length of the hypotenuse in a right-angled triangle

Tangent (tan) The ratio of the length of the opposite side to the length of the adjacent side in a right-angled triangle

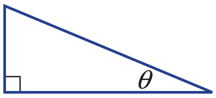
SOH CAH TOA A way of remembering the trigonometric ratios: **S**ine equals **O**pposite over **H**ypotenuse, **C**osine equals **A**djacent over **H**ypotenuse, **T**angent equals **O**pposite over **A**djacent

Exercise 8D

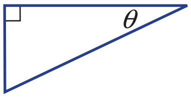
UNDERSTANDING AND FLUENCY 1–4, 5–6(½) 4, 5–6(½)

1 By referring to the angles marked, copy each triangle and label the sides opposite, adjacent and hypotenuse.

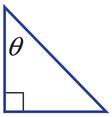
a



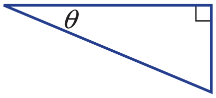
b



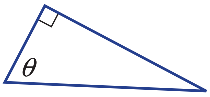
c



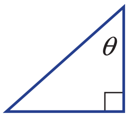
d



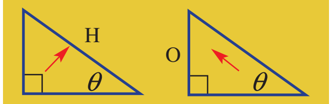
e

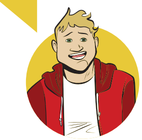


f



Arrows help you find the hypotenuse and the opposite side:





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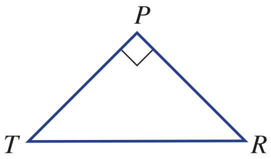
2 Referring to triangle *PTR*, name the:

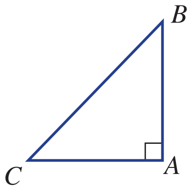
- **a** side opposite the angle at *T*
- **b** side adjacent to the angle at *T*
- **c** side opposite the angle at *R*
- **d** side adjacent to the angle at *R*
- **e** hypotenuse
- **f** angle opposite the side *PR*



'Adjacent' means next to.

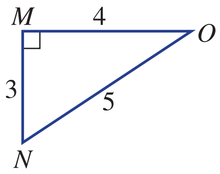
3 Referring to triangle *ABC*, name the:

- **a** hypotenuse
- **b** side opposite the angle at *B*
- **c** side opposite the angle at *C*
- **d** side adjacent to the angle at *B*



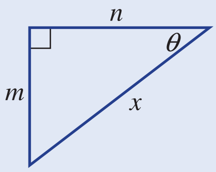
4 In triangle *MNO*, write the ratio of:

- **a** $\dfrac{\text{the side opposite angle } O}{\text{hypotenuse}}$
- **b** $\dfrac{\text{the side opposite angle } N}{\text{hypotenuse}}$
- **c** $\dfrac{\text{the side adjacent angle } O}{\text{hypotenuse}}$



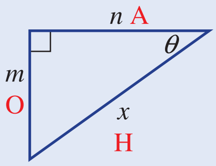
Example 8 Writing trigonometric ratios

Label the sides of the triangle O, A and H and write the ratios for:



a $\sin\theta$ **b** $\cos\theta$ **c** $\tan\theta$

SOLUTION



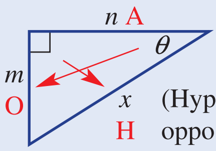
a $\sin\theta = \dfrac{m}{x}$

b $\cos\theta = \dfrac{n}{x}$

c $\tan\theta = \dfrac{m}{n}$

EXPLANATION

Use arrows to label the sides correctly.



(opposite angle θ)

(Hypotenuse is always opposite the right angle.)

SOH CAH TOA

$\sin\theta = \dfrac{\text{O}}{\text{H}} = \dfrac{m}{x}$

$\cos\theta = \dfrac{\text{A}}{\text{H}} = \dfrac{n}{x}$

$\tan\theta = \dfrac{\text{O}}{\text{A}} = \dfrac{m}{n}$

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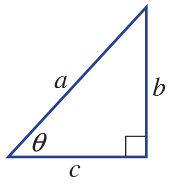
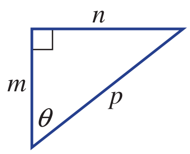
5 For each of the following triangles, write a ratio for:

- **i** sin θ
- **ii** cos θ
- **iii** tan θ

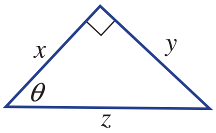
a



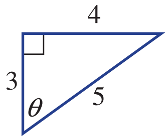
b



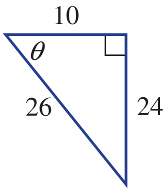
c



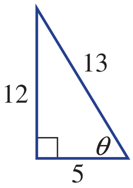
d



e



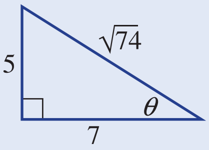
f



Use SOH CAH TOA after labelling the sides as O, A and H.

Example 9 Writing a trigonometric ratio

Write down the ratio of cos θ for this triangle.



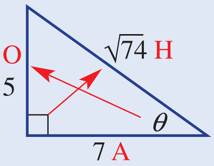
SOLUTION

$$\cos\theta = \frac{\text{A}}{\text{H}}$$

$$\cos\theta = \frac{7}{\sqrt{74}}$$

EXPLANATION

Label the sides of the triangle.

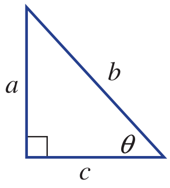


SOH CAH TOA tells us cos θ is $\frac{\text{adjacent}}{\text{hypotenuse}}$.

Substitute the values for the adjacent (A) and hypotenuse (H).

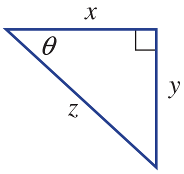
6 Write the trigonometric ratio asked for in each of the following.

a



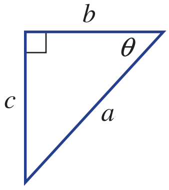
tan $\theta =$

b



sin $\theta =$

c



cos $\theta =$

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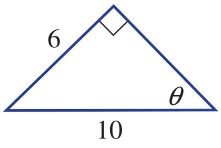
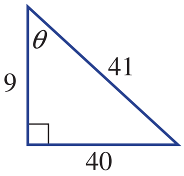
d



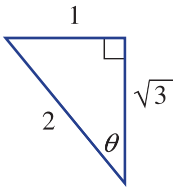
sin $\theta =$

e



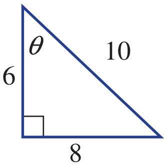
sin $\theta =$

f



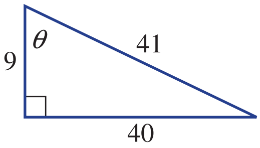
tan $\theta =$

g



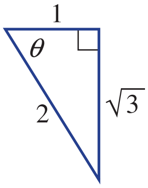
tan $\theta =$

h



cos $\theta =$

i



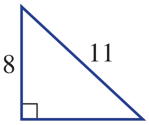
tan $\theta =$

PROBLEM-SOLVING AND REASONING

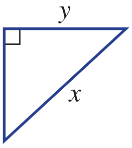
7–9(½) | 8–9(½), 10, 11

7 Copy each of these triangles and mark the angle θ that will enable you to write a ratio for sin θ, using the sides given.

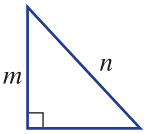
a



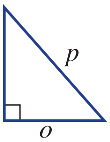
b



c



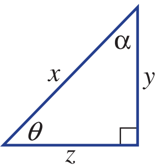
d



8 For the triangle shown on the right, write a ratio for:

a sin θ **b** sin α **c** cos θ

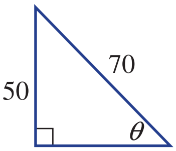
d cos α **e** tan θ **f** tan α



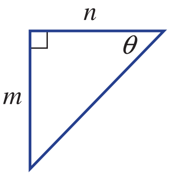
θ and α are letters of the Greek alphabet that are used to mark angles.

9 For each of the triangles below, decide which trigonometric ratio (i.e. sin, cos or tan) you would use.

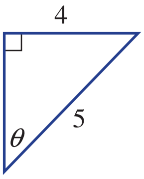
a



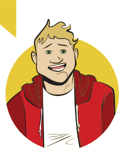
b



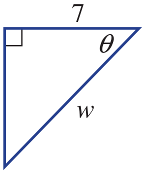
c



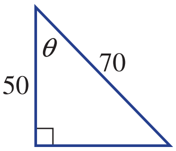
First decide which two sides you have: *O*, *A* or *H*?



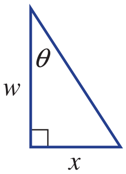
d



e



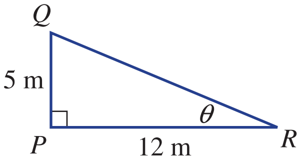
f



10 Consider triangle *PQR*.

a Use Pythagoras' theorem to find the length of *QR*.

b Write down the ratio of sin θ.



11 For a given right-angled triangle, $\sin \theta = \frac{1}{2}$.

- **a** Draw up a right-angled triangle and show this information.
- **b** What is the length of the third side? Use Pythagoras' theorem and answer in square root form (e.g. $\sqrt{7}$).
- **c** Find the value of:
  - **i** $\cos \theta$
  - **ii** $\tan \theta$

ENRICHMENT – 12

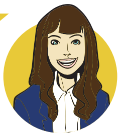
Relationship between sine and cosine

12 Use your calculator to complete the table, answering to 3 decimal places where necessary.

- **a** For what angle is $\sin \theta = \cos \theta$?
- **b** Copy and complete the following.
  - **i** $\sin 5° = \cos$ ______°
  - **ii** $\sin 10° = \cos$ ______°
  - **iii** $\sin 60° = \cos$ ______°
  - **iv** $\sin 90° = \cos$ ______°
- **c** Write down a relationship, in words, between sin and cos.
- **d** Why do you think it's called cosine?

Angle (θ)	$\sin \theta$	$\cos \theta$
0°		
5°		
10°		
15°		
20°		
25°		
30°		
35°		
40°		
45°		
50°		
55°		
60°		
65°		
70°		
75°		
80°		
85°		
90°		

For most calculators, you enter the values in the same order as they are written; e.g.
$\sin 30° \rightarrow \boxed{\text{sin}}\ 30 = 0.5$.



8E Finding unknown sides

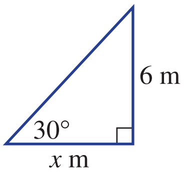
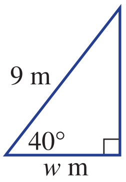
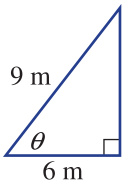
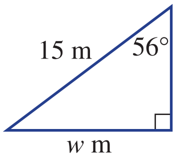
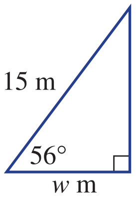
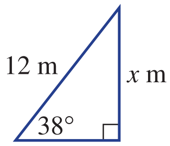
Interactive
Widgets
HOTsheets
Walkthrough

In any right-angled triangle, when given one of the acute angles and a side length, you can find the lengths of the other two sides. This can help builders find the lengths in right-angled triangles if they know an angle and the length of another side.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let’s start: Is it sin, cos or tan?

Out of the six triangles below, only two provide enough information to use the sine ratio. Which two triangles are they?

a 	**b** 	**c** 
d 	**e** 	**f** 

Key ideas

- To find a missing side when given a right-angled triangle with one acute angle and one of the sides:
  - Label the triangle using O (opposite), A (adjacent) and H (hypotenuse).
  - Use SOH CAH TOA to decide on the correct trigonometric ratio.
  - Write down the relationship.
  - Solve the equation, using your calculator, to find the unknown.

  For example:

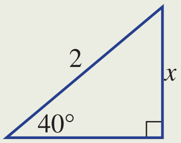
$$\sin 40^\circ = \frac{x}{2}$$

$$\frac{x}{2} = \sin 40^\circ$$

$$x = 2 \times \sin 40^\circ$$

$$x = 1.2855\ldots.$$

$$x = 1.3 \text{ (to 1 d.p.)}$$



- Always check that your answer is reasonable. The hypotenuse (the largest side) is 2, so x must be less than 2.
- Degrees and minutes
  - Sometimes angles cannot be expressed with whole numbers only.

  For example: half of 45° is 22.5° or $22\frac{1}{2}^\circ$.

  This is sometimes written as 22 degrees 30 minutes or as $22^\circ 30'$.

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Key ideas

- There are 60 minutes in 1 degree.

  These conversions can be performed on your calculator:

  $$\begin{aligned} 2.5^\circ &= 2^\circ 30' \\ 3.25^\circ &= 3^\circ 15' \\ 22.75^\circ &= 22^\circ 45' \\ 15.4^\circ &= 15^\circ 24' \end{aligned}$$

Exercise 8E

UNDERSTANDING AND FLUENCY

1–5(½), 6–8(a)

3–5(½), 6–8(b,c), 9(½)

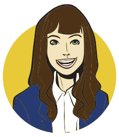
1 Use a calculator to find the value of each of the following, correct to 4 decimal places.

a sin 10° **b** cos 10° **c** tan 10°

d tan 30° **e** cos 40° **f** sin 70°

g cos 80.1° **h** tan 40.5° **i** sin 80.75°

j sin 60° 15′ **k** cos 50° 12′ **l** tan 60° 5′



Locate the sin, cos and tan buttons on your calculator.

2 Evaluate each of the following, correct to 2 decimal places.

a 12 tan 10° **b** 12 sin 25° **c** 18 tan 60°

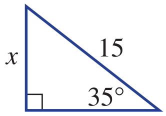
d 56 sin 56° **e** 8 tan 45° **f** 20 sin 70°

g 6 cos 70° **h** 5 cos 15° **i** 27.4 sin 18°

On your calculator, enter 12 tan 10° as 12 × tan 10.

3 Decide which of the three trigonometric ratios is suitable for these triangles.

a



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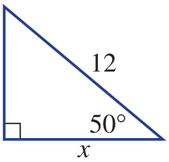

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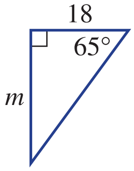

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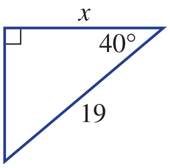

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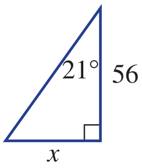

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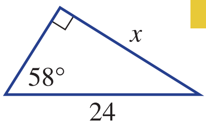
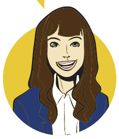


Remember to label the triangle and think SOH CAH TOA. Consider which two sides are involved.



Example 10 Solving a trigonometric equation

Find the value of x, correct to 2 decimal places, for $\cos 30^\circ = \frac{x}{12}$.

SOLUTION

$$\begin{aligned} \cos 30^\circ &= \frac{x}{12} \\ x &= 12 \times \cos 30^\circ \\ &= 10.39230\ldots \\ &= 10.39 \text{ (to 2 d.p.)} \end{aligned}$$

EXPLANATION

Multiply both sides by 12 to get x on its own.

$$12 \times \cos 30^\circ = \frac{x}{\cancel{12}_1} \times \cancel{12}_1$$

Use your calculator.

Round your answer as required.

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4 Find the value of x in these equations, correct to 2 decimal places.

a $\sin 20° = \frac{x}{4}$

b $\cos 43° = \frac{x}{7}$

c $\tan 85° = \frac{x}{8}$

d $\tan 30° = \frac{x}{24}$

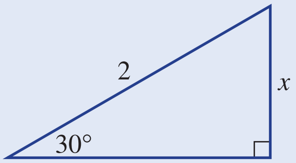
e $\sin 50.1° = \frac{x}{12}$

f $\cos 40° 12' = \frac{x}{12}$

Example 11 Finding a missing side using SOH CAH TOA

Find the value of the unknown length (x) in these triangles. Round your answer to 2 decimal places where necessary.

a



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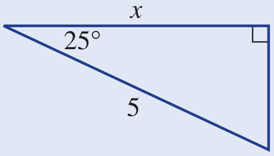

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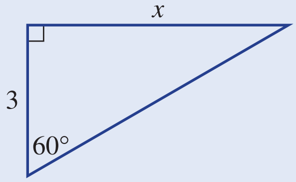


SOLUTION

EXPLANATION

a

$$\sin \theta = \frac{O}{H}$$

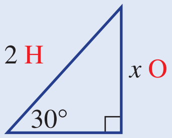
$$\sin 30° = \frac{x}{2}$$

$$x = 2 \times \sin 30°$$

$$\therefore x = 1$$

Label the triangle and decide on your trigonometric ratio using SOH CAH TOA.

Write the ratio.



Solve the equation, using your calculator.

b

$$\cos \theta = \frac{A}{H}$$

$$\cos 25° = \frac{x}{5}$$

$$x = 5 \times \cos 25°$$

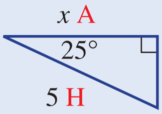
$$x = 4.5315\ldots$$

$$\therefore x = 4.53 \text{ (to 2 d.p.)}$$

Label the triangle.

SOH CAH TOA

Write the ratio.



Solve the equation, using your calculator.

Round to 2 decimal places.

c

$$\tan \theta = \frac{O}{A}$$

$$\tan 60° = \frac{x}{3}$$

$$x = 3 \times \tan 60°$$

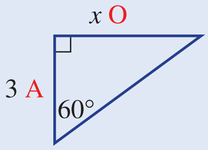
$$x = 5.1961\ldots$$

$$\therefore x = 5.20 \text{ (to 2 d.p.)}$$

Label the triangle.

SOH CAH TOA

Write the ratio.



Solve the equation, using your calculator.

Round to 2 decimal places.

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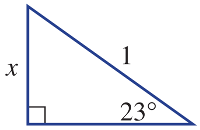
5 Complete the following for the triangles given below.

- **i** Copy each one and label the three sides opposite (O), adjacent (A) and hypotenuse (H).
- **ii** Decide on a trigonometric ratio.
- **iii** Find the value of each pronumeral, correct to 2 decimal places.

a


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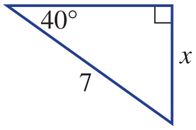

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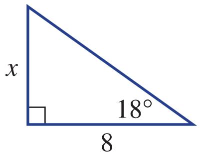

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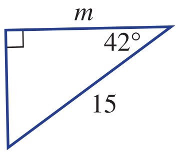

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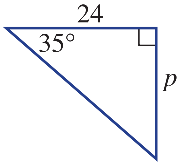

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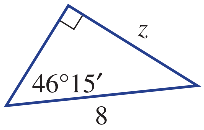

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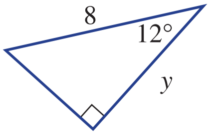
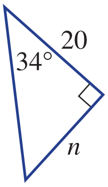
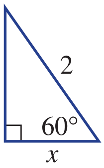
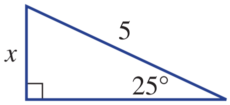


h


i


Use SOH CAH TOA to help you decide which ratio to use; e.g. If O and H are involved, use sin.

6 Find the value of the unknown length (x) in these triangles. Round your answer to 2 decimal places.

a


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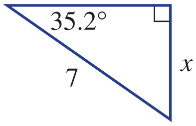

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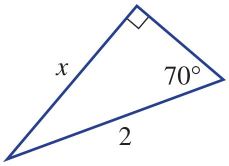
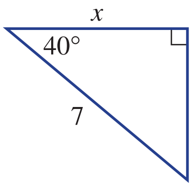


What ratio did you use for each of these?

7 Find the value of the unknown length (x) in these triangles. Round your answer to 2 decimal places.

a


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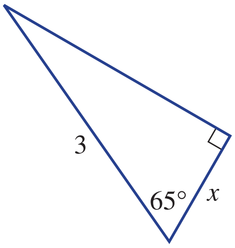

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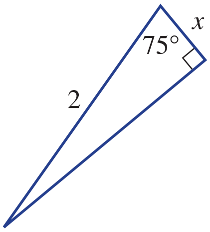
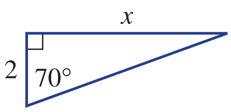


These three all use cos.

8 Find the value of the unknown length (x) in these triangles. Round your answer to 2 decimal places.

a


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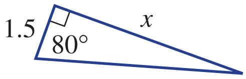

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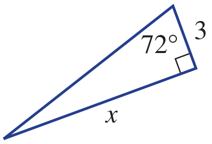
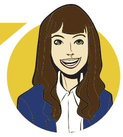
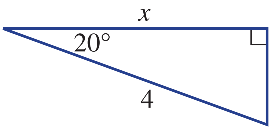


These all use tan.



9 Decide whether to use sin, cos or tan, then find the value of x in these triangles. Round to 2 decimal places.

a


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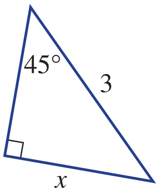

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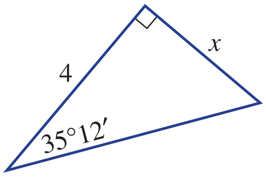

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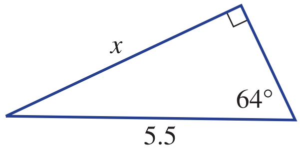

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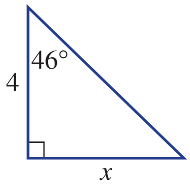

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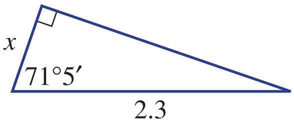
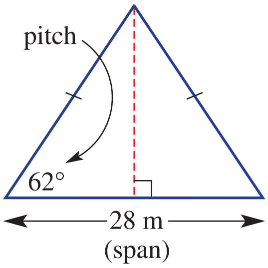


PROBLEM-SOLVING AND REASONING

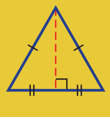
10, 11	11, 12

10 **a** Find the height of this isosceles triangle, which is similar to a roof truss, to 2 decimal places.

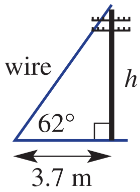
b If the span doubles to 56 m, what is the height of the roof, to 2 decimal places?



In an isosceles triangle, the perpendicular cuts the base in half.

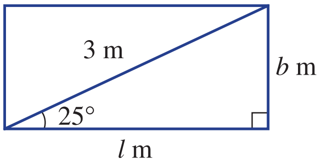


11 The stay wire of a power pole joins the top to the ground. It makes an angle of 62° with the ground. It is fixed to the ground 3.7 m from the bottom of the pole. How high is the pole, correct to 2 decimal places?

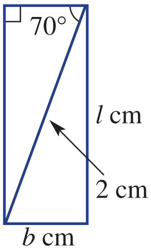


12 Find the length and breadth of these rectangles, to 2 decimal places.

a



b



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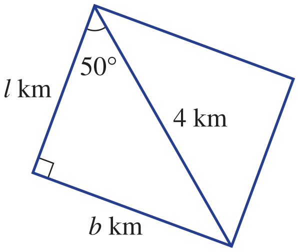
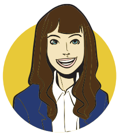


Use the hypotenuse in each calculation of *l* and *b*.



ENRICHMENT

–	13

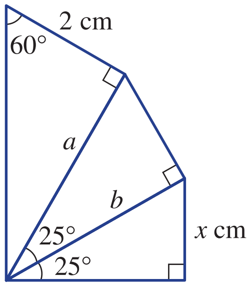
Accuracy and errors

13 Our aim is to find the value of x, correct to 2 decimal places, by first finding the value of a and b.

a Find the value of a, then b and then x, using 1 decimal place for a and b.

b Repeat this process, finding a and b, correct to 3 decimal places each, before finding x.

c Does it make any difference to your final answer for x if you round off the values of a and b during calculations?



8F Solving for the denominator

So far, we have been dealing with equations that have the pronumeral in the numerator. However, sometimes the unknown is in the denominator and these problems can be solved with an extra step in your mathematical working.

Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Solving equations with x in the denominator

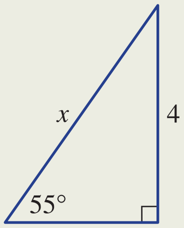
Consider the equations $\frac{x}{3} = 4$ and $\frac{3}{x} = 4$.

- Do the equations have the same solution?
- What steps are used to solve the equations?
- Now solve $\frac{4}{x} = \sin 30°$ and $\frac{2}{x} = \cos 40°$.

Key ideas

- If the unknown value is in the **denominator**, you need to do two algebraic steps to find the unknown. For example:

$$\begin{aligned} \sin\theta &= \frac{\text{opposite}}{\text{hypotenuse}} \\ \sin 55° &= \frac{4}{x} \\ x \times \sin 55° &= 4 \\ x &= \frac{4}{\sin 55°} \\ &= 4.88 \text{ (to 2 d.p.)} \end{aligned}$$



Denominator The part of a fraction that sits below the dividing line

Exercise 8F

UNDERSTANDING AND FLUENCY 1–3(½), 4–6(a) 4–6(b,c), 7(½)

1 Find the value, correct to 2 decimal places, of:

a $\frac{10}{\tan 30°}$ **b** $12 \div \sin 60°$ **c** $\frac{15}{\tan 8°}$

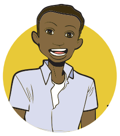
d $\frac{12.4}{\tan 32°}$ **e** $\frac{15.2}{\sin 38.2°}$ **f** $\frac{9}{\cos 47°58'}$

For part **a** enter 10 ÷ tan 30 into your calculator.

2 Solve these equations for x.

a $\frac{4}{x} = 2$ **b** $\frac{10}{x} = 2$ **c** $\frac{15}{x} = 30$

d $\frac{1.2}{x} = 1.2$ **e** $\frac{0.6}{x} = 6$ **f** $\frac{9}{x} = 90$



To solve these, you will need to complete two steps.

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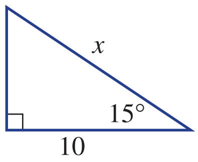
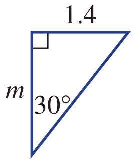
3 For each of these triangles, complete the required trigonometric ratio.

a



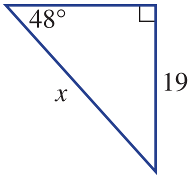
$\cos 15° = \frac{\square}{\square}$

b



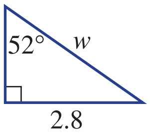
$\tan 30° = \frac{\square}{\square}$

c



$\sin 48° = \frac{\square}{\square}$

d

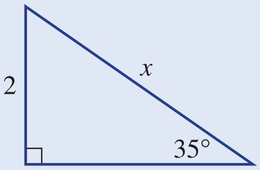


$\sin 52° = \frac{\square}{\square}$

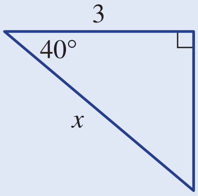
Example 12 Finding the value in the denominator

Find the value of the unknown length (x) in these right-angled triangles. Round your answer to 2 decimal places.

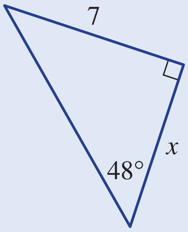
a



b



c



SOLUTION	EXPLANATION
a $\sin 35° = \frac{2}{x}$	Use $\sin\theta = \frac{O}{H}$, as we can use the opposite (2) and hypotenuse (x).
$x \times \sin 35° = 2$	Multiply both sides by x.
$x = \frac{2}{\sin 35°}$	Divide both sides by sin 35° to get x on its own.
$x = 3.48689\ldots$	Recall that sin 35° is just a number.
$\therefore x = 3.49$ (to 2 d.p.)	Evaluate and round your answer.
b $\cos 40° = \frac{3}{x}$	Use $\cos\theta = \frac{A}{H}$, as we can use the adjacent (3) and hypotenuse (x).
$x \times \cos 40° = 3$	Multiply both sides by x.
$x = \frac{3}{\cos 40°}$	Divide both sides by cos 40° to get x on its own.
$x = 3.9162\ldots$	Evaluate and round your answer.
$\therefore x = 3.92$ (to 2 d.p.)	
c $\tan 48° = \frac{7}{x}$	Use $\tan\theta = \frac{O}{A}$, as we can use the adjacent (x) and opposite (7).
$x \times \tan 48° = 7$	Multiply both sides by x.
$x = \frac{7}{\tan 48°}$	Divide both sides by tan 48° to get x on its own.
$x = 6.3028\ldots$	Evaluate and round your answer.
$\therefore x = 6.30$ (to 2 d.p.)	

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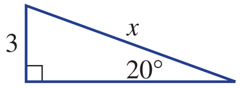
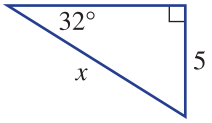
4 Find the value of the unknown length (x) in these right-angled triangles. Round your answer to 2 decimal places.

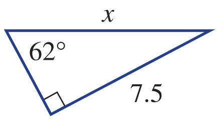
a



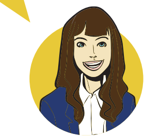
b



c

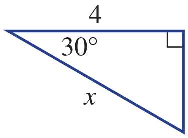


In $\sin 20 = \frac{3}{x}$, multiply both sides by x first.

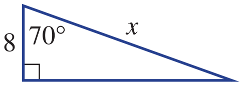


5 Find the value of the unknown length (x) in these right-angled triangles. Round your answer to 2 decimal places.

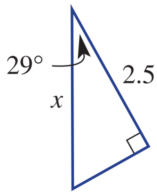
a



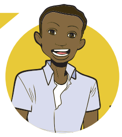
b



c

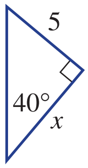


$\cos \theta = \frac{A}{H}$

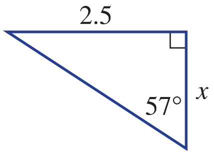


6 Find the value of the unknown length (x) in these right-angled triangles. Round your answer to 2 decimal places.

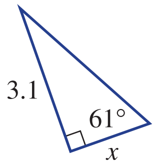
a



b



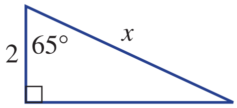
c



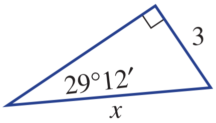
$\tan \theta = \frac{O}{A}$

7 By first deciding whether to use $\sin \theta$, $\cos \theta$ or $\tan \theta$, find the value of x in these triangles. Round your answer to 2 decimal places.

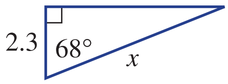
a



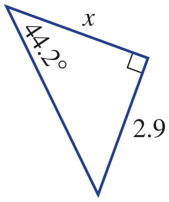
b



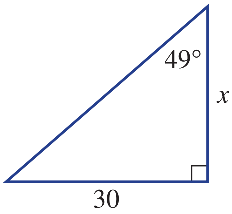
c



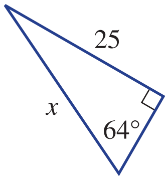
d



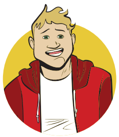
e



f



SOH CAH TOA



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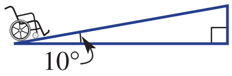
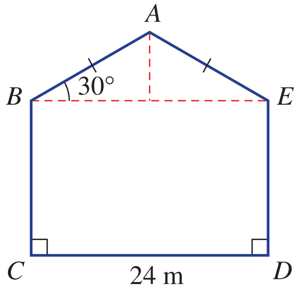
PROBLEM-SOLVING AND REASONING

8–10 9–12

8 The recommended angle of a wheelchair ramp to the horizontal is approximately 10 degrees. How long is the ramp if the horizontal distance is 2.5 metres? Round your answer to 2 decimal places.

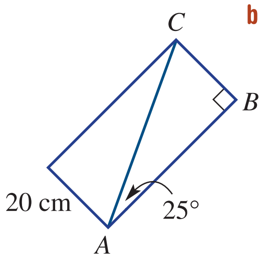


9 The roof of this barn has a pitch of 30°, as shown. Find the length of roof section AB, to 1 decimal place.

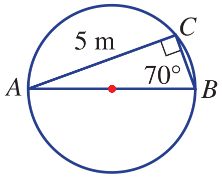


10 Find the length AB and BC in these shapes. Round your answer to 2 decimal places.

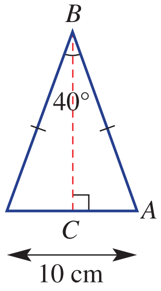
a



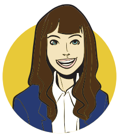
b



c



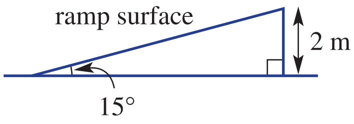
Use the given information when finding AB and BC.



11 The ramp shown has an incline angle of 15° and a height of 2 m. Find, correct to 3 decimal places:

a the base length of the ramp

b the length of the ramp surface



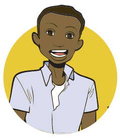
The 'incline' is the angle to the horizontal.

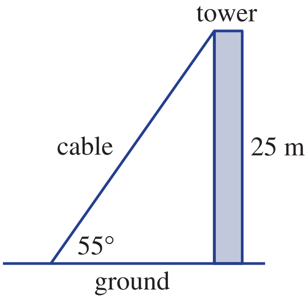
12 For this communications tower, find, correct to 1 decimal place:

a the length of the cable

b the distance from the base of the tower to the point where the cable is attached to the ground

Use 25 m as your known side in both parts **a** and **b**.





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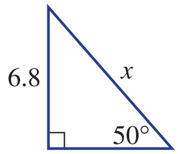
ENRICHMENT – 13

Inverting the fraction

Shown below is another way of solving trigonometric equations with x in the denominator.

Find the value of x, to 2 decimal places.



$$\sin 50^\circ = \frac{6.8}{x}$$

$$\frac{1}{\sin 50^\circ} = \frac{x}{6.8}$$

Invert both fractions so x becomes the numerator.

$$x = \frac{1}{\sin 50^\circ} \times 6.8$$

Multiply both sides by 6.8 to get x on its own.

$$\frac{1}{\sin 50^\circ} \times 6.8 = \frac{x}{6.8} \times 6.8$$

$$x = \frac{6.8}{\sin 50^\circ}$$

Use your calculator.

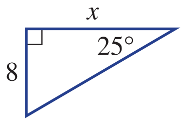
$$x = 8.87676\ldots$$

$$x = 8.88 \text{ (to 2 d.p.)}$$

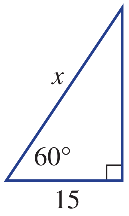
Round your answer as required.

13 Use the method shown above to find the value of x, to 2 decimal places where necessary, in each of the following.

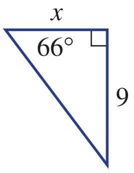
a



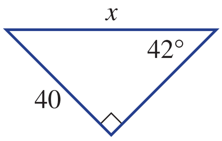
b



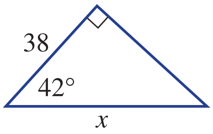
c



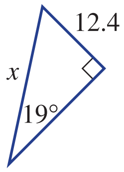
d



e



f



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8G Finding unknown angles

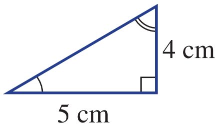
Interactive

Widgets

HOTsheets

Walkthrough

When given two side lengths of a right-angled triangle, you can find either of the acute angles. There are many different situations in which you might be given two side lengths of a right-angled triangle and be asked to find the associated angles.



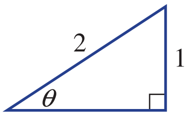
If two sides are known, the angles in the triangle can be calculated.

Stage
- 5.3#
- 5.3
- 5.3§
- 5.2
- 5.2◊
- 5.1
- 4

Let's start: Knowing the angle

Imagine a triangle that produces $\sin\theta = 0.5$.

- Use your calculator and trial and error to find a value of θ for which $\sin\theta = 0.5$.
- Repeat for $\tan\theta = 1$ and $\cos\theta = \frac{\sqrt{3}}{2}$.
- Do you know of a quicker method, rather than using trial and error?



Key ideas

- There are buttons on your calculator that find unknown angles:
  $\boxed{\sin^{-1}}$ $\boxed{\cos^{-1}}$ $\boxed{\tan^{-1}}$
- If $\sin\theta = \frac{3}{4}$, on your calculator press $\boxed{\sin^{-1}}\left(\frac{3}{4}\right)\boxed{=}$ to find θ.

Exercise 8G

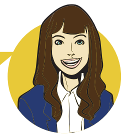
UNDERSTANDING AND FLUENCY 1–3, 4–6(½) 3, 4–6(½)

1 Calculate sin 30°. Now use the $\boxed{\sin^{-1}}$ button to solve $\sin\theta = 0.5$.

2 Use your calculator to find θ.

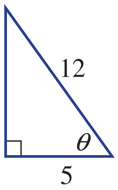
a $\sin\theta = \frac{1}{2}$ **b** $\cos\theta = \frac{1}{2}$ **c** $\tan\theta = 1$

Most calculators use shift to access $\sin^{-1}$ or $\cos^{-1}$ or $\tan^{-1}$.

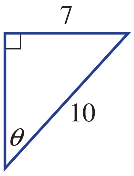


3 Write down only the trigonometric ratio for these triangles. Is it sin, cos or tan?

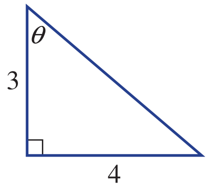
a



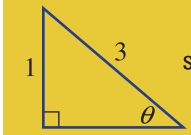
b



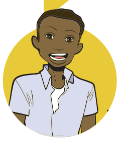
c



Look for SOH CAH TOA.



$\sin\theta = \frac{1}{3}$



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Example 13 Finding an unknown angle, correct to the nearest degree

Find the angle θ, correct to the nearest degree, in each of the following.

a $\sin\theta = \frac{2}{3}$ **b** $\cos\theta = \frac{1}{2}$ **c** $\tan\theta = 1.7$

SOLUTION	EXPLANATION
a $\sin\theta = \frac{2}{3}$	Look for the $\sin^{-1}$ button on your calculator.
$\theta = 41.8103...°$	Evaluate $\sin^{-1}\left(\frac{2}{3}\right)$ on your calculator.
$\theta = 42°$ (to the nearest degree)	Round your answer as required.
b $\cos\theta = \frac{1}{2}$	Look for the $\cos^{-1}$ button on your calculator.
$\theta = 60°$	Evaluate $\cos^{-1}\left(\frac{1}{2}\right)$.
c $\tan\theta = 1.7$ $\theta = 59.53...°$	Look for the $\tan^{-1}$ button on your calculator.
$\theta = 60°$ (to the nearest degree)	Round your answer to the nearest degree.

4 Find the angle θ, to the nearest degree, for the following.

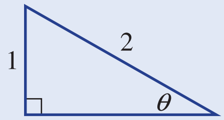
a $\sin\theta = \frac{1}{2}$
b $\cos\theta = \frac{3}{5}$
c $\sin\theta = \frac{7}{8}$
d $\tan\theta = 1$
e $\tan\theta = \frac{7}{8}$
f $\sin\theta = \frac{8}{10}$
g $\cos\theta = \frac{2}{3}$
h $\sin\theta = \frac{1}{10}$
i $\cos\theta = \frac{4}{5}$
j $\tan\theta = 6$
k $\cos\theta = \frac{3}{10}$
l $\tan\theta = \sqrt{3}$
m $\sin\theta = \frac{4}{6}$
n $\cos\theta = \frac{4}{6}$
o $\tan\theta = \frac{4}{6}$

Remember: Use $\boxed{\sin^{-1}}$, $\boxed{\cos^{-1}}$ or $\boxed{\tan^{-1}}$ on the calculator.

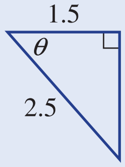
Example 14 Using SOH CAH TOA to find angles

Find θ in the following right-angled triangles, correct to 2 decimal places where necessary.

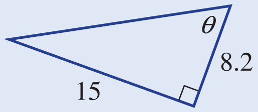
a



b



c



SOLUTION	EXPLANATION
a $\sin\theta = \frac{\text{O}}{\text{H}}$	Use $\sin\theta$ since we know the opposite and the hypotenuse.
$\sin\theta = \frac{1}{2}$	Substitute $\mathbf{O} = 1$ and $\mathbf{H} = 2$.
$\theta = 30°$	Use your calculator to find $\sin^{-1}\left(\frac{1}{2}\right)$.

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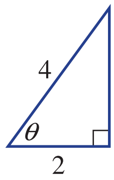
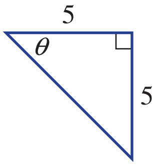
b $\cos\theta = \frac{A}{H}$	Use $\cos\theta$ since we know the adjacent and the hypotenuse.
$\cos\theta = \frac{1.5}{2.5}$	Substitute **A** = 1.5 and **H** = 2.5.
$\theta = 53.1301...^\circ$	Use your calculator to find $\cos^{-1}\left(\frac{1.5}{2.5}\right)$.
$\theta = 53.13^\circ$ (to 2 d.p.)	Round your answer to 2 decimal places.
c $\tan\theta = \frac{O}{A}$	Use $\tan\theta$ since we know the opposite and the adjacent.
$\tan\theta = \frac{15}{8.2}$	Substitute **O** = 15 and **A** = 8.2.
$\theta = 61.336...^\circ$	Use your calculator to find $\tan^{-1}\left(\frac{15}{82}\right)$.
$\theta = 61.34^\circ$ (to 2 d.p.)	Round your answer to 2 decimal places.

5 Use one of sin, cos or tan to find θ in these triangles, rounding your answer to 2 decimal places where necessary.

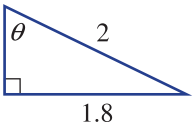
a



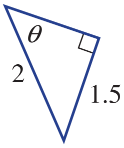
b



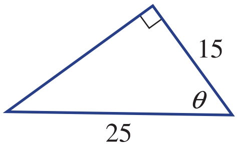
c



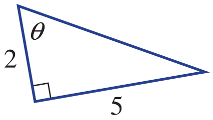
d



e

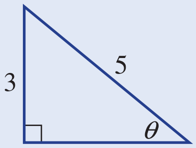


f



Example 15 Expressing your answer, correct to the nearest minute

Find the angle θ, correct to the nearest minute.



SOLUTION	EXPLANATION
$\sin\theta = \frac{3}{5}$	Use $\sin^{-1}\left(\frac{3}{5}\right)$ to find θ.
$\theta = 36.8698...^\circ$	Convert to degrees, minutes and seconds.
$\theta = 36^\circ 52' 11.63...$	Round to the nearest minute by rounding up for 30 or more seconds but rounding down for less than 30 seconds.
$\theta = 36^\circ 52'$ (to the nearest minute)	

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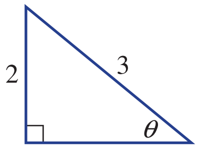
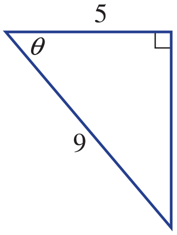
6 Find the angle θ, correct to the nearest minute, in these triangles. You will need to decide whether to use $\sin\theta$, $\cos\theta$ or $\tan\theta$.

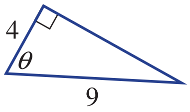
a



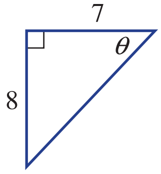
b



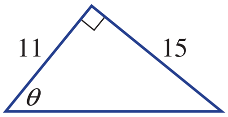
c



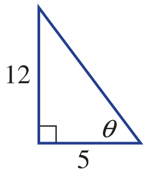
d



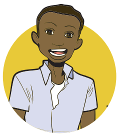
e



f



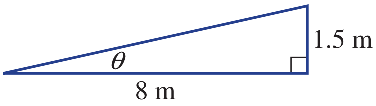
'To the nearest minute' means if the part after minutes is 30 or more, then round up.



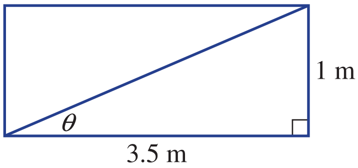
PROBLEM-SOLVING AND REASONING

7–9 9–11

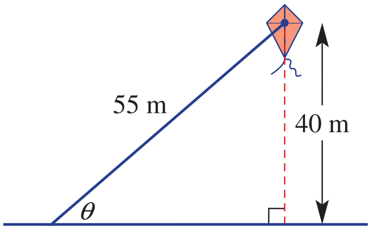
7 A ramp is 8 m long and 1.5 m high. Find the angle that the ramp makes with the ground, correct to the nearest minute.



8 A rectangular piece of timber, measuring 1 m wide and 3.5 m long, is to be cut across the diagonal. Find the angle that the cut makes with the long side (correct to the nearest minute).



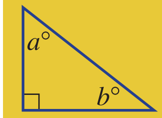
9 At what angle to the ground is a kite (shown) with height 40 m and string length 55 m? Round your answer to the nearest minute.



10 Find the two acute angles in a right-angled triangle with the given side lengths, correct to 1 decimal place.

- **a** hypotenuse 5 cm, other side 3 cm
- **b** hypotenuse 7 m, other side 4 m
- **c** hypotenuse 0.5 mm, other side 0.3 mm
- **d** the two shorter side lengths are 3 cm and 6 cm
- **e** the two shorter side lengths are 10 m and 4 m

- Draw a picture.
- Use SOH CAH TOA.
- Find one acute angle using trigonometry.
- To find the second angle, recall that all triangles have an angle sum of 180°.



$a + b + 90 = 180$

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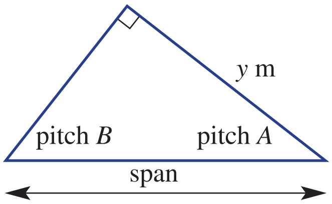
11 A roof is pitched so that the angle at its peak is 90°. If each roof truss spans 10.5 m and distance y is 7.2 m, find the pitch angles A and B, to the nearest degree.

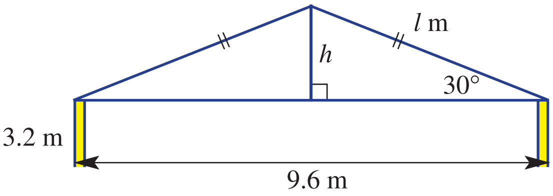


ENRICHMENT	–	12, 13

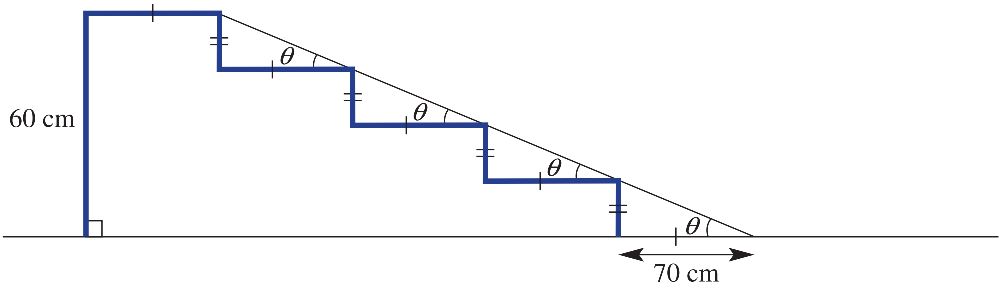
Building construction

12 **a** Find the length of the slats (l metres) needed along each hypotenuse for this roof cross-section, correct to 2 decimal places.

b Find the height of the highest point of the roof above ground level, correct to 2 decimal places.



13 A ramp is to be constructed to allow disabled access over a set of existing stairs, as shown. (Note that the diagram is not to scale.)



a What angle does the ramp make with the ground, to the nearest degree?

b Government regulations state that the ramp cannot be more than 13° to the horizontal. Does this ramp meet these requirements?

c Use Pythagoras' theorem to find the length of the ramp. Round your answer to 1 decimal place.

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8H Angles of elevation and depression

Many applications of trigonometry involve angles of elevation and angles of depression. These angles are measured up or down from a horizontal level. Such angles often involve viewing angles.

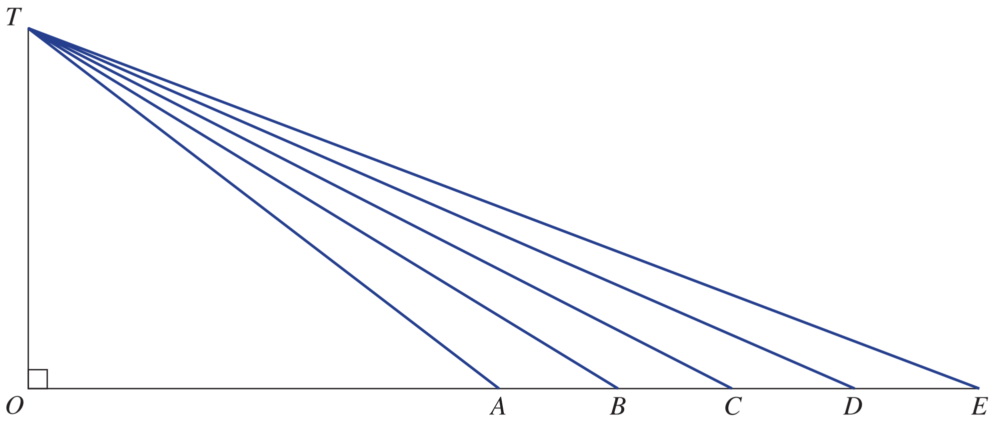
Stage

5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: How close should you sit?

The diagram below shows an outdoor movie screen (OT). The point T is the top of the screen. The points A–E are the five rows of seats in the theatre, from which a person's line of sight is taken. The line OE is the horizontal line of sight.

- Use your protractor to measure the angle of elevation from each point along the horizontal to the top of the movie screen.
- Where should you sit if you wish to have an angle of elevation between 25° and 20° and not be in the first or last row of the theatre?



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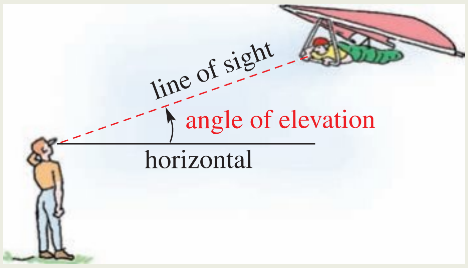
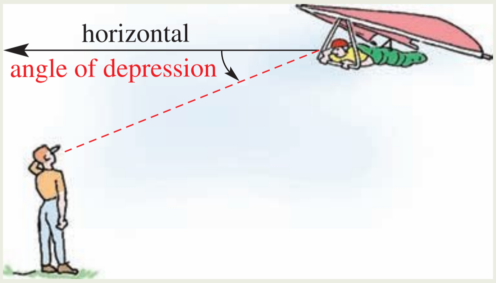
Key ideas

- Looking up to an object forms an **angle of elevation**.

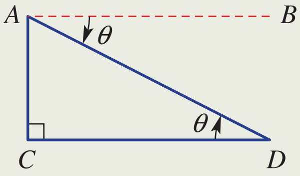


Angle of elevation The angle of your line of sight from the horizontal when looking up at an object

- Looking down to an object forms an **angle of depression**.



Angle of depression The angle of your line of sight from the horizontal when looking down at an object

- 

AB is parallel to CD.

$\therefore \angle BAD = \angle ADC$ because they are alternate angles in parallel lines.

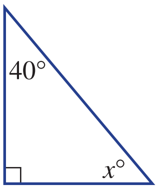
$\therefore$ Angle of elevation = Angle of depression (for the same line of sight).

Exercise 8H

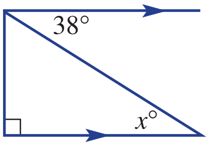
UNDERSTANDING AND FLUENCY 1–3, 4–6(½) 3, 4–6(½)

1 Find the value of x in each triangle.

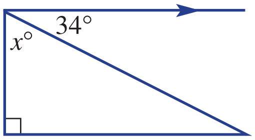
a



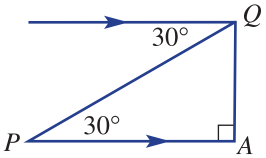
b



c



2 For this diagram:



a What is the angle of elevation of Q from P?

b What is the angle of depression of P from Q?

c What is the size of $\angle PQA$?

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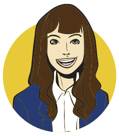
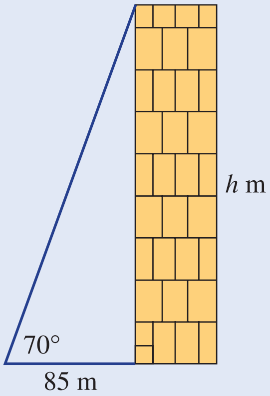
3 For each description, draw a triangle diagram that matches the information given.
- **a** The angle of elevation to the top of a tower from a point 50 m from its base is 55°.
- **b** The angle of depression from the top of a 200 m cliff to a boat out at sea is 22°.
- **c** The angle of elevation to the top of a castle wall from a point on the ground 30 m from the castle wall is 33°.

Always measure angles of elevation from the horizontal.



Example 16 Using an angle of elevation

To find the height of a tall building, Johal stands 85 m away from its base and measures the angle of elevation to the top of the building as 70°. Find the height of the building, correct to the nearest metre.



SOLUTION

$$\tan\theta = \frac{\text{O}}{\text{A}}$$

$$\tan 70° = \frac{h}{85}$$

$$h = 85 \times \tan 70°$$

$$= 233.53558...$$

$$= 234 \text{ (to the nearest metre)}$$

∴ The building is 234 m tall.

EXPLANATION

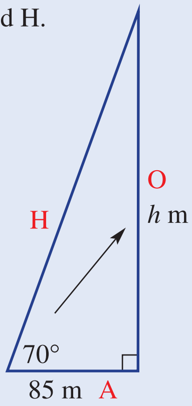
Label the triangle with O, A, and H.

Use tan, since the opposite and adjacent are given.

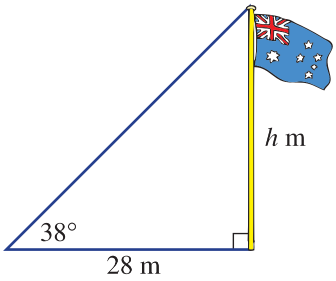
Find h by solving the equation.

$$85 \times \tan 70° = \frac{h}{85} \times 85$$

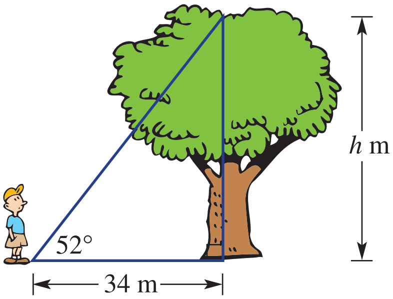
Round to the nearest metre.



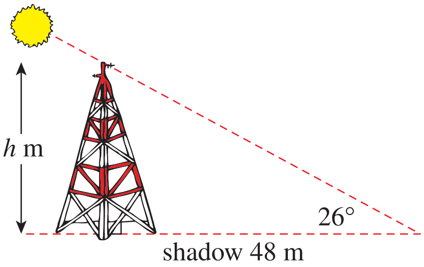
4 Solve the following problems about angles of elevation.
- **a** The angle of elevation to the top of a flagpole from a point 28 m from its base is 38°. How tall is the flagpole, correct to 2 decimal places?



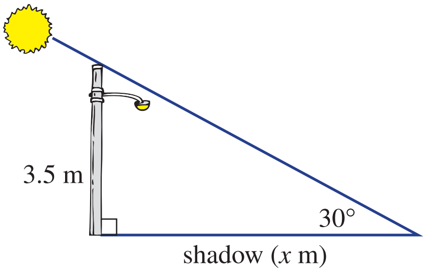
b Alvin is 34 m away from a tree and the angle of elevation to the top of the tree from the ground is 52°. What is the height of the tree, correct to 1 decimal place?



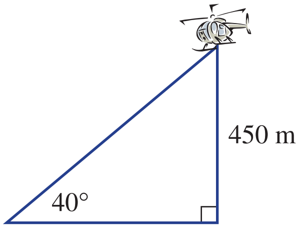
c The sun's rays shining over a tower make an angle of elevation of 26° and casts a 48 m shadow on the ground. How tall, to 2 decimal places, is the tower?



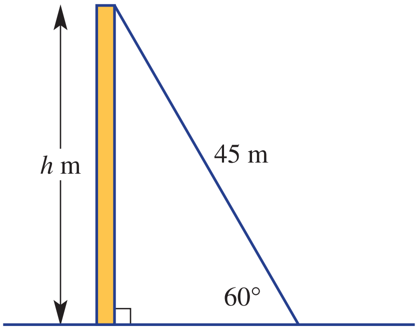
d The sun makes an angle of elevation of 30° with a lamp post 3.5 m tall. How long is the shadow on the ground, correct to 2 decimal places?



e The altitude of a hovering helicopter is 450 m, and the angle of elevation from the helipad to the helicopter is 40°. Find the horizontal distance from the helicopter to the helipad, correct to 2 decimal places.



f A cable of length 45 m is anchored from the ground to the top of a communications mast. The angle of elevation of the cable to the top of the mast is 60°. Find the height of the communications mast, correct to 2 decimal places.



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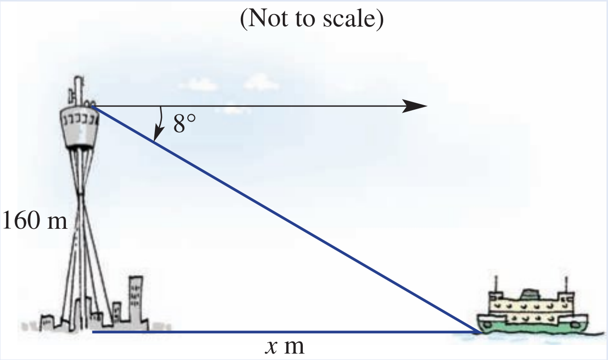
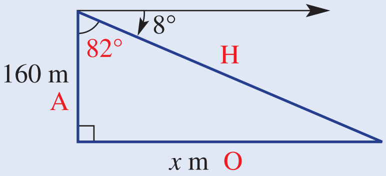
Example 17 Using an angle of depression

From the observation room of Centrepoint Tower in Sydney, which has a height of 160 m, the angle of depression of a boat moored at Circular Quay is observed to be 8°. How far from the base of the tower is the boat, correct to the nearest metre?



SOLUTION



$$\tan\theta = \frac{O}{A}$$

$$\tan 82° = \frac{x}{160}$$

$$\begin{aligned} x &= 160 \times \tan 82° \\ &= 1138.459... \\ &= 1138 \text{ (to the nearest metre)} \end{aligned}$$

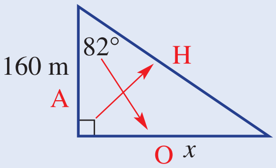
$\therefore$ The boat is about 1138 m from the base of the tower.

EXPLANATION

Draw the triangle and find the angle inside the triangle: 90° − 8° = 82° (*or* use alternate angles to label the angle of elevation as 8°).

Use this angle to label the triangle.

Use tan, since we have the opposite and adjacent.

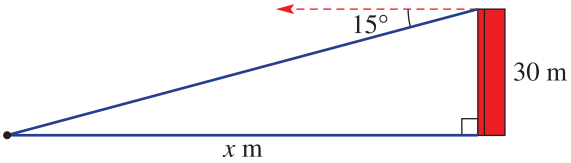


Find x by solving the equation.

Round your answer to the nearest metre.

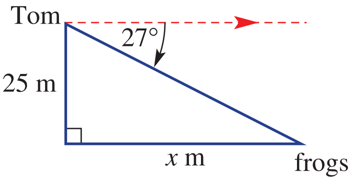
5 Answer these problems relating to angles of depression.

a The angle of depression from the top of a tower 30 m tall to a point x m from its base is 15°. Find the value of x, correct to 1 decimal place.

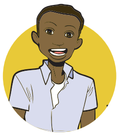


Use the angle of depression to mark an angle inside the triangle.

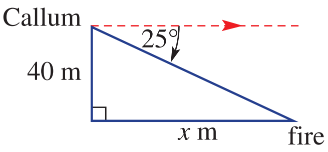
b From a bridge 25 m above a stream, Tom spots two frogs on a lilypad. He estimates the angle of depression to the frogs to be 27°. How far from the bridge are the frogs, to the nearest metre?



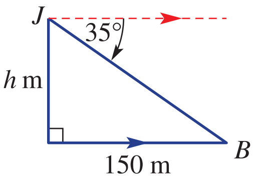
The angle of depression is the angle below the horizontal, looking down at an object.



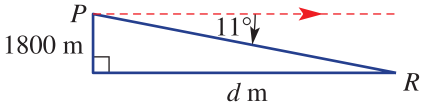
c From a lookout tower, Callum spots a bushfire at an angle of depression of 25°. If the lookout tower is 40 m high, how far away (to the nearest metre) is the bushfire from the base of the tower?



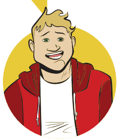
d From the top of a vertical cliff, Jung spots a boat 150 m out to sea. The angle of depression from Jung to the boat is 35°. How many metres (to the nearest whole number) above sea level is Jung?



e A plane is flying 1800 m above the ground. At the time the pilots spot the runway, the angle of depression to the edge of the runway is 11°. How far does the plane have to fly to be above the edge of the runway at its current altitude? Give your answer to the nearest whole number.



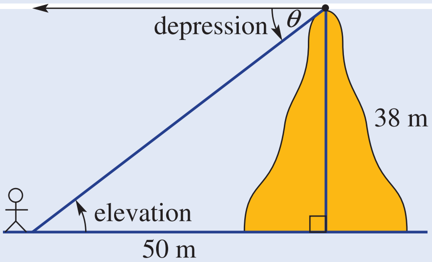
'Altitude' means height.



Example 18 Finding angles of elevation and depression

a Find the angle of depression from the top of the hill to a point on the ground 50 m from the middle of the hill. Answer to the nearest degree.

b What is the angle of elevation from the point on the ground to the top of the 38 m hill? Give your answer to the nearest degree.



SOLUTION

a $\tan\theta = \frac{\text{O}}{\text{A}}$

$\tan\theta = \frac{38}{50}$

$\theta = 37.2348\ldots°$

$\theta = 37°$ (to the nearest degree)

Angle of depression is 37°.

b Angle of elevation is 37°.

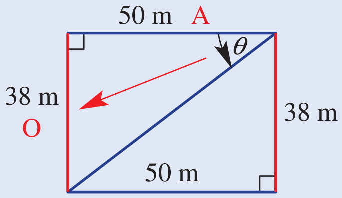
EXPLANATION

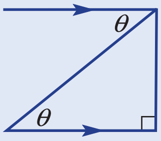
Aim is to find θ.

Redraw the diagram as a rectangle so that θ is inside the triangle.

Label the triangle: opposite and adjacent.

Use tan.

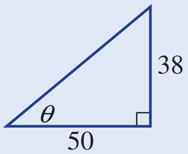




Alternate angles are equal when lines are parallel.

Angle of elevation = Angle of depression

Alternatively, use $\tan\theta = \frac{38}{50}$.



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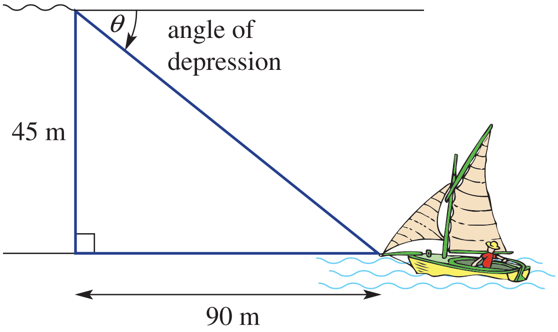
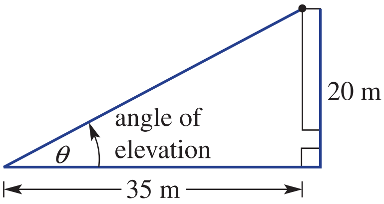
6 Answer these questions about finding angles of elevation and depression. Round all answers to 1 decimal place.

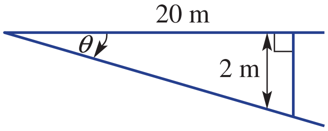
a From the top of a vertical cliff, Jacky spots a boat 90 m out to sea. If the top of the cliff is 45 m above sea level, find the angle of depression from the top of the cliff to the boat.



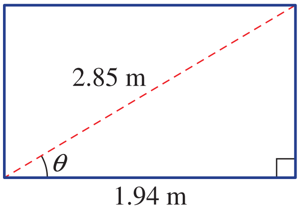
b Find the angle of elevation from a person sitting 35 m from a movie screen to the top of the screen, which is 20 m above the ground.



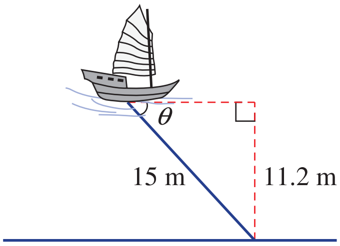
c A person sits 20 m away from a screen that is 2 m below the horizontal viewing level. Find the angle of depression of the person's viewing level to the screen.



d A diagonal cut 2.85 m long is to be made on a piece of plaster board attached to a wall, as shown. The base of the plaster board measures 1.94 m. Find the angle of elevation of the diagonal cut from the base.

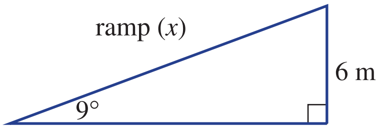


e As shown in the diagram, a 15 m chain with an anchor attached is holding a boat in a position against a current. If the water depth is 11.2 m, find the angle of depression from the boat to where the anchor is fixed to the seabed.

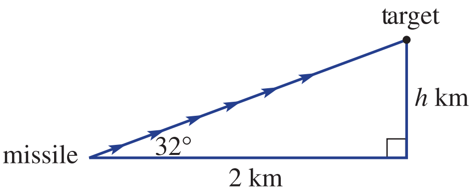


PROBLEM-SOLVING AND REASONING	7, 8	8–10

7 A ramp for wheelchairs is constructed to a footbridge that is 6 m high. The angle of elevation is to be 9°. What is the length of the ramp, correct to 2 decimal places?



8 A missile is launched at an angle of elevation of 32°. If the target is 2 km away on the horizontal, how far above ground level is the target, correct to 2 decimal places?



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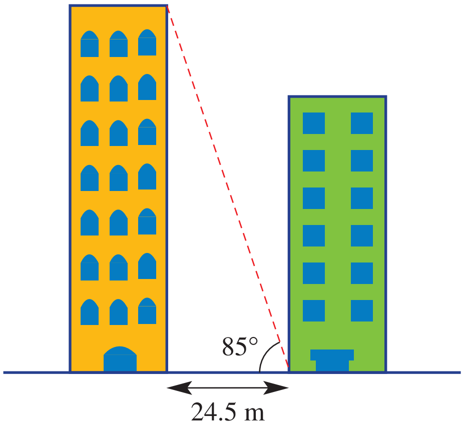
9 The distance between two buildings is 24.5 m. Find the height of the taller building, correct to 2 decimal places, if the angle of elevation from the base of the shorter building to the top of the taller building is 85°.



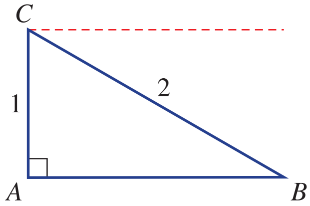
10 For this triangle:

a Find the angle of elevation from B to C.

b State the angle of depression from C to B.

c Describe the relationship that exists between these two angles.

d Find the length AB, correct to 1 decimal place.



ENRICHMENT	–	11

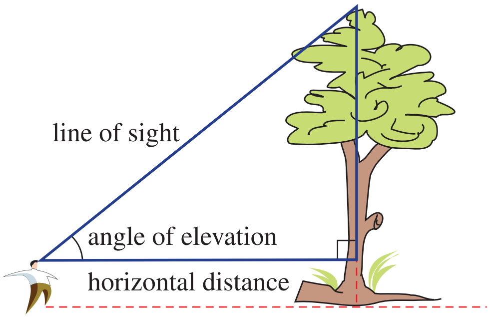
Practical trigonometry – measuring heights

11 It is not always possible or practical to measure the height of an object directly. Here you will find the height of an object that is difficult to measure.

Select a building or other structure (e.g. a statue or flagpole) to calculate its height. You must be able to measure right up to the base of the structure.

a Choose a position from which you can see the top of your structure, and measure the angle of elevation, θ, from your eye level. (Use an inclinometer, if your teacher has one, or simply estimate the angle using a protractor.)

b Measure the distance along the ground (d) from your location to the base of the structure.



c Calculate the height of the structure. *Remember to make an adjustment for the height of your eye level from the ground.*

d Move to another position and repeat the measurements. Calculate the height using your new measurements.

e Was there much difference between the calculated heights? Suggest reasons for any differences.

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8I Direction and bearings

Interactive

Widgets

HOTsheets

Walkthrough

Bearings are used to communicate a direction, and are important in navigation. Ships, planes, bushwalkers and the military all use bearings when communicating direction.

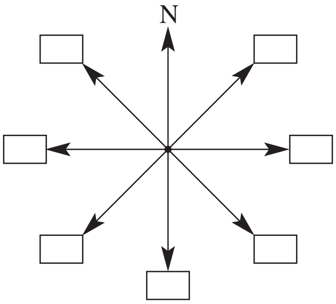
Planes and ships need bearings to navigate the skies and seas.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

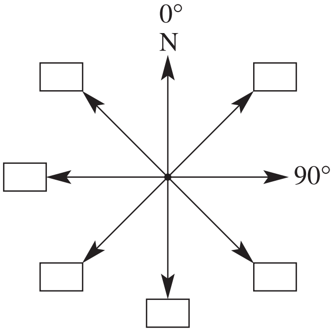
Let's start: Compass bearings

Work together as a class to label the 8-point compass rose, using letters/words in **a** and angles in **b**.

a



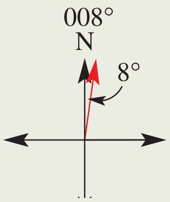
b

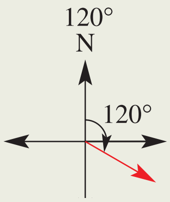


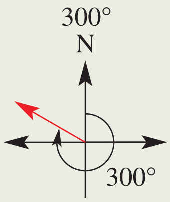
c Use the internet to find the names of the 16 directions on a mariner's compass.

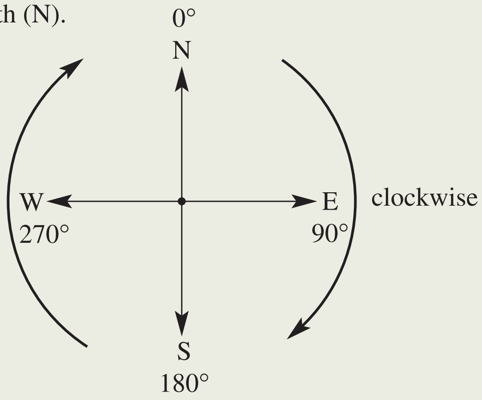
Key ideas

- A **bearing** is an angle measured clockwise from north (N).
  - It is written using 3 digits.
    For example:



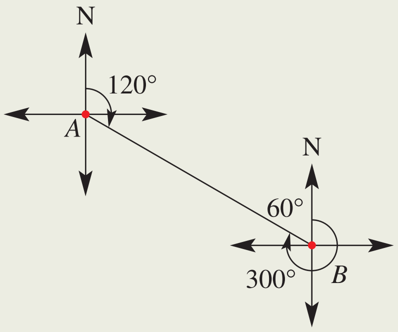






Bearing An angle that is measured clockwise from north (N)

- The word *from* indicates the direction from which a bearing is being taken.
  For example:



The bearing of *B* from *A* is 120°.

The bearing of *A* from *B* is 300°.

- When solving problems relating to bearings, always draw a diagram using N, S, E and W each time a bearing is used.

Exercise 8I

UNDERSTANDING AND FLUENCY 1, 2, 3(½), 4–6 4–8

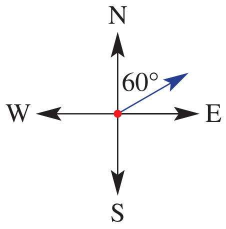
1 What is the opposite direction to:

a north (N)?
b east (E)?
c south (S)?
d north-east (NE)?

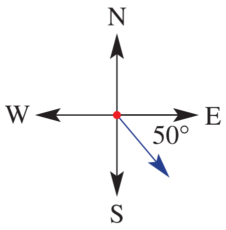
2 Match each diagram below (**A**–**F**) with the correct bearing (**a**–**f**).

a 300° **b** 260°
c 225° **d** 140°
e 060° **f** 350°

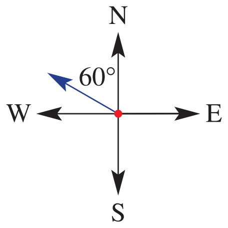
A



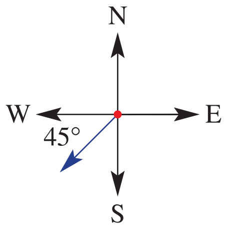
B



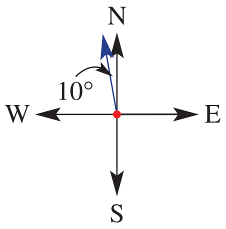
C



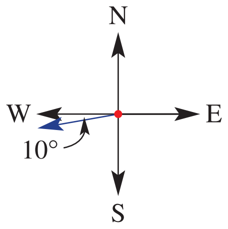
D



E



F



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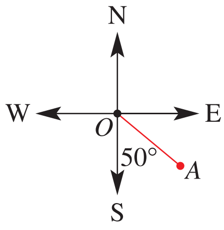
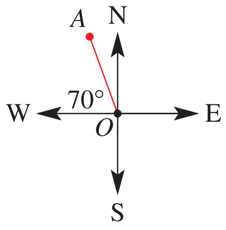
3 Write down the bearings of A from O, as shown in these diagrams.

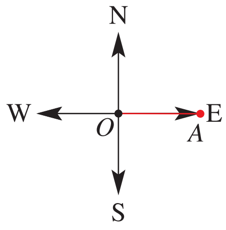
a



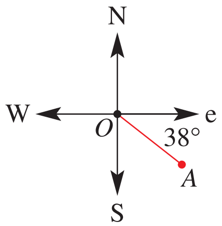
b



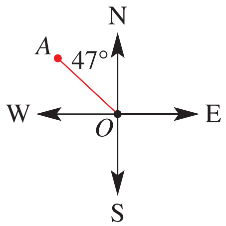
c



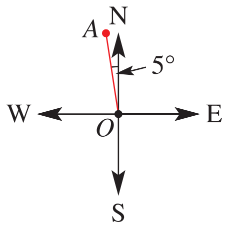
d



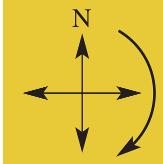
e

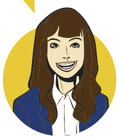


f



Remember to use 3 digits and to go clockwise from north.





4 Fill in the missing terms and values below for the diagram shown.

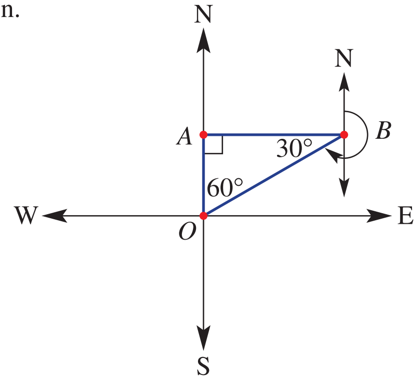
a A is due __________ of O.

b B is due __________ of A.

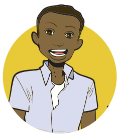
c A is due __________ of B.

d The bearing of B from O is __________.

e The bearing of O from B is __________.



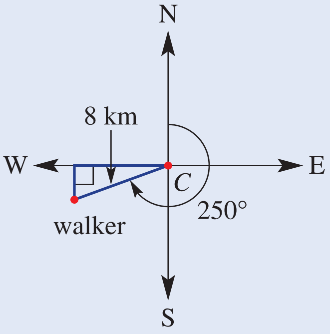
For part **e**, start from north and move clockwise to the line BO.

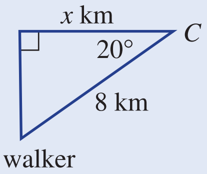


Example 19 Drawing a diagram

A walker leaves camp (C) and walks on a bearing of 250° for 8 km. How far west of camp (x km) is the walker? Show all this information on a right-angled triangle. You do not need to solve for x.

SOLUTION





EXPLANATION

Draw the compass points first.

Start your diagram with the camp at the centre.

Mark in 250° clockwise from north, 8 km.

Draw a line from the walker to the west line at right angles.

Redraw the triangle showing any angles and lengths known (270° − 250° = 20°). Place a pronumeral on the required side.

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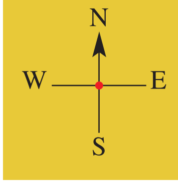
5 Draw a right-angled triangle for each of the situations outlined below.

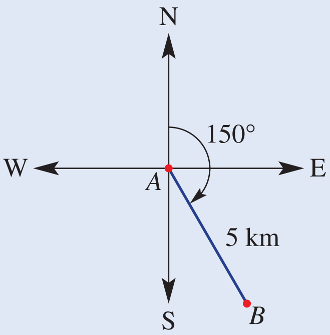
- **a** Zahra runs on a bearing of 300° from her home for 6 km. How far north of home is she when she stops?
- **b** Barry walks 12.5 km from camp *C* on a bearing of 135°. How far south is he now from camp *C*?
- **c** Tim walks due south for 10 km and then turns and walks due east for 12 km. What is his bearing from *O*, his starting point?

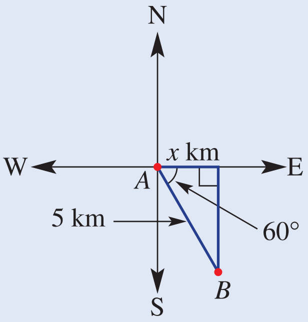
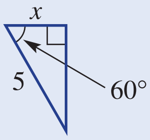
Start by marking the starting point at the centre of a compass.



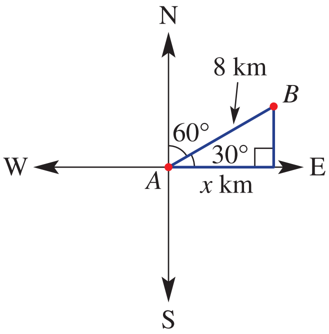
Example 20 Finding distances with bearings

A bushwalker walks 5 km on a bearing of 150° from point *A* to point *B*. Find how far east point *B* is from point *A*.

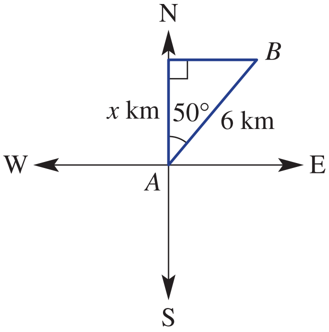


SOLUTION	EXPLANATION
 	Copy the diagram and draw a line from *B* up to the east line. Use the pronumeral *x* along the east line. Find the angle within the triangle: 150° − 90° = 60° Redraw the triangle.
$\cos\ \theta = \frac{\text{A}}{\text{H}}$ $\cos 60° = \frac{x}{5}$	Since the adjacent (A) and hypotenuse (H) are given, use cos.
$x = 5 \times \cos 60°$ $x = 2.5$	Solve the equation to find *x*.
∴ Point *B* is 2.5 km east of point *A*.	Answer the question.

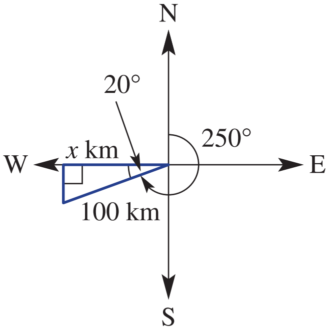
6 Tran walks 8 km from point A to point B on a bearing of 060°. How far east, correct to 1 decimal place, is point B from point A?



7 A bushwalker walks 6 km on a bearing of 050° from point A to point B. Find how far north point B is from point A, correct to 2 decimal places.



8 A speed boat travels 100 km on a bearing of 250°. Find how far west it is from its starting point, correct to 2 decimal places.



PROBLEM-SOLVING AND REASONING

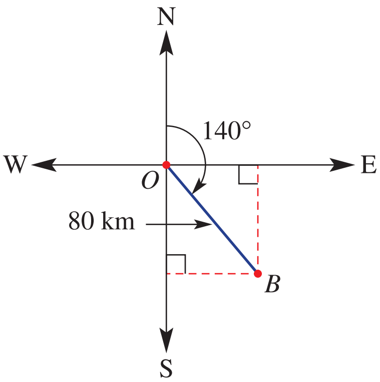
9, 10	9–11

9 A fishing boat starts from point O and sails 80 km on a bearing of 140° to point B.

a How far east of point O is point B? Give your answer to 2 decimal places.

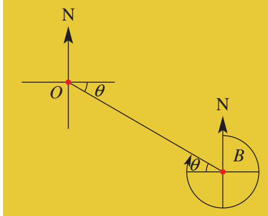
b How far south of point O is point B? Give your answer to 2 decimal places.

c What is the bearing of point O from point B?

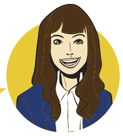


Remember what ‘from’ means!

Remember: To find a bearing, face north and turn clockwise.

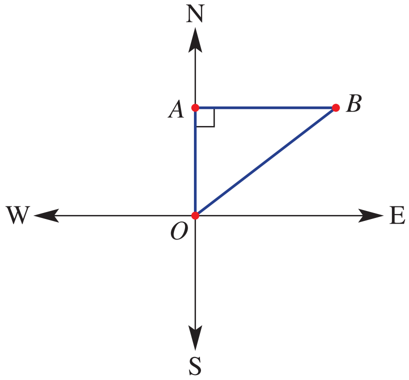


Bearings are given as a 3-digit angle.



10 A plane flies from point O 50 km due north to point A, and then turns and flies 60 km east to point B.

a Copy the diagram below and mark in the lengths 50 km and 60 km.



Pythagoras' theorem:
$c^2 = a^2 + b^2$

b Use Pythagoras' theorem to find the distance of B from O, correct to 2 decimal places.

c Use trigonometry to find the size of angle AOB. Round your answer to the nearest degree.

d What is the bearing of B from O?

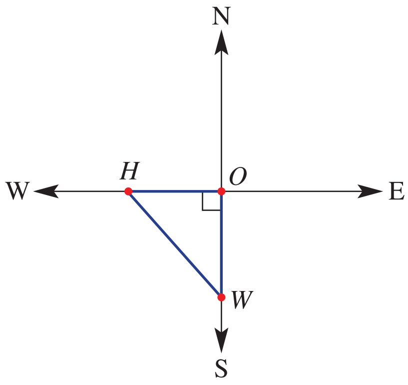
11 William and Harry both leave camp O at the same time. William walks south from O for 10 km. Harry walks west from O for 8 km.

a Copy and complete the diagram for this question.

b How far is Harry from William? Give your answer to 1 decimal place.

c Find the size of angle OWH, correct to the nearest degree.

d What is the bearing of Harry from William?



You can use Pythagoras' theorem here.

ENRICHMENT – 12–14

Drawing your own diagrams

12 Tao walks on a bearing of 210° for 6.5 km. How far west is he from his starting point?

13 A plane flies on a bearing of 320° from airport A for 150 km. At this time how far north of the airport is the plane? Give your answer to the nearest kilometre.

14 Point A is 10 km due east of point O, and point B is 15 km due south of point A.

a How far is it, correct to 2 decimal places, from point B to point O?

b What is the bearing, to the nearest degree, of point B from point O?

Remember: The word 'from' indicates where the bearing is being taken from.

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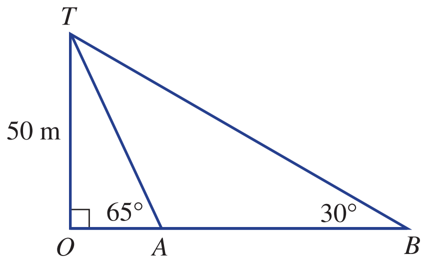
Puzzles and challenges

1 What is the opposite direction to:

a east? **b** NE? **c** SE? **d** 018°? **e** 300°?

2 Use two different right-angled triangles to find the distance from *A* to *B* in this diagram, correct to 2 decimal places.



3 Make up your own saying, using SOH CAH TOA as the first letter of each word.

S ___ O ___ H ___ C ___ A ___ H ___ T ___ O ___ A ___

4 In the wordfind below there are 17 terms that were used in this chapter. See if you can locate all 17 terms and write a definition or draw a diagram for each of them.

S	I	D	R	T	Y	I	P	Y	T	S	O	H	T	H
I	D	E	P	R	E	S	S	I	O	N	D	Y	O	Y
N	T	E	I	N	T	E	W	P	Y	A	D	J	H	P
E	I	O	G	E	D	S	V	B	Y	T	P	U	W	O
Q	U	O	T	R	S	I	A	D	J	A	C	E	N	T
A	D	A	N	G	E	D	E	P	R	A	N	G	L	E
S	E	N	A	R	T	E	E	G	R	I	L	K	O	N
D	P	T	R	I	A	N	G	L	E	H	E	I	P	U
C	T	R	I	G	O	N	O	M	E	T	R	Y	P	S
B	A	C	G	B	L	I	N	O	Y	A	A	W	O	E
H	D	O	H	T	E	A	N	G	L	N	T	H	S	H
U	J	S	T	R	G	A	O	K	Y	G	I	I	I	Y
J	E	I	W	F	L	N	R	M	K	E	O	D	T	P
K	N	N	T	J	T	R	N	I	O	N	P	Z	E	O
E	L	E	V	A	T	I	O	N	N	T	P	A	M	B
E	T	B	A	S	P	Y	T	H	A	G	O	R	A	S

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Right-angled triangles

Trigonometric ratios

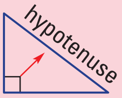
S O H → $\sin\theta = \frac{O}{H}$

C A H → $\cos\theta = \frac{A}{H}$

T O A → $\tan\theta = \frac{O}{A}$

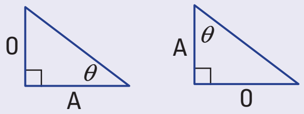
Hypotenuse

The *hypotenuse* is the longest side in a right-angled triangle. It is opposite the right angle.



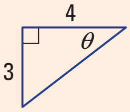
Opposite and Adjacent

In a right-angled triangle, the sides marked 'opposite' and 'adjacent' are named according to the angle used.



Finding angles

Use $\sin^{-1}$, $\cos^{-1}$ or $\tan^{-1}$.



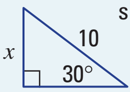
$\tan\theta = \frac{3}{4}$

$\theta = 36.869\ldots°$

$\theta = 37°$

(to the nearest degree)

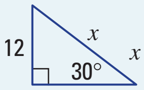
Finding lengths with trigonometry



$\sin 30° = \frac{x}{10}$

$x = 10 \sin 30°$

$x = 5$



$\sin 30° = \frac{12}{x}$

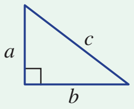
$x \times \sin 30° = 12$

$x = \frac{12}{\sin 30°}$

$x = 24$

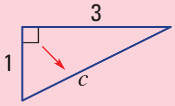
Pythagoras' theorem

For the triangle shown, *Pythagoras' theorem* is:



$c^2 = a^2 + b^2$

Finding the hypotenuse



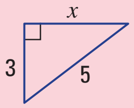
$c^2 = 1^2 + 3^2$

$c^2 = 10$

$c = \sqrt{10}$

$= 3.2$ (1 decimal place)

Finding a shorter side



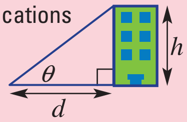
$5^2 = x^2 + 3^2$

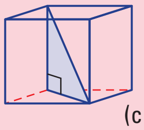
$x^2 = 5^2 - 3^2$

$x^2 = 16$

$x = 4$

Applications

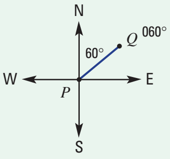




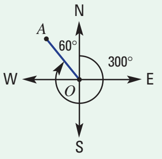
(cube)

Bearings

3-digit angle clockwise from north

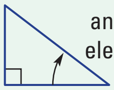


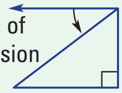
Bearing of *Q* from *P* is 060°.



Bearing of *A* from *O* is 300°.

Elevation and depression





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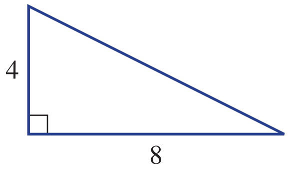
Multiple-choice questions

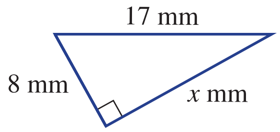
1 The length of the hypotenuse in the triangle shown is closest to:

A 10 **B** 9 **C** 4
D 100 **E** 64



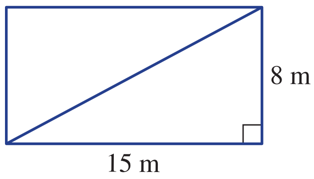
2 The length of the side marked x in the triangle shown is:

A 23 **B** 17 **C** 12
D 19 **E** 15



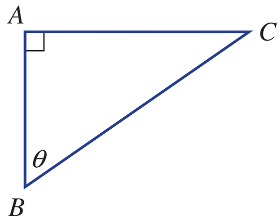
3 For the shape shown to be a rectangle, the length of the diagonal must be:

A 15 m **B** 8 m **C** 17 m
D 23 m **E** 32 m



4 Which side (i.e. *AB*, *AC* or *BC*) is the adjacent to θ in this triangle?

A *AC* **B** *AB* **C** *BC*
D hypotenuse **E** opposite

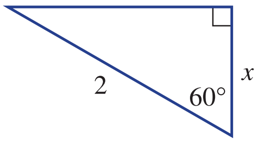


5 The value of $\cos 21^\circ$ is closest to:

A −0.55 **B** 0.9 **C** 0.9336 **D** 0.93 **E** 0.934

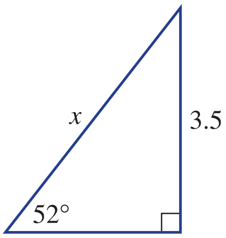
6 The value of x in this triangle is:

A $2 \div \cos 60^\circ$ **B** $2 \div \sin 60^\circ$ **C** $2 \times \cos 60^\circ$
D $2 \times \sin 60^\circ$ **E** $2 \times \tan 60^\circ$



7 The value of x in this triangle is closest to:

A 2.76 **B** 4.48 **C** 5.68
D 4.44 **E** 2.73



8 A metal brace sits at 55° to the horizontal and reaches 4.2 m up a wall. The distance between the base of the wall and the base of the brace is closest to:

A 6.00 m **B** 2.41 m **C** 7.32 m **D** 5.13 m **E** 2.94 m

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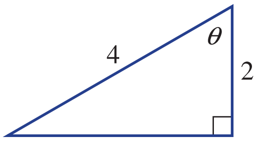
9 The angle θ in this triangle is:

A 60° **B** 30° **C** 26.57°
D 20° **E** none of the above

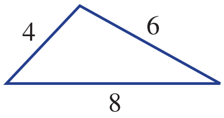


10 The angle of depression from a roof of a building to a trampoline is 75°. If the roof is 12 m above the level of the trampoline, then the distance of the trampoline from the building is closest to:

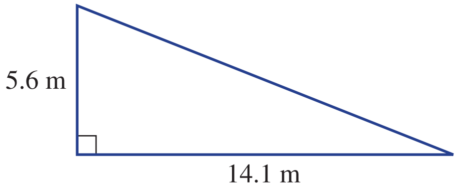
A 12.42 m **B** 11.59 m **C** 3.22 m **D** 44.78 m **E** 3.11 m

Short-answer questions

1 Determine whether this triangle shown contains a right angle.



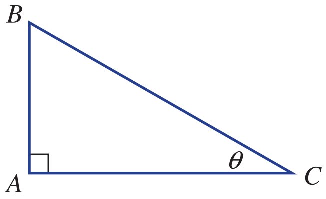
2 Find the length of the hypotenuse, correct to 2 decimal places, in the triangle shown.



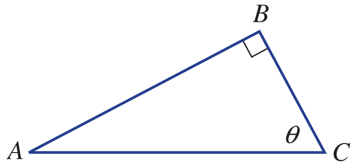
3 Which side (i.e. AB, AC or BC) of these triangles is:

i the hypotenuse?
ii the opposite to θ?
iii the adjacent to θ?

a



b

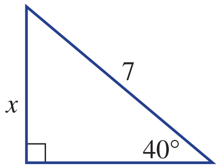


4 Use a calculator to find the value of each of the following, rounding your answer to 2 decimal places.

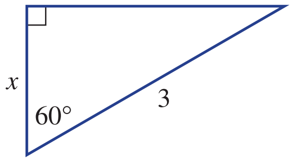
a sin 35°
b cos 17°
c tan 83°12′

5 Find the value of the unknown length (x) in these triangles. Round your answer to 2 decimal places where necessary.

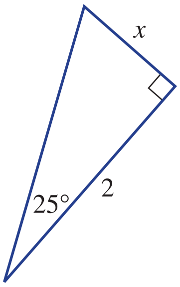
a



b



c



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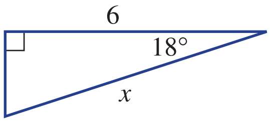
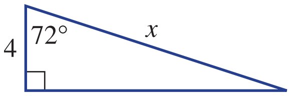
6 Find the value of the unknown length (x) in these right-angled triangles. Round your answer to 2 decimal places.

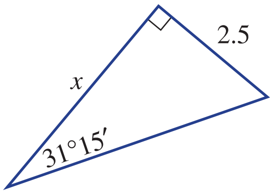
a



b



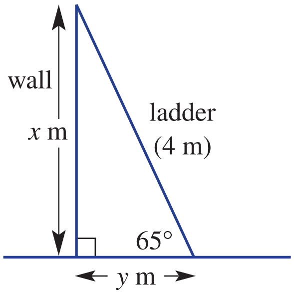
c



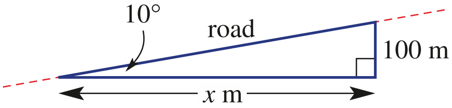
7 A 4 m ladder leans, as shown, against a wall at an angle of 65° to the horizontal.

a Find how high up the wall the ladder reaches (x m), correct to 2 decimal places.

b Find how far the bottom of the ladder is from the wall (y m), correct to 2 decimal places.

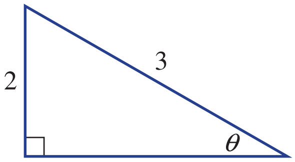


8 A section of road has a slope of 10° and gains 100 m in height. Find the horizontal length of the road (x m), correct to 2 decimal places.

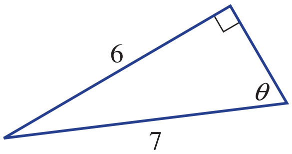


9 Find θ in the following right-angled triangles, correct to the nearest minute.

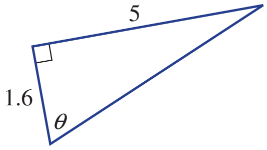
a



b



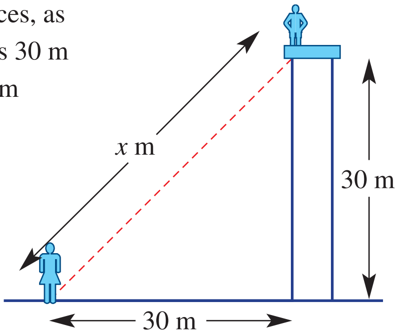
c



10 Barney and Mary view each other from two different places, as shown. Barney is on a viewing platform, whereas Mary is 30 m from the base of the platform, on the ground. The platform is 30 m above the ground.

a Find the angle of elevation from Mary's feet to the base of the platform.

b Using your answer to part **a**, find the distance (x m) between Mary and Barney, correct to 1 decimal place.



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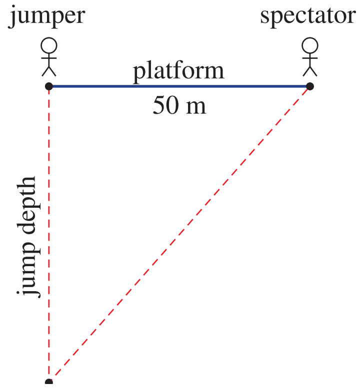
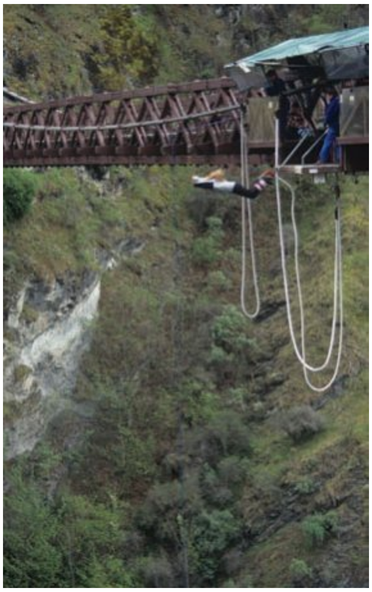
Extended-response questions

1 A spectator is viewing bungee jumping from a point 50 m to the side but level with the jumping platform.





a The first bungee jumper has a maximum fall of 70 m. Find the angle of depression from the spectator to the bungee jumper at the maximum depth, correct to 2 decimal places.

b The second bungee jumper's maximum angle of depression from the spectator is 69°. Find the jumper's maximum depth, correct to 2 decimal places.

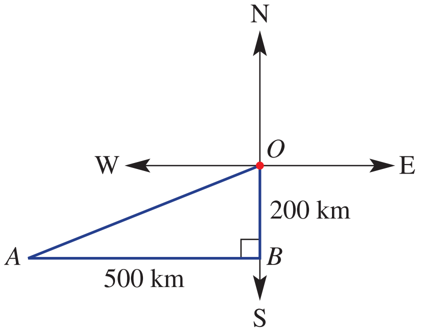
c The third jumper wants to do the 'Head Dunk' into the river below. This occurs when the spectator's angle of depression to the river is 75°. Find, correct to the nearest metre, the height of the platform above the river.

2 A military plane flies 200 km from point O to point B, then west 500 km to point A.

a How far is A from O (to the nearest kilometre)?

b What is angle BOA, correct to the nearest degree?

c What is the bearing of A from O?



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Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

9 Equations, formulas and inequalities

What you will learn

9A Linear equations with pronumerals on one side REVISION
9B Equations with brackets, fractions and pronumerals on both sides
9C Using formulas
9D Linear inequalities
9E Solving simultaneous equations graphically
9F Solving simultaneous equations using substitution
9G Solving simultaneous equations using elimination

NSW syllabus

STRAND: NUMBER AND ALGEBRA

SUBSTRAND: EQUATIONS

Outcome

A student solves linear and simple quadratic equations, linear inequalities and linear simultaneous equations, using analytical and graphical techniques. (MA5.2–8NA)

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Tracking business profits

There are over 2 million businesses in Australia with many thousands of new start-ups each year. To be successful, a business must not confuse incoming cash with profit. All operating expenses need to be considered to accurately determine production costs.

Analysing and monitoring business finances requires mathematical skills. Two important business equations calculate the number of items, N, to breakeven (i.e. no profit and no loss) and profit margin, M (i.e. profit as a percentage of sales).

$$N = \frac{\text{Fixed costs per year}}{\text{Item sale price} - \text{Production cost per item}}$$

$$M = \frac{\text{Total sales in \$} - \text{Production costs}}{\text{Total sales in \$}} \times 100$$

It takes more than talent to come up with good ideas for new products and services for a business to be successful. A good grasp of these equations helps talented business owners keep track of cash flow and ensure their ideas are turned into profit.

Pre-test

1 If $a = 6$ and $b = -3$, evaluate the following.

a $a + b$ **b** $a - b$ **c** ab
d a^2 **e** b^2 **f** $3(a + 2b)$

2 If $m = 4$, $n = 7$ and $p = -2$, evaluate the following.

a $m + n + p$ **b** $4m + p$ **c** $p(4 - n)$
d $3m + 2n$ **e** $\frac{8m}{p}$ **f** $2m^2$

3 Simplify the following.

a $a + 2a$ **b** $4m - m$ **c** $6p + 2p$ **d** $7m - 7m$
e $2m - 7m$ **f** $8x + y - x$ **g** $8p + 4p - 3p$ **h** $7m - 4m + 3m$

4 Simplify the following.

a $5x \times 3$ **b** $4p \times 4$ **c** $8x \times 4y$
d $6a \times (-5)$ **e** $a \times b$ **f** $6x \div 6$
g $m \div m$ **h** $6a \div 3$ **i** $\frac{15a}{5a}$

5 Complete the following.

a $x + 5 - \square = x$ **b** $w - 3 + \square = w$ **c** $p - 5 + \square = p$
d $z + 1 - \square = z$ **e** $w \times 4 \div \square = w$ **f** $a \div 2 \times \square = a$
g $m - 3 + \square = m$ **h** $2m \div \square = m$ **i** $\frac{x}{4} \times \square = x$
j $\frac{m}{3} \times \square = m$ **k** $6a \div \square = a$ **l** $10x \div \square = x$

6 Simplify the following.

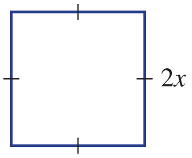
a $a + 6 - 6$ **b** $w + 9 - 9$ **c** $3w \div 3$
d $5z \div 5$ **e** $8n + 3 - 3$ **f** $6x \div 6$
g $2p - 3 + 3$ **h** $\frac{x}{2} + 1 - 1$ **i** $\frac{x}{7} \times 7$

7 Write an expression for each of the following.

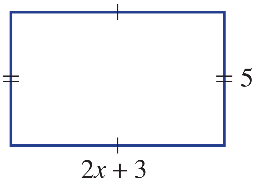
a the sum of x and 3 **b** six more than n
c double w **d** half of x
e six more than double x **f** seven less than x
g three more than x is then doubled **h** one more than triple x

8 Write an expression for the perimeter of the following.

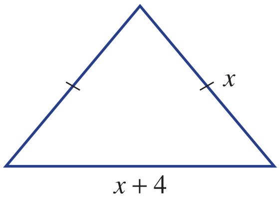
a



b



c



9 Choose the equations from the following.

a $x + 3$ **b** $3x - 6 = 9$ **c** $x^2 - 8$
d $2x$ **e** $3a = 12$ **f** $x^2 = 100$
g $1 = x - 3$ **h** $m - m$ **i** $2p = 0$

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9A Linear equations with pronumerals on one side REVISION

Interactive
Widgets
HOTsheets
Walkthrough

A cricket batsman will put on socks, then cricket shoes and, finally, pads, in that order. When the game is over, these items are removed in reverse order: first the pads, then the shoes and, finally, the socks. Nobody takes their socks off before their shoes. A similar reversal occurs when solving equations.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

We can undo the operations around the pronumeral (e.g. x) by applying the opposite operations in the reverse order to how they have been applied to the pronumeral. To keep each equation balanced, we always apply the same operation to both sides of an equation.

For example:

Applying operations to $x = 7$:

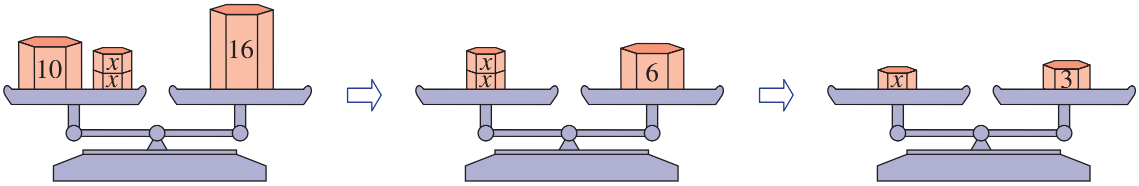
$$\begin{tikzcd} x = 7 \arrow[d, bend right, "\times 2"'] \arrow[d, bend left, "\times 2"] \\ 2x = 14 \arrow[d, bend right, "+12"'] \arrow[d, bend left, "+12"] \\ 2x + 12 = 26 \end{tikzcd}$$

Undoing the operations around x:

$$\begin{tikzcd} 2x + 12 = 26 \arrow[d, bend right, "-12"'] \arrow[d, bend left, "-12"] \\ 2x = 14 \arrow[d, bend right, "\div 2"'] \arrow[d, bend left, "\div 2"] \\ x = 7 \end{tikzcd}$$

Let's start: Keeping it balanced

Three weighing scales are each balanced with various weights on the left and right pans.



Balanced scales 1 **Balanced scales 2** **Balanced scales 3**

- What weight has been removed from each side of scales 1 to get to scales 2?
- What has been done to both the left and right sides of scales 2 to get to scales 3?
- What equations are represented in each of the balanced scales shown above?
- What methods can you recall for solving equations?

Key ideas

- An **equation** is a mathematical statement that contains an equals sign. The equation will be true only for certain value(s) of the pronumeral(s) that make the left-hand side equal to the right-hand side.

  For example: $\frac{5x}{6} = 2$, $3p + 2t = 6$ are equations; $6x - 13$ is not an equation.

Equation A mathematical statement that states that two expressions have the same value

Key ideas

- A **linear equation** contains a pronumeral (e.g. x) to the power of 1 and no other powers.
  For example: $3x - 5 = 7$, $4(m - 3) = m + 6$ are linear equations; $x^2 = 49$ is not linear.

Linear equation An equation whose pronumerals are always to the power of 1 and do not multiply or divide each other

- Every equation has a left-hand side (LHS) and a right-hand side (RHS).
  For example: $\underbrace{2x + 12}_{\uparrow \text{ LHS}} = \underbrace{26}_{\downarrow \text{ RHS}}$

- To **solve** an equation, undo the operations built around the pronumeral by doing the opposite operation in the reverse order.
  - Always perform the same operation to both sides of an equation so it remains balanced.

    Equations are solved like this:

$$\begin{tikzcd} 5x + 2 = 17 \arrow[d, bend right, "-2"'] \arrow[d, bend left, "-2"] \\ 5x = 15 \arrow[d, bend right, "\div 5"'] \arrow[d, bend left, "\div 5"] \\ x = 3 \end{tikzcd}$$

    In the example above, $x = 3$ is called ‘the solution’.
  - Alternatively, a solution need not show the operations applied to each side. These can be done mentally.
    For example:

$$\begin{aligned} 5x + 2 &= 17 \\ 5x &= 15 \\ x &= 3 \end{aligned}$$

Solve To find the value of an unknown quantity

- To ‘verify’ an answer means to check that the solution is correct by substituting the answer to see if it makes the equation true.
  For example:
  Verify that $x = 3$ is a solution to $5x + 2 = 17$, using substitution.

$$\begin{aligned} \text{LHS} &= 5x + 2 \qquad\qquad \text{RHS} = 17 \\ &= 5 \times 3 + 2 \\ &= 17 \end{aligned}$$

  LHS = RHS
  $\therefore x = 3$ is a solution.

- Sometimes it is a good idea to swap the LHS and RHS.
  For example: $15 = 2x + 3$ is the same as $2x + 3 = 15$.

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Exercise 9A REVISION

UNDERSTANDING AND FLUENCY 1–9(½) 4–9(½)

1 Decide whether $x = 2$ is a solution to these equations.

a $x + 3 = 5$ **b** $2x = 7$ **c** $x - 1 = 4$
d $2x - 1 = 10$ **e** $3x + 2 = 8$ **f** $2 - x = 0$

Substitute $x = 2$ to see whether LHS = RHS.

Example 1 Solving one-step equations involving addition

Solve $x + 7 = 12$.

SOLUTION	EXPLANATION
$x + 7 = 12$	Write the equation. The opposite of +7 is −7.
$x = 12 - 7$	Subtract 7 from both sides.
$x = 5$	Simplify.
Verify: LHS $= 5 + 7$ $= 12$ RHS $= 12$ LHS = RHS	Check that your answer is correct, using substitution.

2 Solve the following.

a $t + 5 = 8$ **b** $m + 4 = 10$ **c** $8 + x = 14$
d $m + 7 = 0$ **e** $x + 3 = 11$ **f** $x + 6 = 2$
g $m + 8 = 40$ **h** $a + 1 = -5$ **i** $16 = m + 1$

$8 + x = 14$ is the same as $x + 8 = 14$. $16 = m + 1$ is the same as $m + 1 = 16$.

Example 2 Solving one-step equations involving subtraction

Solve $x - 9 = 3$.

SOLUTION	EXPLANATION
$x - 9 = 3$	Write the equation. The opposite of −9 is +9.
$x = 3 + 9$	Add 9 to both sides.
$x = 12$	Simplify.
Verify: LHS $= 12 - 9$ $= 3$ RHS $= 3$ LHS = RHS	Check that your answer is correct, using substitution.

3 Find the value of x.

a $x - 3 = 3$ **b** $x - 7 = 2$ **c** $x - 8 = 9$
d $x - 3 = 0$ **e** $x - 2 = -8$ **f** $x - 5 = 7$
g $x - 12 = 24$ **h** $x - 50 = 70$ **i** $x - 1 = 100$

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Example 3 Solving one-step equations involving multiplication

Solve $3x = 12$.

SOLUTION	EXPLANATION
$3x = 12$	Write the equation. The opposite of ×3 is ÷3.
$x = \frac{12}{3}$	Divide both sides by 3.
$x = 4$	Simplify.
Verify: $\text{LHS} = 3 \times 4 = 12$ $\text{RHS} = 12$ $\text{LHS} = \text{RHS}$	Check that your answer is correct, using substitution.

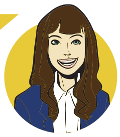
4 Solve the following.

a $8p = 24$ **b** $5c = 30$ **c** $27 = 3d$

d $2m = 16$ **e** $5z = 125$ **f** $9w = 81$

g $15p = 15$ **h** $6m = -42$ **i** $-10 = 20p$

$27 = 3d$ is the same as $3d = 27$. Swap LHS & RHS.



Example 4 Solving one-step equations involving division

Solve $\frac{x}{4} = 20$.

SOLUTION	EXPLANATION
$\frac{x}{4} = 20$	Write the equation. The opposite of ÷4 is ×4.
$x = 20 \times 4$	Divide both sides by 4.
$x = 80$	Simplify.
Verify: $\text{LHS} = \frac{80}{4} = 20$ $\text{RHS} = 20$ $\text{LHS} = \text{RHS}$	Check that your answer is correct, using substitution.

5 Solve each of the following equations.

a $\frac{x}{5} = 10$ **b** $\frac{m}{3} = 7$ **c** $\frac{a}{6} = -2$

d $\frac{z}{7} = 0$ **e** $\frac{x}{8} = -1$ **f** $\frac{w}{9} = -3$

g $8 = \frac{r}{7}$ **h** $\frac{w}{3} = \frac{1}{2}$ **i** $\frac{1}{4} = \frac{m}{2}$

$3 \times \frac{1}{2} = \frac{3}{1} \times \frac{1}{2} = \frac{3}{2}$

6 Solve the following equations.

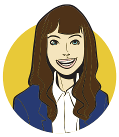
a $x + 9 = 12$ **b** $x + 3 = 12$ **c** $x + 15 = 4$

d $3 = x - 7$ **e** $x - 2 = 12$ **f** $x - 5 = 5$

g $3x = 9$ **h** $4x = 16$ **i** $100 = 2x$

j $\frac{x}{5} = 4$ **k** $\frac{x}{3} = 7$ **l** $1 = \frac{x}{7}$

Carry out the ‘opposite’ operation to solve for x.



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Example 5 Solving two-step equations

Solve $4x + 5 = 17$.

SOLUTION	EXPLANATION
$4x + 5 = 17$	Write the equation.
$4x = 12$	First, subtract 5 from both sides.
$x = \frac{12}{4}$	Then divide both sides by 4.
$x = 3$	Simplify.
Verify: LHS $= 4 \times 3 + 5$ $= 17$ RHS $= 17$ LHS = RHS	Check your answer, using substitution.

7 Solve the following equations.

a $2x + 5 = 7$ **b** $3x + 2 = 11$ **c** $4x - 3 = 9$
d $6x + 13 = 1$ **e** $8x + 16 = 8$ **f** $10x + 92 = 2$
g $3x - 4 = 8$ **h** $2x - 7 = 9$ **i** $5x - 4 = 36$
j $-10 = 2x - 6$ **k** $-24 = 7x - 3$ **l** $27 = 6x - 3$

In parts **j**, **k** and **l** it is okay to swap the LHS and RHS.

Example 6 Solving two-step equations involving simple fractions

Solve $\frac{x}{5} - 3 = 4$.

SOLUTION	EXPLANATION
$\frac{x}{5} - 3 = 4$	Write the equation. The number 'farthest' from x is the -3, so first add 3 to both sides.
$\frac{x}{5} = 7$	
$x = 35$	Multiply both sides by 5. Write the answer.
Verify: LHS $= \frac{35}{5} - 3$ $= 4$ RHS $= 4$ LHS = RHS	Check that your answer is correct, using substitution.

8 Solve the following equations.

a $\frac{x}{3} + 2 = 5$ **b** $\frac{x}{6} + 3 = 3$ **c** $\frac{x}{7} + 4 = 12$
d $\frac{x}{4} - 3 = 2$ **e** $\frac{x}{5} - 4 = 3$ **f** $\frac{x}{10} - 2 = 7$
g $-6 = \frac{x}{8} - 2$ **h** $-8 = \frac{x}{4} - 3$ **i** $10 = \frac{x}{2} - 1$

When solving equations, the order of steps is important. For $\frac{x}{3} - 5$, undo the -5 first, then undo the $\div 3$.

Example 7 Solving more two-step equations

Solve $\frac{x+4}{2} = 6$.

SOLUTION	EXPLANATION
$\frac{x+4}{2} = 6$	Write the equation.
$x + 4 = 12$	$\frac{x+4}{2} = \frac{(x+4)}{2}$, thus the number farthest from x is the 2, so first multiply both sides by 2.
$x = 8$	Subtract 4 from both sides.
Verify: LHS $= \frac{8+4}{2}$ $= 6$ RHS $= 6$ LHS = RHS	Check that your answer is correct, using substitution.

9 Solve the following.

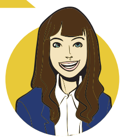
a $\frac{m+1}{2} = 3$ **b** $\frac{a-1}{3} = 2$ **c** $\frac{x+5}{2} = 3$

d $\frac{x+5}{3} = 2$ **e** $\frac{n-4}{5} = 1$ **f** $\frac{m-6}{2} = 8$

g $\frac{w+4}{3} = -1$ **h** $\frac{m+3}{5} = 2$ **i** $\frac{w-6}{3} = 7$

j $2 = \frac{a+7}{4}$ **k** $-5 = \frac{a-3}{8}$ **l** $0 = \frac{m+5}{8}$

When solving equations, the order of steps is important. For $\frac{x+7}{3}$, undo the ÷3 first, then undo the +7. Never cancel a number joined by + or − to an x; e.g. In $\frac{x+8}{4}$, you cannot cancel the 4 into the 8.



PROBLEM-SOLVING AND REASONING 10, 11 10, 12, 13

Example 8 Writing equations from a word problem

For each of the following statements, write an equation and solve for the pronumeral.

a If 7 is subtracted from x, the result is 12.

b If x is divided by 5 and then 6 is added, the result is 10.

c If 4 is subtracted from x and that answer is divided by 2, the result is 9.

SOLUTION	EXPLANATION
a $x - 7 = 12$ $x = 19$	Subtract 7 from x means to start with x and then subtract 7. 'The result' means '='.
b $\frac{x}{5} + 6 = 10$	Divide x by 5, then add 6 and make it equal to 10.
$\frac{x}{5} = 4$	Solve the equation by subtracting 6 from both sides first.
$x = 20$	Then multiply both sides by 5.
c $\frac{x-4}{2} = 9$	Subtracting 4 from x gives $x - 4$, and then divide that answer by 2.
$x - 4 = 18$ $x = 22$	Undo ÷ 2 by multiplying both sides by 2, then add 4 to both sides.

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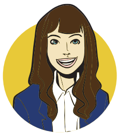
10 For each of the following statements, write an equation and solve for the pronumeral.

- **a** If 4 is added to x, the result is 6.
- **b** If x is added to 12, the result is 8.
- **c** If 5 is subtracted from x, the result is 5.
- **d** If x is divided by 3 and then 2 is added, the result is 8.
- **e** Twice the value of x is added to 3 and the result is 9.
- **f** $(x - 3)$ is divided by 5 and the result is 6.
- **g** 3 times x plus 4 is equal to 16.

5 subtracted from x is $x - 5$.



11 Write an equation and solve it for each of these questions.

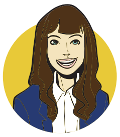
- **a** The perimeter of a square is 52 cm. Determine the length of the side.
- **b** The perimeter of an isosceles triangle is 42 mm. If the equal sides are both 10 mm, determine the length of the other side.

Draw a diagram and choose a pronumeral to represent the unknown side, then write an equation and solve it.

12 Convert the following into equations, then solve them for the unknown number.

- **a** n is multiplied by 2, then 5 is added. The result is 11.
- **b** Four times a certain number is added to 9 and the result is 29. What is the number?
- **c** Half of a number less 2 equals 12. What is the number?
- **d** A number plus 6 has been divided by 4. The result is 12. What is the number?
- **e** 12 is subtracted from a certain number and the result is divided by 5. If the answer is 14, what is the number?

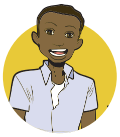
Choose a pronumeral to represent the unknown number, then write an equation using the pronumeral.
$\frac{1}{2}$ of x can be written as $\frac{x}{2}$.



13 Write an equation and solve it for each of these questions.

- **a** The sum of two consecutive numbers is 23. What are the numbers?
- **b** A person is 19 years older than another person. Their age sum is 69. What are their ages?
- **c** Andrew threw the shotput 3 m more than twice the distance that Barry threw it. If Andrew threw the shotput 19 m, how far did Barry throw it?

Consecutive numbers are one number apart; e.g. 3, 4, 5, 6. The next consecutive number after x is $x + 1$.



ENRICHMENT	–	14, 15

Modelling with equations

14 A service technician charges \$40 up front and \$60 for each hour that she works.

- **a** Write a linear equation for the total charge, \$$C$, of any job for h hours worked.
- **b** What will a 4-hour job cost?
- **c** If the technician works on a job for 3 days and averages 6 hours per day, what will be the overall cost?
- **d** If a customer is charged \$400, how long did the job take?

15 A petrol tank holds 71 litres. It originally contained 5 litres. If a petrol pump fills it at 6 litres per minute, find:

- **a** a linear equation for the amount of fuel (V litres) in the tank at time t minutes
- **b** how long it will take to fill the tank to 23 litres
- **c** how long it will take to fill the tank

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9B Equations with brackets, fractions and pronumerals on both sides

Interactive
Widgets
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Walkthrough

More complex linear equations may have variables on both sides of the equation and/or brackets. Examples are $6x = 2x - 8$ or $5(x + 3) = 12x + 4$.

Brackets can be removed by expanding. Equations with variables on both sides can be solved by collecting variables to one side, using addition or subtraction of a term.

More complex linear equations of this type are used when constructing buildings and in science and engineering.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Steps in the wrong order

The steps to solve $8(x + 2) = 2(3x + 12)$ are listed here in the incorrect order.

$$\begin{aligned} 8(x + 2) &= 2(3x + 12) \\ x &= 4 \\ 2x + 16 &= 24 \\ 8x + 16 &= 6x + 24 \\ 2x &= 8 \end{aligned}$$

- Arrange them in the correct order, working from the question to the solution.
- By considering all the steps in the correct order, write what has happened in each step.

Key ideas

■ When solving complicated linear equations:

1 First, **expand** any brackets.
In this example, multiply the 3 into the first bracket and the −2 into the second bracket.

$$\begin{aligned} 3(2x - 1) - 2(x - 2) &= 22 \\ 6x - 3 - 2x + 4 &= 22 \end{aligned}$$

2 Collect any **like terms** on the LHS and any like terms on the RHS.
Collecting like terms on the left side of the example below.
$5x - 3x = 2x$ and $-4 - 9 = -13$

$$\begin{aligned} \enclose{circle}{5x} - 4 \enclose{circle}{-3x} - 9 &= \enclose{circle}{x} - 5 \enclose{circle}{+2x} + 10 \\ 2x - 13 &= 3x + 5 \end{aligned}$$

Expand Remove grouping symbols (such as brackets)

Like terms Terms with the same pronumerals and same powers

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Key ideas

3 Sometimes it is good to swap the LHS and RHS.

For example: $2x - 13 = 3x + 5$

2 is less than 3
∴ swap LHS and RHS.
$2x - 13 = 3x + 5$
becomes
$3x + 5 = 2x - 13$

4 If an equation has variables on both sides, collect to one side by adding or subtracting one of the terms.

For example, when solving the equation $12x + 7 = 5x + 19$, first subtract $5x$ from both sides: LHS: $12x - 5x = 7x$, RHS: $5x - 5x = 0$.

$$12x + 7 = 5x + 19$$
$$7x + 7 = 19$$

5 Start to perform the opposite operation to both sides of the equation.

6 Repeat step 5 until the equation is solved.

7 Verify that the answer is correct, using substitution.

■ To solve a word problem using algebra:

- Read the problem and find out what the question is asking for.
- Define a variable and write a statement such as: 'Let x be the number of …'. The variable is often what you have been asked to find in the question.
- Write an equation using your defined variable.
- Solve the equation and check that the solution is reasonable.
- Answer the question in words.

Exercise 9B

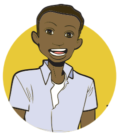
UNDERSTANDING AND FLUENCY 1–8(½) 3–8(½)

1 Expand brackets and collect like terms in each of these expressions.

a $3(x - 1)$
b $5(x + 3)$
c $-2(x + 2)$
d $-3(x - 4)$
e $-4(2x - 1)$
f $2(x + 5) + 3(x + 1)$
g $5(x + 4) + 2(x + 3)$
h $6(x + 2) + 3(x - 1)$
i $2(x - 8) - 3(x + 1)$
j $5(x - 4) - 11(x - 3)$

The number in front of the bracket needs to be multiplied to both terms inside the bracket.

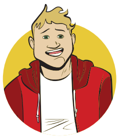
$-5(2x - 3)$
$= -10x + 15$



2 For each of these equations, describe what could be done as the first step to collect the terms with x onto one side.

a $5x = 2x + 12$
b $2x = x - 4$
c $8x = 3x + 25$
d $7x = -x + 8$
e $2x + 11 = 5x - 4$
f $3x + 47 = 8x + 2$
g $7x - 5 = -2x + 13$
h $2x + 3 = -3x + 38$

Add or subtract to remove the term containing x on the RHS.



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Example 9 Solving equations with brackets

Solve $4(x - 1) = 16$.

SOLUTION

$$\begin{aligned} 4(x-1) &= 16 \\ 4x - 4 &= 16 \\ 4x &= 20 \\ x &= 5 \end{aligned}$$

EXPLANATION

Expand the brackets: $4 \times x$ and $4 \times (-1)$.
Add 4 to both sides.
Divide both sides by 4.

3 Solve each of the following equations by first expanding the brackets.

a $3(x + 2) = 9$
b $4(x - 1) = 16$
c $3(x + 5) = 12$
d $4(a - 2) = 12$
e $5(a + 1) = 10$
f $2(x - 10) = 10$
g $6(m - 3) = 6$
h $3(d + 4) = 15$
i $7(a - 8) = 14$
j $20 = 10(a + 2)$
k $15 = 5(3 + x)$
l $0 = 2(a - 3)$

Example 10 Solving equations with two sets of brackets

Solve $3(2x + 4) + 2(3x - 2) = 20$.

SOLUTION

$$\begin{aligned} 3(2x+4) + 2(3x-2) &= 20 \\ 6x + 12 + 6x - 4 &= 20 \\ 12x + 8 &= 20 \\ 12x &= 12 \\ x &= 1 \end{aligned}$$

Verify: LHS $= 3 \times 6 + 2 \times 1$ RHS $= 20$
$= 20$

LHS = RHS

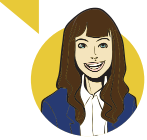
EXPLANATION

Use the distributive law to expand each set of brackets.
Collect like terms on the LHS.
Subtract 8 from both sides.
Divide both sides by 12.
Check your answer.

4 Solve the following equations.

a $3(2x + 3) + 2(x + 4) = 25$
b $2(2x + 3) + 4(3x + 1) = 42$
c $2(2x + 3) + 3(4x - 1) = 51$
d $3(2x - 2) + 5(x + 4) = 36$
e $4(2x - 3) + 2(x - 4) = 10$
f $2(3x - 1) + 3(2x - 3) = 13$
g $2(x - 4) + 3(x - 1) = -21$
h $4(2x - 1) + 2(2x - 3) = -22$

Expand each pair of brackets and collect like terms before solving.



5 Solve the following equations.

a $3(2x + 4) - 4(x + 2) = 6$
b $2(5x + 4) - 3(2x + 1) = 9$
c $2(3x - 2) - 3(x + 1) = -7$
d $2(x + 1) - 3(x - 2) = 8$
e $8(x - 1) - 2(3x - 2) = 2$
f $5(2x - 3) - 2(3x - 1) = -9$
g $5(2x + 1) - 3(x - 3) = 35$
h $4(2x - 3) - 2(3x - 1) = -14$

$-4(x + 2) = -4x - 8$
$-3(x - 2) = -3x + 6$

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Example 11 Solving equations with variables on both sides

Solve the following for x.

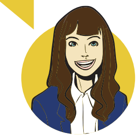
a $7x + 9 = 2x - 11$ **b** $2x + 5 = 5x + 11$

SOLUTION	EXPLANATION
a $7x + 9 = 2x - 11$ $5x + 9 = -11$ $5x = -20$ $x = -4$	Subtract $2x$ from both sides. Subtract 9 from both sides. Divide both sides by 5.
Verify: LHS $= -28 + 9$ RHS $= -8 - 11$ $= -19$ $= -19$ LHS = RHS	Check your answer by substituting $x = -4$ in LHS and RHS.
b $2x + 5 = 5x + 11$	$\underset{\uparrow}{\enclose{circle}{2x}} + 5 = \underset{\nwarrow}{\enclose{circle}{5x}} + 11$
$5x + 11 = 2x + 5$ $3x + 11 = 5$ $3x = -6$ $x = -2$	$2x$ is less than $5x$, so swap LHS and RHS. Collect like terms by subtracting $2x$ from both sides.
Verify: LHS $= 2 \times (-2) + 5$ RHS $= 5 \times (-2) + 11$ $= 1$ $= 1$ LHS = RHS	Always verify your solution, using substitution.

6 Find the value of x in the following.

a $7x = 2x + 10$ **b** $10x = 9x + 12$ **c** $4x - 12 = 8x$
d $6x = 2x + 80$ **e** $2x = 12 - x$ **f** $2x = 8 + x$
g $3x + 4 = x + 12$ **h** $x - 3 = 4x + 9$ **i** $2x - 9 = x - 10$
j $12 + 4x = 6x - 10$ **k** $9x = 10 - x$ **l** $1 - x = x + 3$

For parts **e**, **k** and **l**, you will need to add x to both sides.



Example 12 Solving equations with fractions

Solve $\frac{2x + 3}{4} = 2$ for x.

SOLUTION	EXPLANATION
$\frac{2x + 3}{4} = 2$	Multiply both sides by 4.
$2x + 3 = 8$	Subtract 3 from both sides.
$2x = 5$	Divide both sides by 2.
$x = 2.5$	

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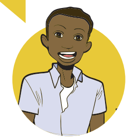
7 Solve the following equations.

a $\frac{x+2}{3} = 5$ **b** $\frac{x+4}{2} = 5$ **c** $\frac{x-1}{3} = 4$

d $\frac{x-5}{3} = 2$ **e** $\frac{2x+1}{7} = 3$ **f** $\frac{2x+2}{3} = 4$

g $9 = \frac{5x-3}{3}$ **h** $9 = \frac{3x-6}{2}$ **i** $-3 = \frac{5x-2}{4}$

First, multiply by the denominator.



Example 13 Solving equations with more difficult fractions

Solve $\frac{3x}{2} - 4 = 2$ for x.

SOLUTION	EXPLANATION
$\frac{3x}{2} - 4 = 2$	Add 4 to both sides.
$\frac{3x}{2} = 6$	Multiply both sides by 2.
$3x = 12$	Divide both sides by 3.
$x = 4$	

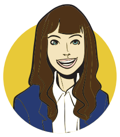
8 Solve the following equations.

a $\frac{x}{3} + 1 = 5$ **b** $\frac{x}{3} + 1 = 7$

c $\frac{x}{4} - 5 = 10$ **d** $5 = \frac{3x}{4} - 2$

e $\frac{2x}{5} - 3 = -1$ **f** $\frac{3x}{2} - 5 = -14$

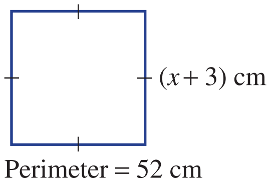
First, add or subtract from both sides.



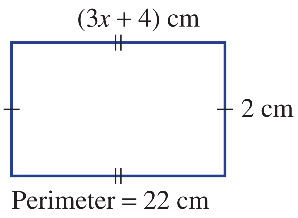
PROBLEM-SOLVING AND REASONING 9, 10–11(½) 10–11(½), 12

9 For each of these questions, write an equation and solve it for x.

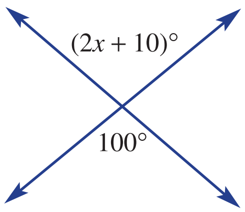
a



b



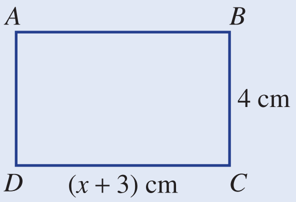
c



Vertically opposite angles are equal.

Example 14 Solving a word problem

Find the value of x if the area of rectangle $ABCD$ shown is 24 cm².



SOLUTION

$$\begin{aligned} A &= l \times b \\ 24 &= (x + 3) \times 4 \\ 24 &= 4x + 12 \\ 4x + 12 &= 24 \\ 4x &= 12 \\ x &= 3 \end{aligned}$$

EXPLANATION

Write an equation for area.

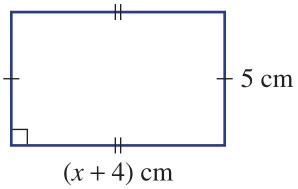
Substitute: $l = (x + 3)$, $b = 4$, $A = 24$

Expand the brackets: $(x + 3) \times 4 = 4(x + 3)$

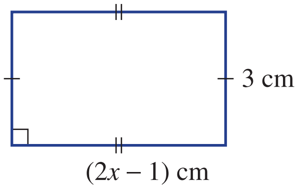
Swap LHS and RHS.

Subtract 12 from both sides, then divide both sides by 4.

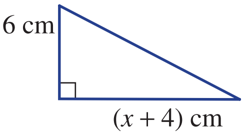
10 **a** Find the value of x if the area is 35 cm².



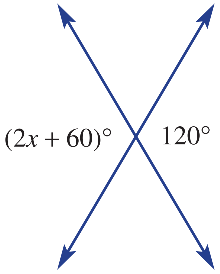
b Find the value of x if the area is 27 cm².



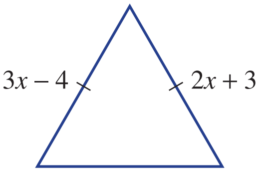
c Find the value of x if the area is 42 cm².



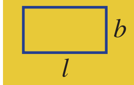
d Vertically opposite angles are equal. Find the value of x.



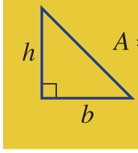
e Find the value of x.



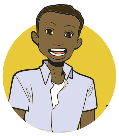
Form the area equation first.



$A = l \times b$



$A = \frac{1}{2}bh$



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11 Using x for the unknown number, write down an equation and then solve it to find the number.

a The product of 5 and 1 more than a number is 40.

b The product of 5 and 6 less than a number is -15.

c When 6 less than 3 lots of a number is doubled, the result is 18.

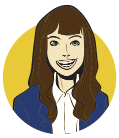
d When 8 more than 2 lots of a number is tripled, the result is 36.

e 10 more than 4 lots of a number is equivalent to 6 lots of the number.

f 5 more than 4 times a number is equivalent to 1 less than 5 times the number.

g 6 more than a doubled number is equivalent to 5 less than 3 lots of the number.

- 'Product' means to multiply.
- 'The product of 5 and 1 more than a number' means $5(x + 1)$.
- '6 less than 3 lots of a number is doubled' will require brackets.
- 'Tripled' means three times a number.
- 'Equivalent' means equal to.



12 Sally and Steve are planning to hire a car for their wedding day. 'Vehicles For You' have the following deal: \$850 hiring fee plus a charge of \$156 per hour. The number of hours must be a whole number.

a Write an equation for the cost (\$$C$) of hiring a car for h hours.

b If Sally and Steve have budgeted for the car to cost a maximum of \$2000, find the maximum number of full hours they can hire the car.

c If the car picks up the bride at 1.15 p.m., at what time must the event finish if the cost is to remain within budget?

ENRICHMENT – 13(½)

More than one fraction

Consider:

$\frac{4x-2}{3} = \frac{3x-1}{2}$	
$\frac{{}^{2}\cancel{6}(4x-2)}{\cancel{3}_{1}} = \frac{{}^{3}\cancel{6}(3x-1)}{\cancel{2}_{1}}$	(Multiply both sides by 6 (i.e. the LCM of 2 and 3) to remove the fractions.)
$2(4x-2) = 3(3x-1)$	(Simplify.)
$8x-4 = 9x-3$	(Expand both sides.)
$9x-3 = 8x-4$	(Swap LHS and RHS.)
$x-3 = -4$	(Subtract $8x$ from both sides.)
$\therefore x = -1$	(Add 3 to both sides.)

13 Solve the following equations.

a $\frac{x+2}{3} = \frac{x+1}{2}$

b $\frac{x+1}{2} = \frac{x}{3}$

c $\frac{3x+4}{4} = \frac{x+6}{3}$

d $\frac{5x+2}{3} = \frac{3x+4}{2}$

e $\frac{2x+1}{7} = \frac{3x-5}{4}$

f $\frac{5x-1}{3} = \frac{x-4}{4}$

9C Using formulas

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

A formula (or rule) is an equation that relates two or more variables. You can find the value of one of the variables if you are given the value of all other unknowns.

You will already be familiar with many formulas. For example:

- $C = 2\pi r$ is the formula for finding the circumference, C, of a circle given its radius, r.
- $F = \frac{9}{5}C + 32$ is the formula for converting degrees Celsius, C, to degrees Fahrenheit, F.
- $s = \frac{d}{t}$ is the formula for finding the speed, s, given the distance, d, and time, t.
- C, F and s are said to be the subjects of the formulas given above.

Let's start: Jumbled solution

Problem: The formula for the area of a trapezium is $A = \frac{h}{2}(a + b)$.

Xavier was asked to find a given that $A = 126$, $b = 10$ and $h = 14$, and to write the explanation beside each step of the solution.

Xavier's solution and explanation are below. His solution is correct, but he has jumbled up the steps in the explanation. Copy Xavier's solution and write the correct instruction(s) beside each step.

SOLUTION	EXPLANATION
$A = \frac{h}{2}(a + b)$	Write the answer.
$126 = \frac{14}{2}(a + 10)$	Subtract 70 from both sides. Divide both sides by 7.
$\frac{14}{2}(a + 10) = 126$	Substitute the given values.
$7(a + 10) = 126$	Copy the formula.
$7a + 70 = 126$	Simplify $\frac{14}{2}$.
$7a = 56$	Expand the brackets.
$a = 8$	Swap LHS and RHS.

Key ideas

- The **subject** of a **formula** is a variable that usually sits on its own on the left-hand side. For example, the C in $C = 2\pi r$ is the subject of the formula.
- A variable in a formula can be evaluated by substituting numbers for all other variables.
- A formula can be rearranged to make another variable the subject:

  $C = 2\pi r$ can be rearranged to give $r = \frac{C}{2\pi}$.
- Note that $\sqrt{a^2} = a$ if $a \geqslant 0$ and $\sqrt{a^2 + b^2} \neq a + b$.

Subject The pronumeral or variable that is alone on one side of an equation

Formula A general rule for finding the value of one quantity given the values of others

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Exercise 9C

UNDERSTANDING AND FLUENCY 1, 2, 3–7(½) 2–9(½)

1 State the letter that is the subject in these formulas.

a $I = PRN$ **b** $F = ma$ **c** $V = \frac{4}{3}\pi r^3$

d $A = \pi r^2$ **e** $c = \sqrt{a^2 + b^2}$ **f** $P = 2x + 2y$

The subject of a formula is the letter on its own, on the left-hand side.

2 Substitute the given values into each of the following formulas to find the value of each subject. Round the answer to 1 decimal place where appropriate.

a $m = \frac{F}{a}$, when $F = 180$ and $a = 3$

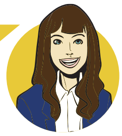
b $A = lb$, when $l = 6$ and $b = 8$

c $A = \frac{1}{2}(a + b)h$, when $a = 6$, $b = 12$ and $h = 4$

d $v^2 = u^2 + 2as$, when $u = 6$ and $a = 12$ and $s = 7$

e $m = \sqrt{\frac{x}{y}}$, when $x = 56$ and $y = 4$

Copy each formula, substitute the given values and then calculate the answer.



Example 15 Substituting values and solving equations

If $v = u + at$, find t when $v = 16$, $u = 4$ and $a = 3$.

SOLUTION	EXPLANATION
$v = u + at$	Substitute each value into the formula: $v = 16, u = 4, a = 3$
$16 = 4 + 3t$	An equation now exists. Solve this equation for t.
$4 + 3t = 16$	Swap LHS and RHS.
$3t = 12$	Subtract 4 from both sides.
$t = 4$	Divide both sides by 3.
	Answer with the pronumeral on the LHS.

3 If $v = u + at$, find t when:

a $v = 16$, $u = 8$ and $a = 2$

b $v = 20$, $u = 8$ and $a = 3$

c $v = 100$, $u = 10$ and $a = 9$

d $v = 84$, $u = 4$ and $a = 10$

4 If $P = 2(l + 2b)$, find b if:

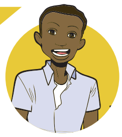
a $P = 60$ and $l = 10$

b $P = 48$ and $l = 6$

c $P = 96$ and $l = 14$

d $P = 12.4$ and $l = 3.6$

First copy the formula. Then substitute the given values. Solve the remaining equation. Sometimes it is wise to swap the LHS and RHS.



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5 If $V = lbh$, find h when:

a $V = 100$, $l = 5$ and $b = 4$

b $V = 144$, $l = 3$ and $b = 4$

c $V = 108$, $l = 3$ and $b = 12$

d $V = 280$, $l = 8$ and $b = 5$

6 If $A = \frac{1}{2}bh$, find b when:

a $A = 90$ and $h = 12$

b $A = 72$ and $h = 9$

c $A = 108$ and $h = 18$

d $A = 96$ and $h = 6$

In $90 = \frac{1}{2} \times b \times 12$,

$$\begin{aligned}\frac{1}{2} \times b \times 12 &= \frac{1}{2} \times 12 \times b \\ &= 6b\end{aligned}$$

So, $90 = 6b$.

Solve for b.

7 If $A = \frac{h}{2}(a + b)$, find h when:

a $A = 20$, $a = 4$ and $b = 1$

b $A = 48$, $a = 5$ and $b = 7$

c $A = 108$, $a = 9$ and $b = 9$

d $A = 196$, $a = 9$ and $b = 5$

When solving this equation, first undo the division by 2 by multiplying both sides by 2.

8 $E = mc^2$. Find m if:

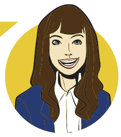
a $E = 100$ and $c = 5$

b $E = 4000$ and $c = 10$

c $E = 72$ and $c = 1$

d $E = 144$ and $c = 6$

Square the c value before solving the equation.



9 If $V = \pi r^2 h$, find h (to 1 decimal place) when:

a $V = 160$ and $r = 3$

b $V = 400$ and $r = 5$

c $V = 1460$ and $r = 9$

d $V = 314$ and $r = 2.5$

For $160 = 9\pi h$, divide both sides by 9π to find h:

$$h = \frac{160}{9\pi}$$

Then evaluate using a calculator.

PROBLEM-SOLVING AND REASONING 10–12 11–14

10 The formula $F = \frac{9C}{5} + 32$ is used to convert temperature from degrees Celsius (°C) (which is used in Australia) to degrees Fahrenheit (°F) (which is used in the USA).

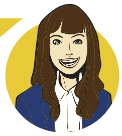
a When it is 30°C in Sydney, what is the temperature in degrees Fahrenheit?

b How many degrees Celsius is 30° Fahrenheit? Answer to 1 decimal place.

c Water boils at 100°C. What is this temperature in degrees Fahrenheit?

d What is 0°F in degrees Celsius? Answer to 1 decimal place.

When finding C you will have an equation to solve.



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11 The cost (in dollars) of a taxi is $C = 3 + 1.45d$, where d is the distance travelled in kilometres.

a What is the cost of a 20 km trip?

b How many kilometres can be travelled for $90?

12 $I = PRN$ calculates interest on an investment.
Find:

a P when $I = 60$, $R = 0.08$ and $N = 1$

b N when $I = 125$, $R = 0.05$ and $P = 800$

c R when $I = 337.50$, $P = 1500$ and $N = 3$

13 The number of tablets a nurse must give a patient is found by using the formula:

$$\text{Tablets} = \frac{\text{strength required}}{\text{tablet strength}}$$

a 750 milligrams of a drug must be administered to a patient. How many 500 milligram tablets should the nurse give the patient?

b If the nurse gives 2.5 of these tablets to another patient, how much of the drug did the patient take?

14 A drip is a way of pumping a liquid drug into a patient's blood. The flow rate of the pump in millilitres per hour is calculated using the formula: $\text{Rate} = \frac{\text{volume (mL)}}{\text{time (h)}}$

a A patient needs 300 mL of the drug over 4 hours. Calculate the rate in mL/h which needs to be delivered by the pump.

b A patient received 100 mL of the drug at a rate of 300 mL/h. How long was the pump running?

ENRICHMENT		–	15, 16

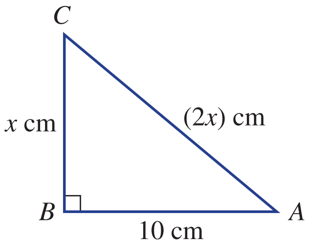
Calculation challenges

15 A tax agent charges $680 for an 8-hour day. The agent uses the formula $F = \frac{680x}{8}$ to calculate a fee to a client, in dollars.

a What does the x represent?

b If the fee charged to a client is $637.50, how many hours, to 1 decimal place, did the agent spend working on the client's behalf?

16 Find the area and perimeter of triangle ABC shown. Round your answer to 2 decimal places.



First use Pythagoras' theorem to find x.

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9D Linear inequalities

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There are many situations where a solution to the problem is best described using one of the symbols $<$, $\leqslant$, $>$ or $\geqslant$. For example, a pharmaceutical company will publish the lowest and highest amounts for a safe dose of a particular medicine such as 20 mg/day $\leqslant$ dose $\leqslant$ 55 mg/day.

An inequality is a mathematical statement that uses an is less than ($<$), is less than or equal to ($\leqslant$), is greater than ($>$) or is greater than or equal to ($\geqslant$) symbol. Inequalities may result in an infinite number of solutions. These can be illustrated using a number line.

The safe dosage range of a drug can be expressed as an inequality.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

You can solve inequalities in a similar way to solving equations.

Let's start: What does it mean for x?

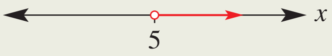
The following inequalities provide some information about the number x.

a $x < 6$ **b** $x \geqslant 4$ **c** $-5 \geqslant x$ **d** $-2 < x$

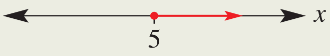
- Can you describe the possible values of x that satisfy each inequality?
- Test some values to check.
- How would you write the solution for x? Illustrate each on a number line.

Key ideas

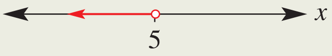
- The four **inequality signs** are $<$, $\leqslant$, $>$ and $\geqslant$.
  - $x > 5$ means x is greater than 5.



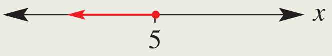
  - $x \geqslant 5$ means x is greater than or equal to 5.



  - $x < 5$ means x is less than 5.



  - $x \leqslant 5$ means x is less than or equal to 5.



- On the number line, a closed circle (•) indicates that the number is included, whereas an open circle (◦) indicates that the number is not included.
- Solving **linear inequalities** follows the same rules as solving linear equations, except:
  - We reverse an inequality sign if we multiply or divide by a negative number. For example: If $-5 < -3$ then $5 > 3$, and if $-2x < 4$ then $x > -2$.
  - We reverse the inequality sign if the sides are switched. For example: If $2 \geqslant x$, then $x \leqslant 2$.

Inequality sign A symbol that compares the size of two or more expressions or numbers by pointing to the smaller one

Linear inequality An inequality that involves a linear function

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Exercise 9D

UNDERSTANDING AND FLUENCY 1, 2–5(½), 6 2–5(½), 7

1 Match each inequality given with the correct number line.

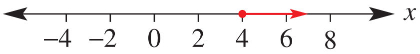
a $x > 4$

b $x < 4$

c $x \geqslant 4$

d $x > -4$

e $x \leqslant -4$

1


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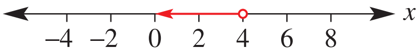

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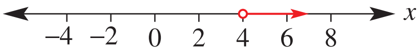

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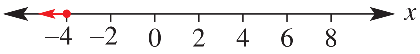

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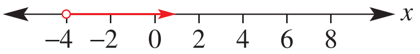
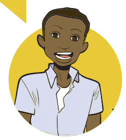
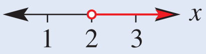


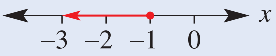
Look back at the Key ideas. The direction of the arrowhead is the same as the direction of the inequality sign.



Example 16 Writing inequalities from number lines

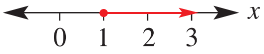
Write each graph as an inequality.

a


b


SOLUTION	EXPLANATION
a $x > 2$	An open circle means 2 is not included.
b $x \leqslant -1$	A closed circle means –1 is included.

2 Write each graph as an inequality.

a


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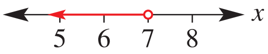

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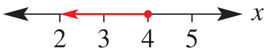
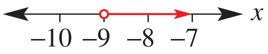
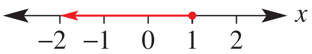
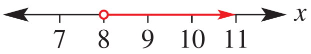
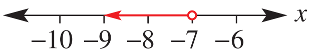
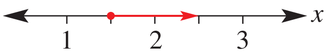


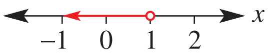
d


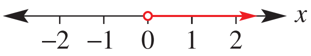
e


f


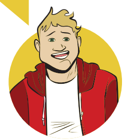
g


h


i


j


The inequality sign will have the same direction as the arrow.



3 Show each of the following on separate number lines.

a $x \geqslant 7$
b $x > 1$
c $x < 1$
d $x \leqslant 1$
e $x \geqslant -1$
f $a \geqslant 0$
g $p \geqslant -2$
h $a > -15$
i $h < 5$

For $x \geqslant 7$, draw a number line showing some numbers around 7.

Use a closed circle (●) for $\geqslant$ and $\leqslant$. Use an open circle (○) for $>$ and $<$.

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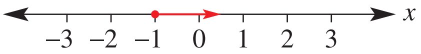
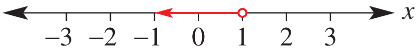
4 Write an inequality to describe what is shown on each of the following number lines.

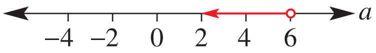
a



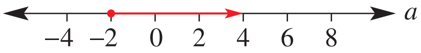
b



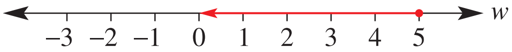
c



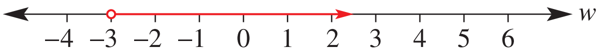
d



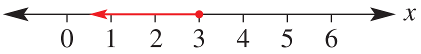
e



f

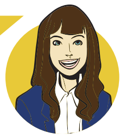


g



h

The pronumeral is at the end of the number line.



Example 17 Writing and graphing inequalities

Write each of the following as an inequality and then show each solution on a number line.

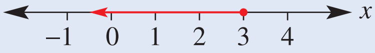
a x is less than or equal to 3

b x is greater than 1

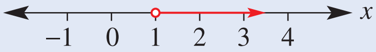
c x is less than 0

d x is greater than or equal to -2

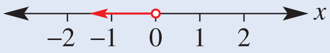
SOLUTION	EXPLANATION
a $x \leqslant 3$	Is less than or equal to, $\leqslant$, closed circle



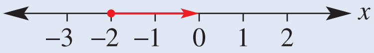
b $x > 1$	Is greater than, $>$, open circle.



c $x < 0$	Is less than, $<$, open circle



d $x \geqslant -2$	Is greater than or equal to, $\geqslant$, closed circle



5 Write each of the following as an inequality and then show each solution on a number line.

a x is less than or equal to 6

b x is less than or equal to -3

c x is greater than 4

d x is less than -1

e x is less than 2

f x is greater than -6

g x is greater than or equal to 5

h x is greater than or equal to zero

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6 Write each of the following as an inequality, using the pronumeral n.

a The number of people who visit the Sydney Opera House each year is more than 100 000.

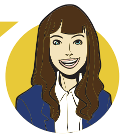
b The number of lollies in a bag should be at least 50.

c A factory worker must pack more than three boxes a minute.

d More than 100 penguins take part in the nightly parade on Philip Island.

e The weight of a suitcase is 30 kg or less.

'At least 50' means 50 or more.



7 Write each of the following statements as an inequality and determine which of the numbers below make each inequality true.

$-6, -2, -\frac{1}{2}, 0, 2, 5, 7, 10, 15, 24$

a x is less than zero

b x is greater than 10

c x is greater than or equal to 10

d x is less than or equal to zero

e x is greater than or equal to -1

f x is less than 10

Write the inequality, then list the given numbers that make it true.

PROBLEM-SOLVING AND REASONING 8–9(½), 11 9–10(½), 11, 12(½)

Example 18 Solving and graphing inequalities

Solve the following and show your solution on a number line.

a $2x - 1 > 17$

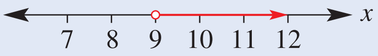
b $\frac{x}{3} \leqslant -2$

SOLUTION

a $2x - 1 > 17$

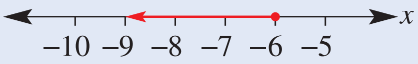
$2x > 18$

$x > 9$



b $\frac{x}{3} \leqslant -2$

$x \leqslant -6$



EXPLANATION

Add 1 to both sides.

Divide both sides by 2.

$>$ uses an open circle.

Multiply both sides by 3.

$\leqslant$ uses a closed circle.

8 Solve each of the following inequalities and show your solution on a number line.

a $2x > 10$ **b** $x + 2 < 7$ **c** $3x > 15$

d $\frac{x}{2} \geqslant 8$ **e** $x - 3 > 4$ **f** $x - 3 < 4$

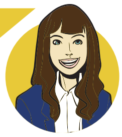
g $p + 8 \leqslant 0$ **h** $3a > 0$ **i** $x - 7 < 0$

j $2x \leqslant 14$ **k** $5m > -15$ **l** $d - 3 > 2.4$

m $\frac{x}{7} \leqslant 0.1$ **n** $\frac{1}{2}x \leqslant 6$ **o** $5 + x > 9$

Keep the inequality sign the same when:

- adding or subtracting a number from both sides
- multiplying or dividing both sides by a positive number



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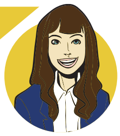
9 Solve the following.

- **a** $2 + 4a \leqslant 10$
- **b** $5 + 2y > 11$
- **c** $3p - 1 > 14$
- **d** $3x - 2 \geqslant 10$
- **e** $3x - 2 < 1$
- **f** $5 + 2w \geqslant 8$
- **g** $5x + 5 < 10$
- **h** $5x - 5 \geqslant 0$
- **i** $10p - 2 < 8$

10 Give the solution set for each of the following.

- **a** $\dfrac{x+2}{4} \leqslant 1$
- **b** $\dfrac{a-3}{2} \leqslant -1$
- **c** $\dfrac{x}{4} - 1 \geqslant 6$
- **d** $\dfrac{x}{3} + 7 > 2$
- **e** $5 + \dfrac{x}{2} < 7$
- **f** $\dfrac{x+2}{4} < 8$
- **g** $\dfrac{2x-7}{3} > 4$
- **h** $\dfrac{2x+1}{5} < 0$
- **i** $\dfrac{3x}{2} + 1 \geqslant -3$
- **j** $5x - 4 > 2 - x$
- **k** $4(2x + 1) \geqslant 16$
- **l** $3x + 7 < x - 2$

For $\dfrac{x+2}{4} \leqslant 1$, first multiply both sides by 4.
For $\dfrac{x}{4} - 1 \geqslant 6$, first add 1 to both sides.



11 For each of the following, write an inequality and solve it to find the possible values of x.

- **a** If a number, x, is multiplied by 3, the result is less than 9.
- **b** If a number, x, is multiplied by 3 and the result divided by 4, it creates an answer less than 6.
- **c** If a number, x, is doubled and then 15 is added, the result is greater than 20.
- **d** Thuong is x years old and Gary is 4 years older. The sum of their ages is less than 24.
- **e** Kaitlyn has x rides on the Ferris wheel at \$4 a ride and spends \$7 on food. The total amount she spends is less than or equal to \$27.

Example 19 Solving inequalities when the variable has a negative coefficient

Solve $4 - x \geqslant 6$.

SOLUTION	EXPLANATION
$4 - x \geqslant 6$	Subtract 4 from both sides.
$-x \geqslant 2$	Divide both sides by -1.
$x \leqslant -2$	When we divide both sides by a *negative* number, the inequality sign is reversed.
Alternative solution:	
$4 - x \geqslant 6$	Add the x to both sides so that it is positive.
$4 \geqslant 6 + x$	Subtract 6 from both sides.
$-2 \geqslant x$	Swap LHS and RHS and reverse the inequality sign.
$x \leqslant -2$	Note that the inequality sign still 'points' to the x.

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12 Choose an *appropriate strategy* to solve the following.

- **a** $5 - x < 6$
- **b** $7 - x \geqslant 10$
- **c** $-p \leqslant 7$
- **d** $9 - a < -10$
- **e** $-w \geqslant 6$
- **f** $-3 - 2p < 9$
- **g** $5 - 2x < 7$
- **h** $-2 - 7a \geqslant 4$

Remember to reverse the inequality sign when multiplying or dividing by a negative number.
e.g.

$$\begin{tikzcd} -x < 7 \arrow[d, bend right, "\div(-1)"'] \arrow[d, bend left, "\div(-1)"] \\ x > -7 \end{tikzcd}$$

$$\begin{tikzcd} -2x \geqslant 20 \arrow[d, bend right, "\div(-2)"'] \arrow[d, bend left, "\div(-2)"] \\ x \leqslant -10 \end{tikzcd}$$

ENRICHMENT – 13

Investigating inequalities

13 **a** Let us start with the numbers 4 and 6 and the true relationship 4 < 6. Copy and complete the following table.

				True or false?
4 and 6	4	6	$4 < 6$	true
add 3	$4 + 3$	$6 + 3$	$7 < 9$	true
subtract 3	$4 - 3$		$1 < 3$	true
multiply by 2				
divide by 2				
multiply by −2				false $(-8 > -12)$
divide by −2	$4 \div (-2)$	$6 \div (-2)$		

b Copy and complete the following.
When solving an inequality, you can add or __________ a number from both sides and the inequality remains true. You can multiply or __________ by a __________ number and the __________ also remains true. However, if you __________ or __________ by a negative __________, then the inequality sign must be reversed for the inequality to remain __________.

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9E Solving simultaneous equations graphically

Interactive
Widgets
HOTsheets
Walkthrough

When we approach an intersection while driving, we near the shared position of two or more roads.

Like two roads, two straight lines in the same plane will always intersect unless they are parallel.

If we try to find the point of intersection, we are said to be solving the equations simultaneously.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Which job has better pay?

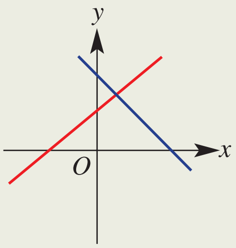
You start working as a delivery person for the Hasty Tasty Pizza Company. You're paid \$25 per shift and \$4 per pizza delivery.

A second pizza company, More-2-Munch Pizzas, offers you a job at \$15 per shift and \$5 per pizza delivery.

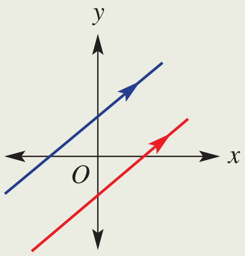
- How much does each company pay for delivery of 7 pizzas in one shift? How much does each company pay for delivery of 12 pizzas in one shift?
- For each pizza company, draw up a table to show the money you could earn for delivery of up to 15 pizzas delivered in one shift.
- On the same sheet, draw a graph of the information in your tables for each pizza company. Draw the graph for each pizza company on the same set of axes.
- What does the point of intersection show us?
- Write a sentence describing which job pays better for different numbers of pizzas delivered.
- Write down one advantage of using a graph to compare these two wages.

Key ideas

- At a point of intersection, two lines will have the same **coordinates**.
- If two lines are **parallel** they have the same gradient and there is no point of intersection.



1 point of intersection



0 points of intersection

Coordinates An ordered pair written in the form (x, y) that states the location of a point on the Cartesian plane

Parallel lines Lines in the same plane that are the same distance apart and never intersect

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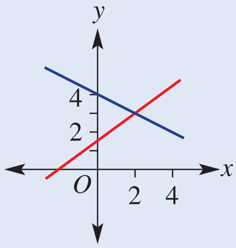
Exercise 9E

UNDERSTANDING AND FLUENCY 1(½), 2–4 3(½), 4–6

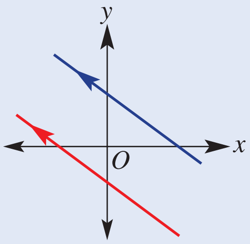
Example 20 Reading the coordinates of the point of intersection of two lines

State the point of intersection (x, y) for the following lines, if there is one.

a



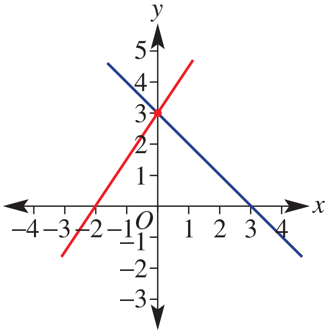
b



SOLUTION	EXPLANATION
a Point of intersection at (2, 3).	Read the x-coordinate, then the y-coordinate, directly from the graph.
b No point of intersection.	Parallel lines have no point of intersection.

1 State the point of intersection (x, y) for the following lines, if there is one.

a



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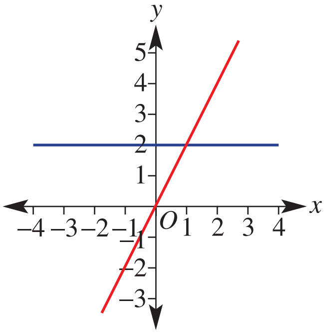
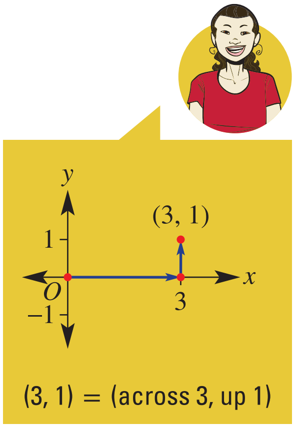
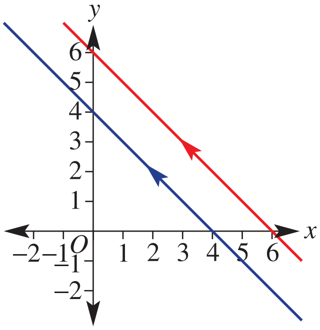




(3, 1) = (across 3, up 1)

c



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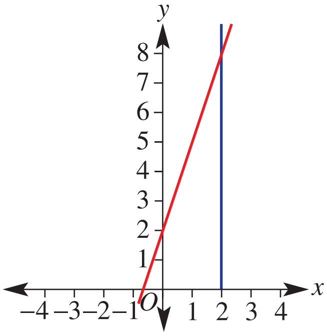

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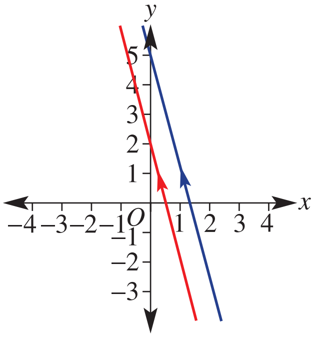

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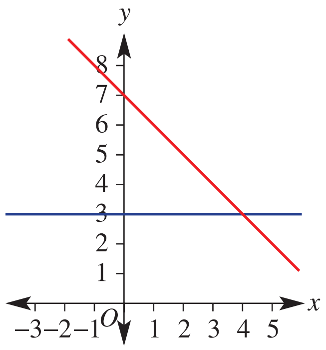
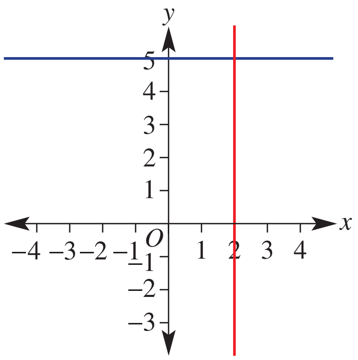
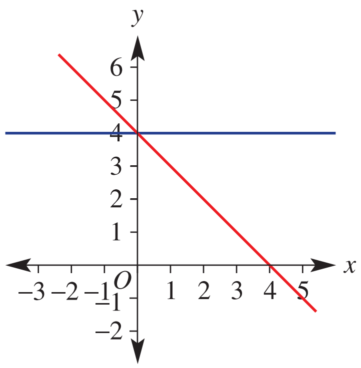


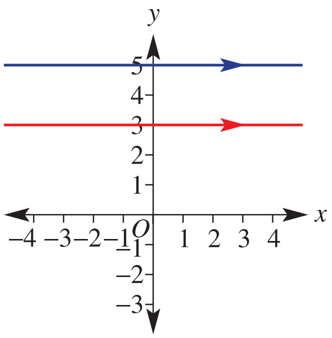
g



h



i



2 Complete the following.

a At the x-intercept, $y =$ ________.

b At the y-intercept, $x =$ ________.

Example 21 Finding the point of intersection by graphing

Find the point of intersection (x, y) of $y = 2x + 4$ and $3x + y = 9$ by sketching accurate graphs on the same axes.

SOLUTION	EXPLANATION
$y = 2x + 4$	First, find the x- and y-intercepts of each graph.
y-intercept at $x = 0$: $y = 2(0) + 4 = 4$	Substitute $x = 0$ to give the y-intercept.
x-intercept at $y = 0$: $0 = 2x + 4$	Substitute $y = 0$ to give the x-intercept.
$2x = -4$	Subtract 4 from both sides.
$x = -2$	Divide both sides by 2.
$\therefore$ $y = 2x + 4$ has y-intercept $= 4$ and x-intercept $= -2$.	
$3x + y = 9$	
y-intercept at $x = 0$: $3(0) + y = 9$	Substitute $x = 0$.
$y = 9$	Simplify.
x-intercept at $y = 0$: $3x + (0) = 9$	Substitute $y = 0$.
$3x = 9$	Simplify.
$x = 3$	Divide both sides by 3.
$\therefore$ $3x + y = 9$ has y-intercept $= 9$ and x-intercept $= 3$.	

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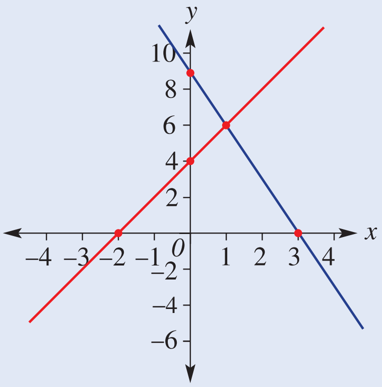


Sketch the graphs using the x- and y-intercepts.

$y = 2x + 4$ < y-intercept $= 4$, x-intercept $= -2$

$3x + y = 9$ < y-intercept $= 9$, x-intercept $= 3$

The point of intersection is (1, 6).

Read off the intersection point, listing x followed by y.

3 Find the point of intersection (x, y) of each pair of equations by plotting an accurate graph.

- **a** $y = x + 1$ and $3x + 2y = 12$
- **b** $y = 3x + 2$ and $2x + y = 12$
- **c** $y = 2x + 9$ and $3x + 2y = 18$
- **d** $y = x + 11$ and $4x + 3y = 12$

4 Find the point of intersection of each pair of equations by plotting an accurate graph.

- **a** $y = 3$ and $x = 2$
- **b** $y = -2$ and $x = 3$

For y-intercept, let $x = 0$.
For x-intercept, let $y = 0$.

$y = 3$ cuts the y-axis at 3 and is horizontal.
$x = 2$ cuts the x-axis at 2 and is vertical.

5 Find the point of intersection of each pair of equations by plotting an accurate graph.

- **a** $y = 3x$ and $y = 2x + 3$
- **b** $y = -3x$ and $y = 2x - 5$

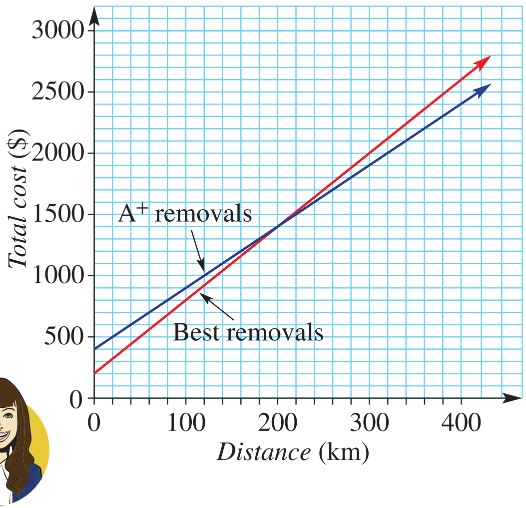
6 Find the point of intersection of each pair of equations by plotting an accurate graph.

- **a** $y = 2x - 6$ and $y = 3x - 7$
- **b** $y = -2x + 3$ and $y = 3x - 2$

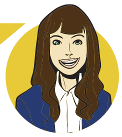
PROBLEM-SOLVING AND REASONING 7, 8 8–10

7 This graph represents the cost of hiring two different removalist companies to move a person's belongings for various distances.

- **a** Determine the number of kilometres for which the total cost of the removalists is the same.
- **b** What is the price when the total cost is equal?
- **c** If a person wanted to move 100 km, which company would be cheaper and by how much?
- **d** If a person wanted to move 400 km, which company would be cheaper and by how much?



The cost is the same at the point of intersection.



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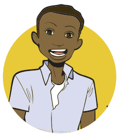
8 The wage structures for baking companies A and B are given by the following.
Company A: \$20 per hour
Company B: \$45 plus \$15 per hour

- **a** Complete two tables showing the wage for each company for up to 12 hours.
- **b** Draw a graph of the wage for each company (on the vertical axis) versus time in hours (on the horizontal axis). Draw the graphs for both companies on the same set of axes.
- **c** State the number of hours worked for which the earnings are the same for the two companies.
- **d** State the amount earned when the earnings are the same for the two companies.

9 **a** Graph these three lines on the same coordinate axes by plotting the axes intercepts for each: $y = 3$, $y = x + 1$, $y = 1 - x$.

- **b** Write the coordinates of the points of intersection.
- **c** Find the length of each line segment formed between the intersection points.
- **d** What type of triangle is formed by these line segments?



Use Pythagoras' theorem to find the length of a line segment.

10 The value of two cars is depreciating (i.e. decreasing) at a constant rate according to the information in this table.

Car	Initial value	Annual depreciation
luxury sports coupe	\$70 000	\$5000
family sedan	\$50 000	\$3000

Annual depreciation means how much the car's value goes down by each year.

- **a** Complete two tables, showing the value of each car every second year from zero to 12 years.
- **b** Draw a graph of the value of each car (on the vertical axis) versus time in years (on the horizontal axis). Draw both graphs on the same set of axes.
- **c** From the graph, determine the time taken for the cars to have the same value.
- **d** State the value of the cars when they have the same value.

ENRICHMENT – 11, 12

Multiple intersections

Using technology, complete these questions.

11 On the same set of axes, plot the graphs of $y = 2x$, $y = 2x + 1$, $y = 2x + 2$ and $y = 2x + 3$.

- **a** Are there any points of intersection?
- **b** Suggest a reason for your answer to part **a**.
- **c** Plot the graph of $y = 3x + 6$.
- **d** Determine the points of intersection of the graphs already drawn and $y = 3x + 6$.

12 On the same set of axes, plot $y = x - 1$, $y = 2x - 1$, $y = 3x - 1$ and $y = 4x - 1$.

- **a** Are there any points of intersection?
- **b** Suggest a reason for your answer to part **a**.
- **c** Plot the graph of $y = 2x + 1$.
- **d** Determine the points of intersection of the graphs already drawn and $y = 2x + 1$.

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9F Solving simultaneous equations using substitution

Interactive
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Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Two simultaneous equations can be made when there are two unknown quantities (variables) and two lots of information relating these quantities. The solution gives the values that make both equations true.

In the previous section, the solution was found from the point of intersection of two line graphs. In this section, you will learn how to find the solution using the algebraic method of *substitution*.

An example of two variables is the cost of a wedding reception and the number of invited guests. Two simultaneous equations could be made about the costs of two different catering companies. The solution will be the number of guests that make the costs equal for the two companies. Using equations gives an accurate comparison of two deals.

Simultaneous equations can be used to compare the costs of two different catering companies for a wedding reception.

Let's start: Equations and solutions

Match each set of simultaneous equations with the correct solution.

SIMULTANEOUS EQUATIONS

J
$a + b = 100$
$12a + 5b = 920$

M
$y = 500 + 70x$
$y = 700 + 68x$

K
$x = 4y$
$2x + 2y = 1000$

N
$a + b = 50$
$a - b = 6$

L
$3x + 2y = 29$
$2x - y = 3$

O
$a = b - 5$
$2a + b = 35$

SOLUTIONS

- **a** $x = 5$ and $y = 7$
- **b** Elias' age (a) is 10 years and Maria's age (b) is 15 years.
- **c** Nicole's age (a) is 28 years and Julian's age (b) is 22 years.
- **d** The length (x) of a playing field is 400 m and the width (y) is 100 m.
- **e** 60 adults (a) and 40 children (b) attended a rugby match. The tickets cost \$12 per adult and \$5 per child.
- **f** A wedding reception hosting 100 guests (x) costs \$7500 (y).

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Key ideas

- The algebraic method of substitution is generally used when at least one of the linear equations has x or y as the subject.

  e.g. $y = 3x + 4$ or $y = -2x + 6$ or $x = 2$

  $3x + y = 2$ $\quad$ $y = -x - 1$ $\quad$ $2x - y = 5$

- The method involves:
  - substituting one equation into the other
  - solving for the remaining variable
  - substituting to find the value of the second variable.

- When problem-solving with simultaneous linear equations:
  - Define/describe two unknowns, using pronumerals.
  - Write down two equations, using your pronumerals.
  - Solve the equations, using the method of substitution.
  - Answer the original question in words.

Exercise 9F

UNDERSTANDING AND FLUENCY		1–4(½)	1–5(½)

Example 22 Using the substitution method to solve simultaneous equations

Determine the point of intersection of $y = 5x$ and $y = 2x + 6$.

SOLUTION	EXPLANATION
$y = 5x$...............................(1)	Label the two equations.
$y = 2x + 6$.........................(2)	
Substitute (1) into (2):	Explain how you are substituting the equations.
$5x = 2x + 6$	Replace y in the second equation with $5x$.
$3x = 6$	Subtract $2x$ from both sides.
$x = 2$	Divide both sides by 3.
Substitute $x = 2$ into (1):	Alternatively, substitute into equation (2).
$y = 5(2)$	Replace x with the number 2.
$y = 10$	Simplify.
The point of intersection is (2, 10).	Write the solution.
	Substitute your solution into both equations to check.

1 Determine the point of intersection for the following pairs of lines.

a $y = 5x$
$y = 3x + 4$

b $y = 3x$
$y = 2x - 5$

c $y = 2x$
$y = 4x + 8$

d $y = 4x$
$y = -3x + 7$

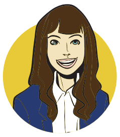
e $y = x$
$y = -5x + 12$

f $y = 6x$
$y = -2x + 16$

$y = \boxed{5x}$

$\boxed{y} = 3x + 4$ so

$5x = 3x + 4$



Example 23 Solving simultaneous equations with the substitution method

Solve the simultaneous equations $y = x + 3$ and $2x + 3y = 19$ using the substitution method; i.e. find the point of intersection.

SOLUTION	EXPLANATION
$y = x + 3$ ....(1)	Label the two equations.
$2x + 3y = 19$ ....(2)	
Substitute (1) into (2):	Explain how you are substituting the equations.
$2x + 3(x + 3) = 19$	Replace y in the second equation with $(x + 3)$.
$2x + 3x + 9 = 19$	Expand the brackets.
$5x + 9 = 19$	Simplify.
$5x = 10$	Subtract 9 from both sides.
$x = 2$	Divide both sides by 5.
Substitute $x = 2$ into (1):	Alternatively, substitute into equation (2).
$y = 2 + 3$	Replace x with the number 2.
$y = 5$	Simplify.
The point of intersection is (2, 5).	Write the solution. Check by substituting your solution into both equations.

2 Solve the following pairs of simultaneous equations using the substitution method; i.e. find the point of intersection.

- **a** $y = x + 1$ and $2x + 3y = 18$
- **b** $y = x + 2$ and $3x + y = 6$
- **c** $y = x - 1$ and $3x + 2y = 8$
- **d** $y = x - 1$ and $3x + 5y = 27$
- **e** $y = x + 2$ and $2x + 3y = -19$
- **f** $y = x + 5$ and $5x - y = -1$
- **g** $y = x - 3$ and $5x - 2y = 18$
- **h** $y = x - 4$ and $3x - y = 2$

In part **a**, replace y in the second equation with $(x + 1)$. It is important to use brackets.

$y = \boxed{x + 1}$

$2x + 3\boxed{y} = 18$

Remember that

$3(x + 1) = 3x + 3$

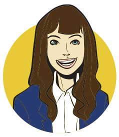
3 Solve the following pairs of simultaneous equations; i.e. find the point of intersection.

- **a** $y = 2$
$y = 2x + 4$
- **b** $y = -1$
$y = 2x - 7$
- **c** $y = 4$
$2x + 3y = 20$
- **d** $y = 4$
$2x - y = 0$
- **e** $y = -2$
$x + y = 9$
- **f** $y = 0$
$2x + 3y = 8$

Replace y in the second equation with 2.

$y = \boxed{2}$

$\boxed{y} = 2x + 4$



4 Determine the point of intersection for the following.

a $x = 2$
$3x + 2y = 14$

b $x = -3$
$y = -2x - 4$

c $x = 7$
$4x - 3y = 31$

d $x = 4$
$2x - y = 4$

e $x = -2$
$x - y = 5$

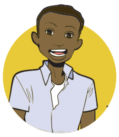
f $x = -1$
$2x + 3y = 4$

Replace x in the second equation with 2.

$x = \boxed{2}$

$3\boxed{x} + 2y = 4$

Remember that $3x$ means $3 \times x$.



5 Solve the following pairs of simultaneous equations using the substitution method; i.e. find the point of intersection.

a $y = 2x + 3$
$11x - 5y = -14$

b $y = 3x - 2$
$7x - 2y = 8$

c $y = 3x - 5$
$3x + 5y = 11$

d $y = 4x + 1$
$2x - 3y = -23$

Be careful with signs when expanding brackets.

$-5 \times (+3) = -15$

$11x - 5(2x + 3)$

$= 11x - 10x - 15$

When multiplying numbers with different signs, the answer is negative.

PROBLEM-SOLVING AND REASONING 6, 7 6, 8, 9

Example 24 Solving word problems with simultaneous equations (substitution)

Jade is 5 years older than Marian. If their combined age is 33, find their ages.

SOLUTION	EXPLANATION
Let j be Jade's age and m be Marian's age.	Define two pronumerals using words.
$j = m + 5$..................(1)	The first piece of information is that Jade is 5 years older than Marian.
$j + m = 33$................(2)	The second is that their combined age is 33.
$(m + 5) + m = 33$	Substitute $m + 5$ for j in the second equation.
$2m + 5 = 33$	Collect any like terms, so $m + m = 2m$.
$2m = 28$	Subtract 5 from both sides.
$m = 14$	Divide both sides by 2.
$j = m + 5$............(1) $j = 14 + 5$ $j = 19$	Use the first equation, $j = m + 5$, to find j.
Jade is 19 years old and Marian is 14 years old.	Answer the original question in words. Check that the solution is reasonable.

6 Paul is 5 years older than Mary. If their combined age is 81, determine their ages.

First define a pronumeral for Paul's age and another pronumeral for Mary's age. Then write two equations before solving.

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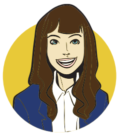
7 The length of a rectangle is three times its breadth. If the perimeter of the rectangle is 48 cm, determine its dimensions.

Draw a diagram to help form the perimeter equation.

8 A vanilla thickshake is \$2 more than a fruity twirl. If three vanilla thickshakes and five fruity twirls cost \$30, determine their individual prices.

If a fruity twirl costs $\$x$, then 5 will cost $\$5x$.



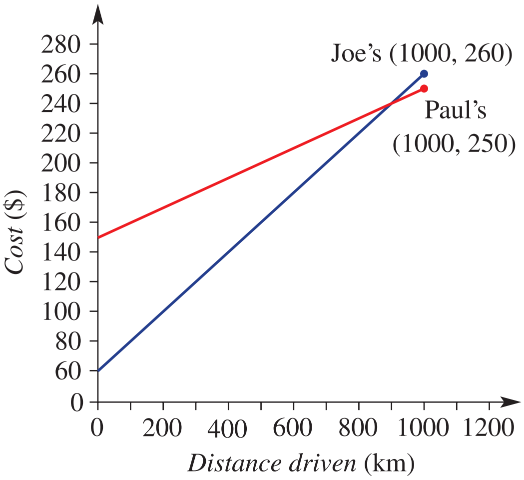
9 Carlos is 3 years more than twice Ella's age. If the sum of their ages is 54 years, determine their ages.

ENRICHMENT – 10

Rentals

10 The given graph represents the rental cost of a new car from two car rental firms called Paul's Motor Mart and Joe's Car Rental.

- **a** Determine:
  - **i** the initial rental cost from each company
  - **ii** the cost per kilometre when renting from each company
  - **iii** the linear equations for the total cost from each company
  - **iv** the number of kilometres at which the total cost is the same from both rental firms, using the method of substitution
- **b** Describe when you would use Joe's or Paul's rental firm.



9G Solving simultaneous equations using elimination

Interactive
Widgets
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Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Another method for solving simultaneous equations, called elimination, can sometimes be more efficient, depending on how the equations are structured in the first place.

When setting up equations for real situations, we should use pronumerals to define the unknown quantities. When solving simultaneous linear equations, there should be only two unknown quantities and two equations that can be formed from the given information.

For example, two related variables are the cost of owning a car and the number of kilometres driven. For two different cars, two equations could be made relating these variables. The simultaneous solution gives the number of kilometres that makes the total running costs of each car equal. Solving simultaneous equations provides information for an accurate comparison of costs between two vehicles.

Using simultaneous equations, we can compare the overall cost of a diesel 4WD to that of a petrol 4WD.

Let's start: Eliminating a variable

One step in the elimination method involves adding or subtracting two equations in order to eliminate one of the variables. When adding, we write (1) + (2); when subtracting, we write (1) − (2).

- A student has either added or subtracted pairs of equations, but has many incorrect answers.
- Determine which answers are incorrect and write the correct answer for these. (Note: Do not solve the equations for x or y.)

A

$5x + 3y = 34$ (1)
$7x - 3y = 26$ (2)
(1) + (2)
$12x + 0 = 60$

B

$3x + 2y = 18$ (1)
$2x - 2y = 2$ (2)
(1) + (2)
$5x - 4y = 20$

C

$3x - 3y = 9$ (1)
$2x - 3y = 4$ (2)
(1) − (2)
$5x + 0 = 5$

D

$2x - 2y = 8$ (1)
$4x - 2y = 24$ (2)
(1) − (2)
$2x - 4y = 16$

E

$4x + 3y = 16$ (1)
$-4x + 2y = 3$ (2)
(1) + (2)
$0 + y = 19$

F

$3x + 2y = 25$ (1)
$2x + 2y = 18$ (2)
(1) − (2)
$x + 0 = 43$

G

$5x + 3y = 31$ (1)
$5x - 3y = 19$ (2)
(1) + (2)
$0 + 0 = 12$

H

$x + 3y = 15$ (1)
$x + 2y = 12$ (2)
(1) − (2)
$2x + y = 3$

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Key ideas

- **Elimination** is generally used to solve simultaneous equations when both equations are in the form $ax + by = d$.

  For example: $2x - y = 6$ or $-5x + y = -2$

  $3x + y = 10$ $6x + 3y = 5$
- Adding or subtracting multiples of these two equations allows one of the pronumerals to be eliminated.
- When problem-solving with simultaneous linear equations:
  - Define/describe two unknowns, using pronumerals.
  - Write down two equations, using your pronumerals.
  - Solve the equations, using the method of elimination.
  - Answer the original question in words.

Elimination A method for solving simultaneous equations, where one equation is added to or subtracted from another to eliminate one of the variables

Exercise 9G

UNDERSTANDING AND FLUENCY 1–4, 5(½), 7(½) 4, 5(½), 6, 7–9(½)

1 What operation (i.e. + or −) will make these equations true?

a $2x$___$2x = 0$ **b** $-3y$___$3y = 0$ **c** $4x$___$(-4x) = 0$

2 Multiply both sides of the equation $3x - 2y = -1$ by the following numbers. Write the new equations.

a 2 **b** 3 **c** 4

Example 25 Eliminating a variable by addition of equations then solving

Add equation (1) to equation (2), then solve for x and y.

$x + 2y = 10$ (1)

$x - 2y = 2$ (2)

SOLUTION	EXPLANATION
$x + 2y = 10$ (1)	Copy equations with the labels (1) and (2).
$x - 2y = 2$ (2)	
(1) + (2)	Write the instruction to add: (1) + (2)
$2x + 0 = 12$	Add the x column: $x + x = 2x$.
$2x = 12$	Add the y column: $2y + (-2y) = 2y - 2y = 0$.
$x = 6$	Add the RHS: $10 + 2 = 12$.
	Solve the remaining equation for x.
Substitute $x = 6$ into (1):	In equation (1) replace x with 6. Equation (2) could have been used also.
$6 + 2y = 10$	Subtract 6 from both sides.
$2y = 4$	Divide both sides by 2.
$y = 2$	
Solution is $x = 6$, $y = 2$ or $(6, 2)$.	Write the solution as an ordered pair. Check that the solution satisfies both equations.

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3 Copy each pair of equations, add equation (1) to (2), then solve for x and y following the steps in **Example 25**.

a $x + y = 7$ (1)
$x - y = 5$ (2)
(1) + (2)

b $x + 2y = 11$ (1)
$x - 2y = -5$ (2)
(1) + (2)

c $3x + 2y = 20$ (1)
$-3x + y = 1$ (2)
(1) + (2)

Adding equations:
(1) + (2)

$$\begin{array}{ccccc} x & +y & = & 7 & (1) \\ x & -y & = & 5 & (2) \\ \downarrow & \downarrow & & \downarrow & \\ 2x & +0 & = & 12 & \end{array}$$

Remember that
$+y + (-y) = +y - y = 0$

4 Copy each pair of equations, subtract equation (2) from equation (1), then solve for x and y, showing all steps.

a $2x + y = 16$ (1)
$x + y = 9$ (2)
(1) − (2)

b $3x + 5y = 49$ (1)
$3x + 2y = 25$ (2)
(1) − (2)

c $5x - 4y = 16$ (1)
$2x - 4y = 4$ (2)
(1) − (2)

Subtracting equations:
(1) − (2)

$$\begin{array}{ccccc} 5x & -2y & = & 16 & (1) \\ 2x & -2y & = & 4 & (2) \\ \downarrow & \downarrow & & \downarrow & \\ 3x & +0 & = & 12 & \end{array}$$

Remember that
$-2y - (-2y)$
$= -2y + 2y = 0$

Example 26 Using the elimination method to find the coordinates of the point of intersection

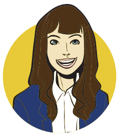
Determine the point of intersection of the lines $x + y = 6$ and $3x + y = 10$, using the elimination method.

SOLUTION	EXPLANATION
$x + y = 6$...............................(1) $3x + y = 10$...........................(2)	Label the two equations and decide whether to eliminate x or y. Choose y since there is $1y$ in each equation.
(2) − (1):	Subtract the two equations because $y - y = 0$.
$2x = 4$	$3x - x = 2x$ and $10 - 6 = 4$.
$x = 2$	Solve for x.
Substitute $x = 2$ into (1):	Alternatively, substitute into equation (2).
$2 + y = 6$ $y = 4$	Replace x with the number 2 and solve for y.
Solution is $x = 2$, $y = 4$.	Write the solution as an ordered pair.
Point of intersection is (2, 4).	Check that the solution satisfies both equations.

5 Determine the point of intersection of the following lines, using the elimination method.

a $x + y = 7$ and $5x - y = 5$
b $x + y = 5$ and $3x - y = 3$
c $x - y = 2$ and $2x + y = 10$
d $x - y = 0$ and $4x + y = 10$

Label the two equations, one under the other, and decide whether to eliminate x or y.
Remember that $+y + (-y) = 0$.
The point of intersection is the same as the simultaneous solution of the equations.



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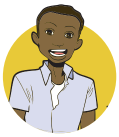
6 Solve the following pairs of simultaneous equations, using the elimination method. You will need to subtract the equations to eliminate one of the variables.

a $3x + 4y = 7$
$2x + 4y = 6$

b $4x + 3y = 11$
$x + 3y = 5$

c $2x + 3y = 1$
$2x + 5y = -1$

Always label the equations and write the instruction. e.g. (1) − (2) or (2) − (1).



Example 27 Solving simultaneous equations using the elimination method

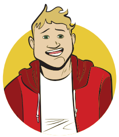
Solve the simultaneous equations $3x + 2y = 6$ and $5x + 3y = 11$, using the elimination method.

SOLUTION	EXPLANATION
$3x + 2y = 6$ ....(1) $5x + 3y = 11$ ....(2)	Label the two equations and decide whether to eliminate x or y.
(1) × 3 $9x + 6y = 18$ ....(3) (2) × 2 $10x + 6y = 22$ ....(4)	Multiplying the first equation by 3 and the second equation by 2 results in a matching pair $6y$ in each equation.
(3) − (4) $-x = -4$	Subtract the equations since $6y - 6y = 0$.
$x = 4$	Divide both sides by −1.
Substitute $x = 4$ into (1): $3(4) + 2y = 6$	Alternatively, substitute into equation (2). Replace x with the number 4.
$2y = -6$	Subtract 12 from both sides since $3 \times 4 = 12$.
$y = -3$	Divide both sides by 2.
Solution is $x = 4$, $y = -3$.	Write the solution.
Point of intersection is $(4, -3)$.	Check that the solution satisfies both equations.

7 Solve the following pairs of simultaneous equations, using the elimination method.

a $3x + 2y = 2$ and $4x + 3y = 4$
b $3x + 2y = 5$ and $2x + 3y = 5$
c $2x + y = 4$ and $5x + 2y = 10$
d $2x + 5y = 7$ and $x + 3y = 4$
e $3x + y = 8$ and $x + 2y = 1$
f $2x + 3y = 5$ and $x + 2y = 3$

When multiplying an equation by a number, multiply every term on the LHS and RHS by that number. In part **c** and **d** you can simply multiply one of the two equations to obtain a matching pair.



8 Solve the following pairs of simultaneous equations, using the elimination method.

a $3x + 5y = 8$
$x - 2y = -1$

b $2x + y = 10$
$3x - 2y = 8$

c $4x - 3y = 0$
$3x + 4y = 25$

d $2x + 4y = 8$
$x - 3y = -1$

e $3x - 2y = 11$
$2x + y = 5$

f $2x - y = -9$
$3x + 2y = 4$

Choose to eliminate x or y. The coefficients must be the same size (with + or −); e.g. $-4x$ and $4x$ or $-5y$ and $-5y$. Choose to add or subtract the equations to eliminate one variable.

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9 Solve the following pairs of simultaneous equations.

- **a** $5x + 3y = 18$ and $3y - x = 0$
- **b** $3x - y = 13$ and $x + y = -9$
- **c** $2x + 7y = -25$ and $5x + 7y = -31$
- **d** $2x + 6y = 6$ and $3x - 2y = -2$
- **e** $4x - 5y = -14$ and $7x + y = -5$
- **f** $7x - 3y = 41$ and $3x - y = 17$
- **g** $5x - 3y = 4$ and $3x + 2y = 10$
- **h** $3x + 2y = 5$ and $2x - 3y = -1$

PROBLEM-SOLVING AND REASONING

10–12 12–16

Example 28 Solving word problems with simultaneous equations (elimination)

Kathy is older than Blake. The sum of their ages is 17 years and the difference is 5 years. Find Kathy and Blake's ages.

SOLUTION	EXPLANATION
Let k be Kathy's age and b Blake's age.	Define two pronumerals.
$k + b = 17$................................(1)	The first piece of information is 'the sum of their ages is 17'.
$k - b = 5$..................................(2)	The second piece of information is 'the difference is 5 and Kathy is older than Blake'.
(1) + (2) $2k = 22$ $k = 11$	Add the two equations to eliminate b or, alternatively, subtract to eliminate k.
Substitute $k = 11$ into (1): $11 + b = 17$	Alternatively, substitute into (2).
$b = 6$	Subtract 11 from both sides.
Kathy is 11 years old and Blake is 6.	Answer the original question in words. Check that the solution is reasonable.

10 Bob is older than Francine. The sum of their ages is 56 years and the difference is 16 years. Use simultaneous equations to find Bob and Francine's ages.

11 Let x and y be two numbers that satisfy the following statements. Set up two linear equations according to the information and solve them simultaneously to determine the numbers in each case.

- **a** Their sum is 16 but their difference is 2.
- **b** Their sum is 30 but their difference is 10.
- **c** Twice the larger number plus the smaller is 12 and their sum is 7.

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Example 29 Problem solving with simultaneous equations

John purchases three daffodils and five petunias from the local nursery and the cost is $25.
Julia buys four daffodils and three petunias and the cost is $26.
Determine the cost of each type of flower.

SOLUTION	EXPLANATION
Let d be the cost of a daffodil and p be the cost of a petunia.	Define your pronumerals.
$3d + 5p = 25 \ldots\ldots (1)$	Three daffodils and five petunias from the local nursery cost $25.
$4d + 3p = 26 \ldots\ldots (2)$	Four daffodils and three petunias cost $26.
(1) × 4 $12d + 20p = 100 \ldots\ldots (3)$	Multiply (1) by 4 and (2) by 3 to obtain a
(2) × 3 $12d + 9p = 78 \ldots\ldots (4)$	matching pair (12d and 12d).
(3) − (4) $11p = 22$	Subtract the equations to eliminate d.
$p = 2$	Divide both sides by 11.
Substitute $p = 2$ into (1):	Alternatively, substitute into (2).
$3d + 5(2) = 25$	Replace p with the number 2.
$3d + 10 = 25$	Simplify.
$3d = 15$	Subtract 10 from both sides.
$d = 5$	Divide both sides by 3.
	Check the solution by substituting into both equations.
Daffodils cost $5 and petunias cost $2 each.	Answer the question in words.
	Check that the solution is reasonable.

12 Chris the fruiterer sells two fruit packs.
Pack 1: 10 apples and 5 mangos ($12.50)
Pack 2: 15 apples and 4 mangos ($13.50)

- **a** Define two pronumerals and set up a pair of linear equations to eventually find the cost of each fruit.
- **b** Solve the two simultaneous equations to determine the individual prices of each piece of fruit.
- **c** Determine the cost of one apple and five mangos.

13 A maths test contains multiple-choice questions worth 2 marks each and short-answer questions worth 3 marks each. The test is out of 50 marks and there are 22 questions.

- **a** Define two pronumerals to represent the number of each question type.
- **b** Set up two linear equations.
- **c** Solve the two equations simultaneously to determine the number of multiple-choice questions.

Total marks is 50. Number of questions is 22.

14 Tickets to a basketball game cost $3 for children and $7 for adults. If 5000 people attended the game and the total takings at the door were $25 000, determine the number of children and adults who attended the game.

What you are being asked to find is often what you define as your variables.

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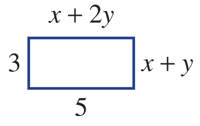
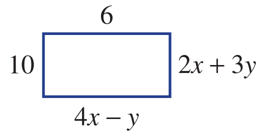
15 Find the value of x and y in the following rectangles. You will need to write two equations and then solve them using the elimination method.

a



b



Opposite sides of rectangles are of equal length.

16 Gary is currently 31 years older than his daughter. In 30 years' time he will be twice his daughter's age. Using g for Gary's current age and d for Gary's daughter's current age, complete the following.

a Write down expressions for:

- **i** Gary's age in 30 years' time
- **ii** Gary's daughter's age in 30 years' time

b Write down two linear equations, using the information at the start.

c Solve the equations to find the current ages of Gary and his daughter.

ENRICHMENT – 17

Using technology

17 Use technology to solve these simultaneous equations.

a $3x + 2y = 6$ and $5x + 3y = 11$

b $3x + 2y = 5$ and $2x + 3y = 5$

c $4x - 3y = 0$ and $3x + 4y = 25$

d $2x + 3y = 10$ and $3x - 4y = -2$

e $-2y - 4x = 0$ and $3y + 2x = -2$

f $-7x + 3y = 22$ and $3x - 6y = -11$

1 The answers to these equations will form a magic square: each row, column and diagonal will add to the same number. Draw a 4 by 4 square for your answers and check that they do make a magic square.

$x - 3 = 6$	$x + 15 = 10$	$\frac{x}{2} = -2$	$5x = 30$
$3x + 7 = 1$	$\frac{x}{4} - 8 = -7$	$\frac{x + 7}{2} = 5$	$3(x + 4) = x + 14$
$\frac{x}{2} - 5 = -4$	$4x - 9 = -9$	$x + 7 = 4x + 10$	$2(3x - 12) - 5 = 1$
$\frac{9 - 3x}{3} = 6$	$-2(3 - x) = x + 1$	$x - 16 = -x$	$5x + 30 - 3x = -3x$

2 Write an equation and solve it to help you find the unknown number in these puzzles.

a Three-quarters of a number plus 16 is equal to 64.

b A number is increased by 6, then that answer is doubled and the result is four more than triple the number.

c The average of a number and its triple is equal to 58.6.

d In 4 years' time, Ahmed's age will be double the age he was 7 years ago. How old is Ahmed now?

3 By applying at least two operations to x, write three different equations so that each equation has the solution $x = -2$. Verify that $x = -2$ makes each equation true.

For example: $3 \times (-2) + 10 = 4$, so one possible equation would be $3x + 10 = 4$.

4 Which Australian city has its centre on the intersection of the Warrego Highway and the New England Highway?

To decode this puzzle, solve the inequalities and simultaneous equations below, and match them to a number line or graph. Place the corresponding letters above the matching numbers to find the answer.

6	4	4	3	4	4	5	1	2

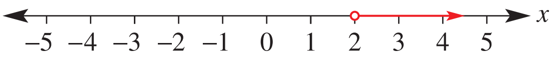
Solve these inequalities and match the solution to a number line (**1**–**3**).

W $2 - 3x > 8$

A $3x + 10 \geqslant 1$

B $x + 5 > 7$

1



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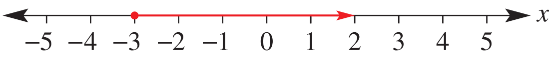

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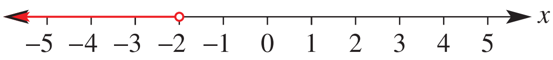


Solve these simultaneous equations and match the solution to a graph (**4**–**6**).

M

$3x - y = 7$

$2x + y = 3$

O

$y = 2x + 1$

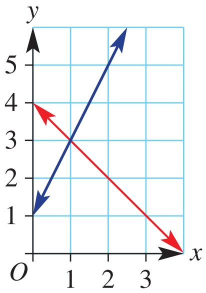
$x + y = 4$

T

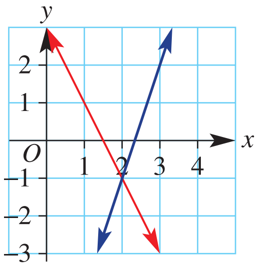
$2x - y = -1$

$x - 2y = 4$

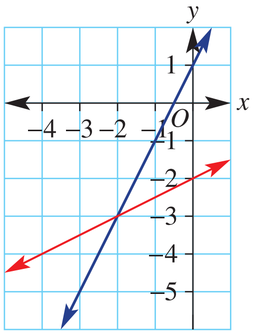
4



5



6



5 Write two sets of simultaneous equations so that each pair has the solution (3, −2).

6 Jules and Enzo have a long-distance bike race. Jules rides at 18 km/h and has a 2-hour head start. Enzo travels at 26 km/h.

a How long does it take for Enzo to catch up to Jules? (Use distance = speed × time.)

b How far did they both ride before Enzo caught up to Jules?

7 Talia travelled a distance of 138 km by jogging for 2 hours and cycling for 5 hours. She could have travelled the same distance by jogging for 4 hours and cycling for 4 hours. Find the speed at which she was jogging and the speed at which she was cycling.

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Equations, formulas and inequalities

Solving linear equations that have brackets

- Expand all brackets
- Collect like terms on each side of the equation
- Collect terms with a pronumeral to one side (usually the LHS)
- Solve for unknown

e.g.

$$\begin{aligned} 12(x+1) - 2(3x-3) &= 4(x+10) \\ 12x + 12 - 6x + 6 &= 4x + 40 \\ 6x + 18 &= 4x + 40 \\ 2x + 18 &= 40 \\ 2x &= 22 \\ x &= 11 \end{aligned}$$

Solving linear equations

Solving involves finding the value that makes an equation true.

e.g. $2x + 5 = 9$

$2x = 4$ (subtract 5)

$x = 2$ (divide by 2)

Equations with fractions

e.g.

$\frac{3x}{4} - 2 = 7$ (first $+2$ to both sides)

$\frac{3x}{4} = 9$ ($\times 4$ both sides)

$3x = 36$ ($\div 3$ both sides)

$x = 12$

e.g.

$\frac{2x-5}{3} = 7$ (first $\times 3$ to both sides)

$2x - 5 = 21$ ($+5$ both sides)

$2x = 26$ ($\div 2$ both sides)

$x = 13$

Solving word problems

1. Define variable(s).
2. Set up equation(s).
3. Solve equation(s).
4. Check each answer and write in words.

Formulas

Some common formulas

e.g. $A = \pi r^2$, $C = 2\pi r$

An unknown value can be found by substituting values for the other variables.

A formula can be rearranged to make a different variable the subject.

e.g. $E = mc^2$, find m when $E = 320$ and $c = 4$.

$320 = m \times 4^2$ (substitute values)

$320 = 16m$

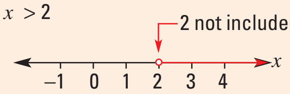
$16m = 320$ (swap LHS and RHS)

$m = 20$ (divide both sides by 16)

Inequalities

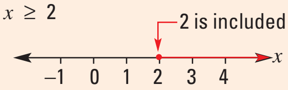
These can be represented using $>, <, \geq, \leq$ rather than $=$.

e.g. $x > 2$



2 not included

e.g. $x \geq 2$



2 is included

Solving inequalities uses the same steps as solving equations, except when multiplying or dividing by a negative number. In this case, the inequality sign must be reversed.

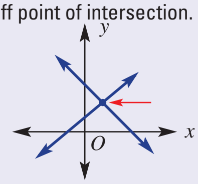
e.g. $4 - 2x > 10$ (subtract 4)

$-2x > 6$ (divide by -2)

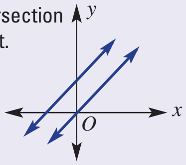
$x < -3$ (reverse sign)

Graphical solutions of simultaneous equations

Graph each line and read off point of intersection.



Parallel lines have no intersection point.



Simultaneous equations

Use substitution or elimination to find the solution that satisfies two equations.

Substitution

e.g. $2x + y = 12$ (1)

$y = x + 3$ (2)

In (1) replace y with (2):

$2x + (x + 3) = 12$

$3x + 3 = 12$

$3x = 9$

$x = 3$

Sub. $x = 3$ to find y:

In (2) $y = 3 + 3 = 6$

Solution is (3, 6).

Elimination

Ensure both equations have a matching pair.

Add the two equations if matching pair has different sign; subtract them if have same sign.

e.g. $x + 2y = 2$ (1)

$2x + 3y = 5$ (2)

(1) × 2 $2x + 4y = 4$ (3)

(3) – (2) $y = -1$

In (1) $x + 2(-1) = 2$

$x - 2 = 2$

$x = 4$

Solution is (4, –1).

Multiple-choice questions

1 The solution to is $x + 7 = 9$ is:

A $x = 16$ **B** $x = -2$ **C** $x = 2$ **D** $x = 1$ **E** $x = -16$

2 To solve the equation $3(2x + 4) - 4(x + 2) = 6$, you would first:

A divide both sides by 12 **B** expand the brackets
C subtract 6 from both sides **D** multiply both sides by 6
E add $4(x + 2)$ to both sides

3 A number is increased by 6 and then doubled. The result is 36. This translates to:

A $6x + 2 = 36$ **B** $2x + 6 = 36$ **C** $2(x + 6) = 36$
D $2(x - 6) = 36$ **E** $x + 12 = 36$

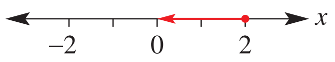
4 If $4a - 6 = 2a$, then a equals:

A -1 **B** 1 **C** 6 **D** 3 **E** -3

5 $x \leqslant 4$ is a solution to:

A $x + 1 < 3$ **B** $3x - 1 \leqslant 11$ **C** $\frac{x}{2} - 1 \geqslant 0$
D $x - 1 \geqslant 1$ **E** $-x \leqslant -4$

6 Which number line shows $x + 4 < 6$?

A


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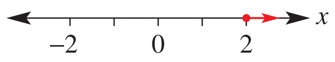
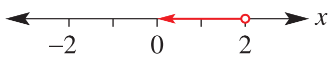
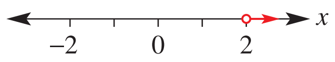
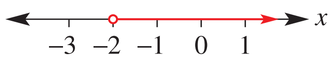


C


D


E


7 The solution to $\frac{5x}{9} - 4 = 1$ is:

A $x = 6$ **B** $x = -9$ **C** $x = -5$ **D** $x = 9$ **E** $x = 5$

8 If two lines are not parallel, the number of intersection points they will have is:

A 0 **B** 1 **C** 2 **D** 3 **E** 4

9 The intersection point for the graphs of $y = 2$ and $x = 3$ is:

A $(-1, 2)$ **B** $(2, 2)$ **C** $(3, 2)$ **D** $(3, 3)$ **E** $(2, 3)$

10 The solution to $3(x - 1) = 12$ is:

A $x = -1$ **B** $x = 2$ **C** $x = 0$ **D** $x = 5$ **E** $x = 4$

11 $y = 3x$ and $x + y = 4$ has the solution:

A $(1, 3)$ **B** $(3, 1)$ **C** $(2, 6)$ **D** $(2, 2)$ **E** $(-1, 5)$

12 Substituting $y = x - 1$ into $x + 2y = 3$ gives:

A $x - 2x - 2 = 3$ **B** $x + 2y - 2 = 3$ **C** $x - x - 1 = 3$
D $x + 2x - 1 = 3$ **E** $x + 2(x - 1) = 3$

13 Adding $x + y = 3$ to $x - y = 4$ gives:
A $2x - 2y = 7$ **B** $2x = 7$ **C** $x = 7$ **D** $y = 7$ **E** $2y = 7$

14 Subtracting $2x + 3y = 10$ from $5x + 3y = 16$ gives:
A $3x = -6$ **B** $6y = 6$ **C** $6x = 26$ **D** $3x = 6$ **E** $8x = 26$

15 The solution to $2x - y = 3$ and $3x + y = 7$ is:
A $(2, 1)$ **B** $(1, -1)$ **C** $(1, 4)$ **D** $(3, 3)$ **E** $(3, -2)$

16 The sum of two numbers is 15 and their difference is 7. The two numbers are:
A 4 and 11 **B** 5 and 12 **C** 5 and 10 **D** 3 and 12 **E** 2 and 13

17 Two apples and three bananas cost \$3.40, whereas three apples and two bananas cost \$3.10. The cost of an apple is:
A \$0.70 **B** \$1.50 **C** 80 cents **D** \$1 **E** 50 cents

Short-answer questions

1 Solve the following.
a $4a = 32$ **b** $\frac{m}{5} = -6$ **c** $1 = 9 + x$
d $x + x = 16$ **e** $9m = 0$ **f** $9 = w - 6$
g $8m = -1.6$ **h** $\frac{w}{4} = 1$ **i** $3 = r - 3$

2 Find the solutions to the following.
a $2m + 7 = 11$ **b** $3w - 6 = 18$ **c** $6 = 1 + \frac{m}{2}$
d $\frac{5w}{4} - 3 = 7$ **e** $\frac{m - 6}{2} = 4$ **f** $1 = \frac{3m + 2}{6}$
g $6a - 9 = 0$ **h** $4 - x = 3$ **i** $9 = 6 + x$

3 Solve the following by first expanding the brackets.
a $3(m + 1) = 12$ **b** $4(a - 3) = 16$ **c** $30 = 5(2 + x)$
d $4(2x + 1) = 16$ **e** $2(3m - 3) = 9$ **f** $9 = 2(1 + 4x)$
g $2(2x + 3) + 3(5x - 1) = 41$ **h** $3(2x + 4) - 4(x - 7) = 56$

4 Find the value of p in the following.
a $7p = 5p + 8$ **b** $2p = 12 - p$ **c** $5p = 6p + 9$
d $2p + 10 = p + 8$ **e** $3p + 1 = p - 9$ **f** $p - 2 = 4p - 8$

5 **a** $A = \frac{1}{2}hb$. Find b if $A = 24$ and $h = 6$.
b $V = lbh$. Find b if $V = 84$, $l = 6$ and $h = 4$.
c $A = \frac{x + y}{2}$. Find x if $A = 3.2$ and $y = 4$.
d $E = mc^2$. Find m if $E = 40$ and $c = 2$.
e $F = \frac{9}{5}C + 32$. Find C if $F = 95$.

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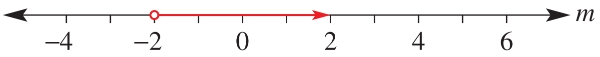
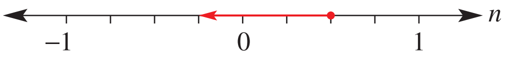
6 Write the inequality displayed on each of the following number lines.

a 

b 

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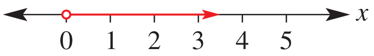
d 

e 

7 Solve the following.

a $x + 8 \geqslant -10$ **b** $2m < 7$ **c** $2x + 6 > 10$

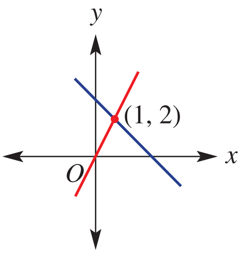
d $x - 3 < 0$ **e** $\frac{x}{4} + 1 \leqslant 3$ **f** $m - 6 \geqslant 4$

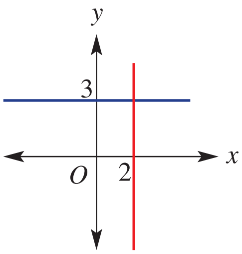
8 Solve the following.

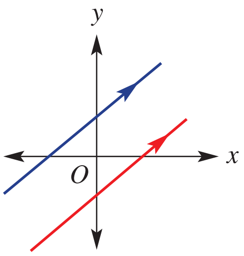
a $-6x \leqslant 12$ **b** $8 - x \leqslant 10$ **c** $-x > 0$

d $1 - 2x < 3$ **e** $9 < 3 - 2x$ **f** $1 - \frac{x}{4} \geqslant 6$

9 Determine the point of intersection of the following lines.

a 

b 

c 

10 Find the point of intersection (x, y) of the following by plotting an accurate graph.

a $y = 2x + 4$
$3x + y = 9$

b $y = 2$
$x = 3$

c $y = 3x$
$y = -3x$

11 Solve the simultaneous equations using the substitution method; i.e. find the point of intersection.

a $y = 5x - 13$
$2x + 3y = 12$

b $y = 3x$
$y = 2x + 5$

c $2x + y = 5$
$x + 3y = 5$

12 Determine the point of intersection of the following lines, using the elimination method.

a $2x + 7y = -25$
$5x + 7y = -31$

b $3x + 2y = 8$
$x - 2y = 0$

c $2x + 5y = 6$
$3x + 2y = -2$

13 Solve the following simultaneous equations using any method.

a $2x + y = -12$
$y = 2x$

b $2x - 5y = 13$
$x = -1$

c $5x - y - 9 = 0$
$x = 2$

d $y = 9$
$3x + y = 0$

e $\frac{x}{3} - y = 0$
$2x - 3y = 6$

f $3x + 2y = -19$
$4x - y = -7$

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14 Write an equation for the following and then solve it.

- **a** Six times a number equals 420. What is the number?
- **b** Eight more than a number equals 5. What is the number?
- **c** A number divided by 9 gives 12. What is the number?
- **d** Seven more than three times a number gives 16. What is the number?
- **e** Two lots of the sum of a number and 6 is 18. What is the number?

15 Thomas earns \$96 a day as a portrait photographer, plus \$2 per photography package sold.

- **a** How much does he earn if he sells 12 packages in a day?
- **b** How much does he earn if he sells n packages in a day?
- **c** If Thomas earns \$308 in one day, write an equation and find the number of photography packages sold.

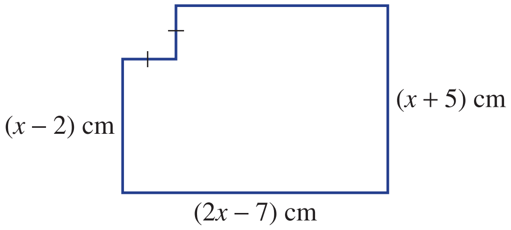
16 A money box contains 20-cent and 50-cent coins. The amount in the money box is \$50 and there are 160 coins.

- **a** Define two variables and set up a pair of linear equations.
- **b** Solve the two simultaneous equations to determine the number of 20-cent coins and the number of 50-cent coins.

17 There are twice as many adults as children at a local grand final football match. It costs \$10 for adults and \$2 for children to attend the match. If the football club collected \$1100 at the entrance gates, how many children went to see the match?

Extended-response questions

1 Complete the following for the shape shown.



- **a** Determine the equation of its perimeter.
  - **i** If the perimeter is 128 cm, determine the value of x.
  - **ii** Find the actual side lengths.
- **b** Repeat part **b** for perimeters of:
  - **i** 152 cm
  - **ii** 224 cm

2 Two computer consultants have an up-front fee plus an hourly rate. Rhys charges \$50 plus \$70 per hour and Agnes charges \$100 plus \$60 per hour.

- **a** Using \$$C$ for the cost and t hours for the time, write a rule for the cost of hiring:
  - **i** Rhys
  - **ii** Agnes
- **b** By drawing a graph of C versus t for both Rhys and Agnes on the same set of axes, find the coordinates of the intersection point.
- **c** Use the algebraic method of substitution to solve the simultaneous equations and confirm your answer to part **b**.

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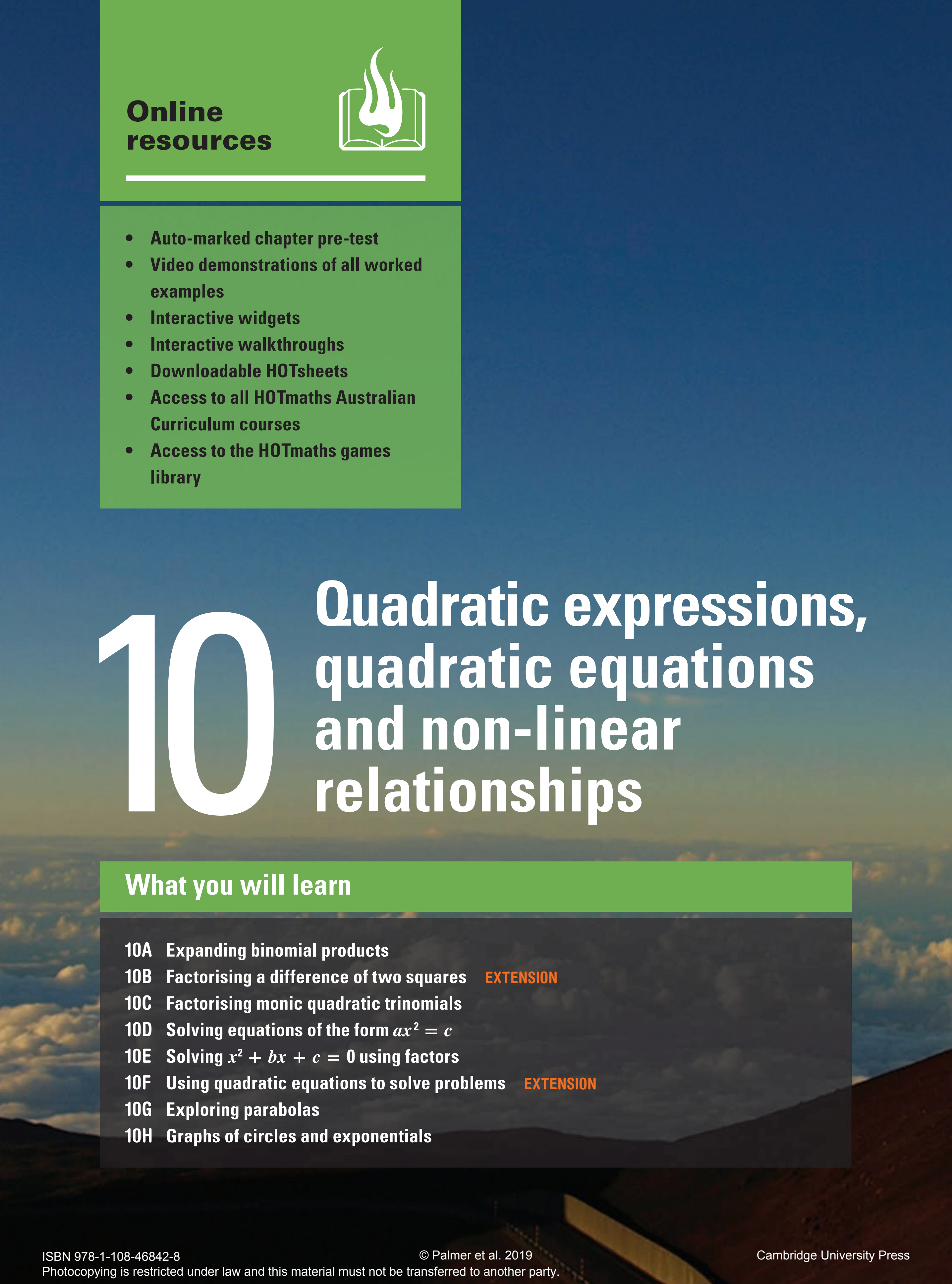

Online resources

- Auto-marked chapter pre-test
- Video demonstrations of all worked examples
- Interactive widgets
- Interactive walkthroughs
- Downloadable HOTsheets
- Access to all HOTmaths Australian Curriculum courses
- Access to the HOTmaths games library

10

Quadratic expressions, quadratic equations and non-linear relationships

What you will learn

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NSW syllabus

STRAND: NUMBER AND ALGEBRA

SUBSTRANDS: ALGEBRAIC TECHNIQUES; EQUATIONS; NON-LINEAR RELATIONSHIPS

Outcomes

A student simplifies algebraic fractions, and expands and factorises quadratic expressions.
(MA5.2–6NA)

A student solves linear and simple quadratic equations, linear inequalities and linear simultaneous equations, using analytical and graphical techniques.
(MA5.2–8NA)

A student graphs simple non-linear relationships.
(MA5.1–7NA)

A student connects algebraic and graphical representations of simple non-linear relationships.
(MA5.2–10NA)

Parabolic telescope mirrors

The graph of a quadratic equation forms a shape called a parabola. The rotated graph forms a parabolic dish shape. Telescopes use a parabolic mirror to reflect parallel beams of light or radio waves to a focal point above the base of the dish. This more intense energy beam can be transmitted to a telescope's computers and digital camera for analysis and photography.

The Canada–France–Hawaii Telescope is located at 4200 m altitude on the top of Mauna Kea volcano in Hawaii. It has a powerful parabolic reflecting mirror that is 3.6 metres in diameter and weighs 14 tonnes. Using this telescope, astronomers have discovered new moons of Uranus and Saturn and captured amazing photographs of dying stars exploding in remote galaxies.

Pre-test

1 Consider the expression $5 + 2ab - b$.
- **a** How many terms are there?
- **b** What is the coefficient of ab?
- **c** What is the value of the constant term?

2 Simplify each of the following by collecting like terms.
- **a** $7x + 2y - 3x$
- **b** $3xy + 4x - xy - 5x$
- **c** $4ab - 2ba$

3 Simplify:
- **a** $\frac{4a}{2}$
- **b** $\frac{-24mn}{12n}$
- **c** $6a \times 3a$
- **d** $-2x \times 3xy$
- **e** $x \times (-3) \div (9x)$
- **f** $4x^2 \div (2x)$

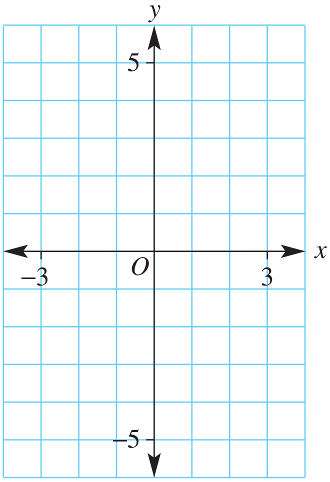
4 Expand and simplify by collecting like terms where possible.
- **a** $4(m + n)$
- **b** $-3(2x - 4)$
- **c** $2x(3x + 1)$
- **d** $4a(1 - 2a)$
- **e** $5 + 3(x - 4)$
- **f** $5 - 2(x + 3) + 2$

5 Factorise each of the following by taking out a common factor.
- **a** $7x + 7$
- **b** $-9x - 27x^2$
- **c** $a^2 + ab$

6 Solve:
- **a** $2x + 1 = 0$
- **b** $2(x - 3) = 0$
- **c** $\frac{3x + 1}{4} = 4$

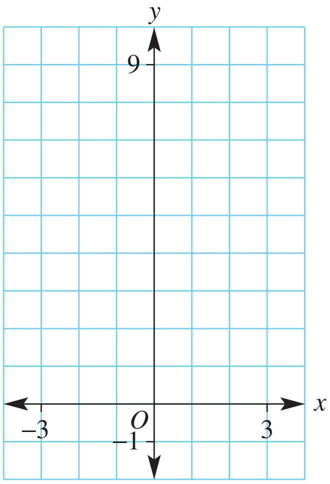
7 Complete the table below and plot the graph of $y = 2x - 1$.

x	–2	–1	0	1	2	3
y						



8 Complete the table below and plot the graph of $y = x^2$.

x	–3	–2	–1	0	1	2	3
y	9						



10A Expanding binomial products

Interactive

Widgets

HOTsheets

Walkthrough

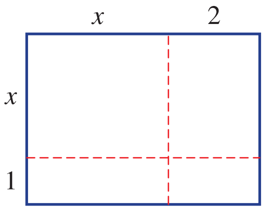
Expressions that include numerals and variables (or pronumerals) are central to the topic of algebra. Sound skills in algebra are essential for solving most mathematical problems and this includes the ability to expand expressions involving brackets. This includes binomial products, perfect squares and the difference of perfect squares. Exploring how projectiles fly subject to the Earth's gravity, for example, can be modelled with expressions with and without brackets.

The path of projectiles flying through the air can be modelled using algebra.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Why does $(x + 1)(x + 2) = x^2 + 3x + 2$?

Look at this rectangle with side lengths $x + 1$ and $x + 2$.



- What are the areas of the four regions?
- Add up the areas to find an expression for the total area.
- Why does this explain that $(x + 1)(x + 2) = x^2 + 3x + 2$?

Key ideas

- **Like terms** have the same pronumeral part.
  - They can be collected (added and subtracted) to form a single term. For example: $7x - 11x = -4x$ and $4a^2b - 7ba^2 = -3a^2b$
- The **distributive law** is used to expand brackets.

$$a(b + c) = ab + ac$$

$$(a + b)(c + d) = ac + ad + bc + bd$$

$$a(b - c) = ab - ac$$

	a
b	ab
c	ac

	a	b
c	ac	bc
d	ad	bd

$(a + b)(c + d)$ is called a binomial product because each expression in the brackets has two terms.

Like terms Terms with the same pronumerals and the same powers

Distributive law Adding numbers and then multiplying the total gives the same answer as multiplying each number first and then adding the products

Key ideas

- **Perfect squares**

  $(a+b)^2 = (a+b)(a+b) = a^2 + ab + ba + b^2 = a^2 + 2ab + b^2$

  $(a-b)^2 = (a-b)(a-b) = a^2 - ab - ba + b^2 = a^2 - 2ab + b^2$

- **Difference of two squares**

  $(a+b)(a-b) = a^2 - \cancel{ab} + \cancel{ba} - b^2 = a^2 - b^2$

Perfect square An expression that can be expressed as a single square

Difference of two squares When one square term is subtracted from another

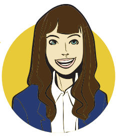
Exercise 10A

UNDERSTANDING AND FLUENCY 1, 2(½), 3, 4–7(½) 4–7(½)

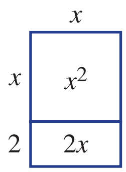
1 Decide whether the following are a perfect square or a difference of two squares.
a $(x+1)^2$ **b** $x^2 - 16$ **c** $4x^2 - 25$ **d** $(2x-3)^2$

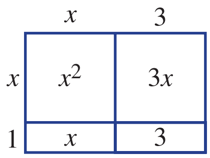
2 Simplify these expressions.
a $2 \times 3x$ **b** $-4 \times 5x$ **c** $x \times 2x$
d $-x \times 4x$ **e** $5x \div 10$ **f** $3x \div 9$
g $-4x^2 \div x$ **h** $-6x^2 \div (2x)$ **i** $3x - 21x$
j $12x - 5x$ **k** $-3x + 8x$ **l** $-5x - 8x$

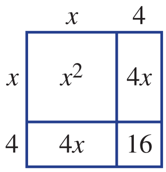
Write ÷ as a fraction and cancel: $5x \div 10 = \frac{5x}{10} = \ldots$



3 Use each diagram to help expand the expressions.
a $x(x+2)$ **b** $(x+3)(x+1)$ **c** $(x+4)^2$







Simply add up all the areas inside the rectangular diagram.

Example 1 Expanding simple expressions

Expand and simplify where possible.
a $-3(x-5)$ **b** $-2x(1-x)$

SOLUTION

a $-3(x-5) = -3 \times x - (-3) \times 5$
$= -3x + 15$

b $-2x(1-x) = -2x \times 1 - (-2x) \times x$
$= -2x + 2x^2$

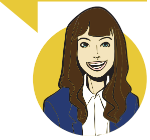
EXPLANATION

Use the distributive law $a(b-c) = ab - ac$.
A negative times a negative is a positive.

Recall that $x \times x = x^2$.

4 Expand and simplify where possible.
a $2(x+5)$ **b** $3(x-4)$ **c** $-5(x+3)$ **d** $-4(x-2)$
e $3(2x-1)$ **f** $4(3x+1)$ **g** $-2(5x-3)$ **h** $-5(4x+3)$
i $x(2x+5)$ **j** $x(3x-1)$ **k** $2x(1-x)$ **l** $3x(2-x)$
m $-2x(3x+2)$ **n** $-3x(6x-2)$ **o** $-5x(2-2x)$ **p** $-4x(1-4x)$

$a(b+c) = ab + ac$



Example 2 Expanding binomial products

Expand the following.

a $(x + 5)(x + 4)$

b $(2x - 1)(3x + 5)$

SOLUTION	EXPLANATION
a $(x + 5)(x + 4) = x^2 + 4x + 5x + 20$ $= x^2 + 9x + 20$	For binomial products use $(a + b)(c + d) = ac + ad + bc + bd$. Simplify by collecting like terms, so $4x + 5x = 9x$.
b $(2x - 1)(3x + 5) = 6x^2 + 10x - 3x - 5$ $= 6x^2 + 7x - 5$	Expand, using the distributive law, and simplify. Note that $2x \times 3x = 2 \times 3 \times x \times x = 6x^2$ and $-1 \times 3x = -3x$, $-1 \times 5 = -5$.

5 Expand the following.

a $(x + 2)(x + 8)$
b $(x + 3)(x + 4)$
c $(x + 7)(x + 5)$
d $(x + 8)(x - 3)$
e $(x + 6)(x - 5)$
f $(x - 2)(x + 3)$
g $(x - 7)(x + 3)$
h $(x - 4)(x - 6)$
i $(x - 8)(x - 5)$
j $(2x + 1)(3x + 5)$
k $(4x + 5)(3x + 2)$
l $(5x + 3)(2x + 7)$
m $(3x + 2)(3x - 5)$
n $(5x + 3)(4x - 2)$
o $(2x + 5)(3x - 5)$

$(a + b)(c + d) =$
$ac + ad + bc + bd$

Example 3 Expanding perfect squares

Expand these perfect squares.

a $(x + 2)^2$

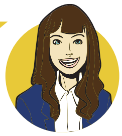
b $(x - 4)^2$

SOLUTION	EXPLANATION
a $(x + 2)^2 = (x + 2)(x + 2)$ $= x^2 + 2x + 2x + 4$ $= x^2 + 4x + 4$	First write in expanded form, then use the distributive law.
OR $(x + 2)^2 = x^2 + 2(x)(2) + 2^2$ $= x^2 + 4x + 4$	$(a + b)^2 = a^2 + 2ab + b^2$ with $a = x$ and $b = 2$.
b $(x - 4)^2 = (x - 4)(x - 4)$ $= x^2 - 4x - 4x + 16$ $= x^2 - 8x + 16$	Rewrite and expand using the distributive law. $-4 \times (-4) = 16$
OR $(x - 4)^2 = x^2 - 2(x)(4) + 4^2$ $= x^2 - 8x + 16$	Alternatively, for perfect squares $(a - b)^2 = a^2 - 2ab + b^2$. Here, $a = x$ and $b = 4$.

6 Expand these perfect squares.

a $(x + 5)^2$
b $(x + 7)^2$
c $(x + 6)^2$
d $(x - 3)^2$
e $(x - 8)^2$
f $(x - 10)^2$
g $(2x + 5)^2$
h $(5x + 6)^2$
i $(7x - 1)^2$

Recall:
$(x + 5)^2 = (x + 5)(x + 5)$
$= \ldots$



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Example 4 Expanding to form a difference of two squares

Expand to form a difference of two squares.

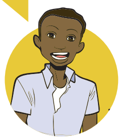
a $(x-3)(x+3)$ **b** $(2x+1)(2x-1)$

SOLUTION	EXPLANATION
a $(x-3)(x+3) = x^2 + 3x - 3x - 9$ $= x^2 - 9$ OR $(x-3)(x+3) = x^2 - 3^2$ $= x^2 - 9$	$x \times x = x^2, x \times 3 = 3x, -3 \times x = -3x, -3 \times 3 = -9$ Note that the two middle terms cancel. $(a-b)(a+b) = a^2 - b^2$
b $(2x+1)(2x-1) = 4x^2 - 2x + 2x - 1$ $= 4x^2 - 1$ OR $(2x+1)(2x-1) = (2x)^2 - (1)^2$ $= 4x^2 - 1$	Expand, recalling that $2x \times 2x = 4x^2$. Cancel the $-2x$ and $+2x$ terms. Alternatively, for difference of two squares $(a-b)(a+b) = a^2 - b^2$. Here $a = 2x$ and $b = 1$ and $(2x)^2 = 2x \times 2x = 4x^2$.

7 Expand to form a difference of two squares.

- **a** $(x+4)(x-4)$
- **b** $(x+9)(x-9)$
- **c** $(x+8)(x-8)$
- **d** $(3x+4)(3x-4)$
- **e** $(2x-3)(2x+3)$
- **f** $(8x-7)(8x+7)$
- **g** $(4x-5)(4x+5)$
- **h** $(2x-9)(2x+9)$
- **i** $(5x-7)(5x+7)$

The two middle terms will cancel to give $(a+b)(a-b) = a^2 - b^2$.



PROBLEM-SOLVING AND REASONING

8–9(½) 8–9(½), 10, 11

8 Write the missing number.

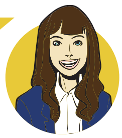
- **a** $(x+2)(x-3) = x^2 - x - \square$
- **b** $(x-4)(x-3) = x^2 - \square x + 12$
- **c** $(x-4)(x+4) = x^2 - \square$
- **d** $(2x-1)(2x+1) = \square x^2 - 1$
- **e** $(x+2)^2 = x^2 + \square x + 4$
- **f** $(3x-1)^2 = 9x^2 - \square x + 1$

Expand if you need to.

9 Write the missing number.

- **a** $(x + \square)(x+2) = x^2 + 5x + 6$
- **b** $(x + \square)(x+5) = x^2 + 8x + 15$
- **c** $(x+7)(x - \square) = x^2 + 4x - 21$
- **d** $(x+4)(x - \square) = x^2 - 4x - 32$
- **e** $(x-6)(x - \square) = x^2 - 7x + 6$
- **f** $(x - \square)(x-8) = x^2 - 10x + 16$

Notice how the two numerals in the brackets multiply to give the constant term.



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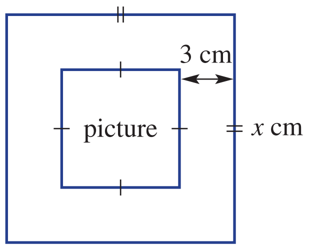
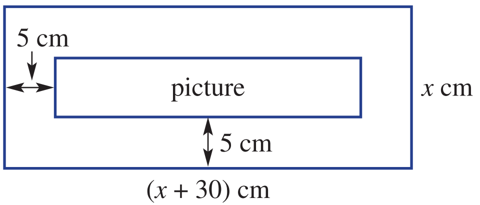
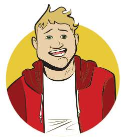
10 Find an expanded expression for the area of the pictures centred in these frames.

a



b





For part **a**, the side length of the picture will be $(x - 6)$ cm.

11 Each problem below has an incorrect answer. Find the error and give the correct answer.

a $-x(x - 7) = -x^2 - 7x$

b $3a - 7(4 - a) = -4a - 28$

c $(x - 9)(x + 9) = x^2 - 18x - 81$

d $(2x + 3)^2 = 4x^2 + 9$

ENRICHMENT – 12

Swimming pool algebra

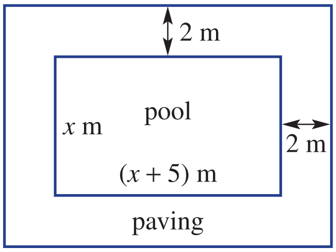
12 A pool company builds rectangular pools that are 5 m longer than their breadth. The company then paves around the outside of the pool, using a width of 2 m.

a Find an expanded expression for:

- **i** the pool area
- **ii** the total area (including the pool and paving)
- **iii** the paved area

b If $x = 4$, find the area of:

- **i** the pool
- **ii** the paved area



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10B Factorising a difference of two squares EXTENSION

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

A common and key step in the simplification and solution of equations involves factorisation. Factorisation is the process of writing a number or expression as a product of its factors. For example: $6 = 2 \times 3$, $2x + 6 = 2(x + 3)$, $x^2 - x = x(x - 1)$ and $x^2 - 9 = (x + 3)(x - 3)$.

In this section, we look at expressions in which each term has a common factor and expressions that are a difference of two squares.

Let's start: It's just a difference of two squares expansion in reverse

Complete each column to see the connection when expanding or factorising a difference of two squares.

Expand	**Factorise**
$(x + 2)(x - 2) = x^2 - 4$	$x^2 - 4 = (x \_\_\_\_\_\_)(x \_\_\_\_\_\_)$
$(x - 3)(x + 3) = \_\_\_\_\_\_$	$x^2 - 9 = (x \_\_\_\_\_\_)(\_\_\_\_\_\_)$
$(2x + 3)(2x - 3) = 4x^2 - 9$	$4x^2 - 9 = (2x \_\_\_\_\_\_)(\_\_\_\_\_\_)$
$(7x - 6)(7x + 6) = \_\_\_\_\_$	$\_\_\_\_\_ = (\_\_\_\_\_\_)(\_\_\_\_\_\_)$

Key ideas

- **Factorise** expressions with common factors by 'taking out' the highest common factor (HCF).
  For example: $-5x - 20 = -5(x + 4)$ and $4x^2 - 8x = 4x(x - 2)$
- Factorise a difference of two squares using

$$a^2 - b^2 = (a + b)(a - b)$$

For example:

$$x^2 - 16 = x^2 - 4^2 = (x + 4)(x - 4) \quad \text{and} \quad 9x^2 - 25 = (3x)^2 - 5^2 = (3x + 5)(3x - 5)$$

Factorise To write an expression as a product, often involving brackets

Exercise 10B EXTENSION

UNDERSTANDING AND FLUENCY	1–4(½)	2–5(½)

1 Complete these statements.

a $2(x + 3) = 2x + 6$ so $2x + 6 = 2(\_\_\_\_\_\_)$

b $-4(x - 1) = -4x + 4$ so $-4x + 4 = -4(\_\_\_\_\_\_)$

c $(x + 2)(x - 2) = x^2 - 4$ so $x^2 - 4 = (\_\_\_\_\_\_)\ (\_\_\_\_\_\_)$

d $(3x + 2)(3x - 2) = 9x^2 - 4$ so $9x^2 - 4 = (\_\_\_\_\_\_)\ (\_\_\_\_\_\_)$

2 Determine the highest common factor of these pairs of terms.

a $7x$ and 14 **b** $12x$ and 30

c $-8y$ and 40 **d** $-5y$ and -25

e $4a^2$ and $2a$ **f** $12a^2$ and $9a$

g $-5a^2$ and $-50a$ **h** $-3x^2y$ and $-6xy$

Include a common negative.

Example 5 Taking out common factors

Factorise by taking out the highest common factor.

a $-3x - 12$

b $20a^2 + 30a$

SOLUTION	EXPLANATION
a $-3x - 12 = -3(x + 4)$	-3 is common to both $-3x$ and -12.
b $20a^2 + 30a = 10a(2a + 3)$	The HCF of $20a^2$ and $30a$ is $10a$.

3 Factorise by taking out the highest common factor.

a $3x - 18$
b $4x + 20$
c $7a + 7b$
d $9a - 15$
e $-5x - 30$
f $-4y - 2$
g $-12a - 3$
h $-2ab - bc$
i $4x^2 + x$
j $5x^2 - 2x$
k $6b^2 - 18b$
l $14a^2 - 21a$
m $10a - 5a^2$
n $12x - 30x^2$
o $-2x - x^2$
p $-4y - 8y^2$

Find the highest common factor, then take it out and divide each term by it.

Example 6 Factorising a difference of two squares

Factorise the following differences of two squares.

a $x^2 - 16$

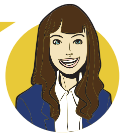
b $9a^2 - 4b^2$

SOLUTION	EXPLANATION
a $x^2 - 16 = (x)^2 - (4)^2$ $= (x - 4)(x + 4)$	Use $a^2 - b^2 = (a - b)(a + b)$ with $a = x$ and $b = 4$. $(x + 4)(x - 4)$ is an equivalent answer.
b $9a^2 - 4b^2 = (3a)^2 - (2b)^2$ $= (3a - 2b)(3a + 2b)$	$9a^2 = (3a)^2$ and $4b^2 = (2b)^2$.

4 Factorise the following differences of two squares.

a $x^2 - 9$
b $x^2 - 25$
c $y^2 - 49$
d $y^2 - 1$
e $a^2 - 16$
f $b^2 - 36$
g $y^2 - 144$
h $z^2 - 400$
i $4x^2 - 9$
j $36a^2 - 25$
k $1 - 81y^2$
l $100 - 9x^2$
m $25x^2 - 4y^2$
n $64x^2 - 25y^2$
o $9a^2 - 49b^2$
p $144a^2 - 49b^2$

$a^2 - b^2 =$
$(a + b)(a - b)$



5 Factorise these differences of two squares.

a $4 - x^2$
b $9 - y^2$
c $36 - a^2$
d $100 - 9x^2$
e $b^2 - a^2$
f $400 - 25a^2$
g $4a^2 - 9b^2$
h $16y^2 - 121x^2$

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PROBLEM-SOLVING AND REASONING

6(½), 7 6(½), 7, 8(½)

Example 7 Factorising by first taking out a common factor

Factorise $12y^2 - 1452$ by first taking out a common factor.

SOLUTION	EXPLANATION
$12y^2 - 1452 = 12(y^2 - 121)$	First take out the common factor of 12.
$= 12(y - 11)(y + 11)$	$121 = (11)^2$, use $a^2 - b^2 = (a - b)(a + b)$.

6 Factorise the following by first taking out a common factor.

a $2x^2 - 32$ **b** $5x^2 - 45$ **c** $6y^2 - 24$

d $3y^2 - 48$ **e** $3x^2 - 75y^2$ **f** $3a^2 - 300b^2$

g $12x^2 - 27y^2$ **h** $63a^2 - 112b^2$ **i** $108x^2 - 147y^2$

As a first step, take out a common factor and then factorise the difference of two squares.

7 The height (in metres) of a falling object above ground level is given by $100 - t^2$, where t is in seconds.

a Find the height of the object:

 i initially (at $t = 0$)

 ii after 2 seconds

 iii after 8 seconds

b Factorise the expression $100 - t^2$.

c Use your factorised expression from part **b** to find the height of the object:

 i initially (at $t = 0$) **ii** after 2 seconds **iii** after 8 seconds

d How long does it take for the object to hit the ground?

8 We can work out problems such as $19^2 - 17^2$ without a calculator, like this:

$$\begin{aligned}19^2 - 17^2 &= (19 + 17)(19 - 17)\\ &= 36 \times 2\\ &= 72\end{aligned}$$

Factorise first, using $a^2 - b^2 = (a + b)(a - b)$, then evaluate.

Use this idea to evaluate the following by first factorising, without the use of a calculator.

a $16^2 - 14^2$ **b** $18^2 - 17^2$ **c** $13^2 - 10^2$ **d** $15^2 - 11^2$

e $17^2 - 15^2$ **f** $11^2 - 9^2$ **g** $27^2 - 24^2$ **h** $52^2 - 38^2$

ENRICHMENT

– 9

Flexible framing

9 A special picture frame can hold a square picture of any size up to 40 cm.

a Using a picture side length of x cm, write expressions for the area of:

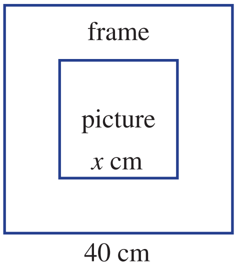
 i the picture **ii** the frame (not including the picture)

b Factorise your expression for the frame area.

c Find the frame area if:

 i $x = 20$ **ii** $x = 10$

d Using trial and error, what value of x is required if the frame area is to be 700 cm²?



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10C Factorising monic quadratic trinomials

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

A quadratic trinomial of the form $x^2 + bx + c$ is called a monic quadratic because the coefficient of x^2 is 1. ('Monic' comes from the word 'mono', which means 'one'.)

Now consider:

$$\begin{aligned}(x+m)(x+n) &= x^2 + xn + mx + mn\\ &= x^2 + (m+n)x + mn\end{aligned}$$

We can see from this expansion that mn gives the constant term (c) and $m + n$ is the coefficient of x. This tells us that to factorise a monic quadratic, we should look for factors of the constant term (c) that add to give the coefficient of the middle term (b).

Let's start: So many choices of factors?

We know that to factorise $x^2 - 5x - 24$ we need to choose a pair of numbers that multiply to give -24 and add to give -5. Look at the following equations and discuss how many of them are true.

$x^2 - 5x - 24 = (x+8)(x+3)$	$x^2 - 5x - 24 = (x+6)(x-4)$
$x^2 - 5x - 24 = (x-12)(x-2)$	$x^2 - 5x - 24 = (x-6)(x+4)$
$x^2 - 5x - 24 = (x-12)(x+2)$	$x^2 - 5x - 24 = (x-8)(x+3)$
$x^2 - 5x - 24 = (x-8)(x-3)$	$x^2 - 5x - 24 = (x-24)(x+1)$

Key ideas

- **Monic quadratics** have a coefficient of x^2 equal to 1.
- Monic quadratics of the form $x^2 + bx + c$ can be factorised by finding the two numbers that multiply to give the constant term (c) and add to give the coefficient of x (b).
  For example:

$$x^2 + \underset{\underset{2+3}{\uparrow}}{5}x + \underset{\underset{2\times 3}{\uparrow}}{6} = (x+3)(x+2)$$

$$x^2 \underset{\underset{-2+(-3)}{\uparrow}}{-5}x + \underset{\underset{-2\times(-3)}{\uparrow}}{6} = (x-3)(x-2)$$

$$x^2 \underset{\underset{-3+2}{\uparrow}}{-} x - \underset{\underset{-3\times 2}{\uparrow}}{6} = (x-3)(x+2)$$

$$x^2 \underset{\underset{-2+3}{\uparrow}}{+} x - \underset{\underset{3\times(-2)}{\uparrow}}{6} = (x+3)(x-2)$$

Monic quadratic
A quadratic expression where the coefficient of the squared term is 1

Exercise 10C

UNDERSTANDING AND FLUENCY 1–2(½), 3, 4–5(½) 3, 4–5(½)

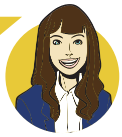
1 Expand and simplify these expressions.

a $(x + 2)(x + 3)$ **b** $(x - 4)(x + 2)$ **c** $(x - 7)(x - 3)$
d $(x - 1)^2$ **e** $(x + 5)^2$ **f** $(x - 6)^2$

2 Find two integers that multiply to give the first number and add to give the second number.

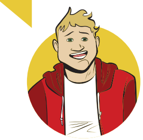
a 18, 11 **b** 20, 12 **c** −15, 2 **d** −12, 1
e −24, −5 **f** −30, −7 **g** 10, −7 **h** 36, −15

The integers include ..., −3, −2, −1, 0, 1, 2, 3, ...



3 **a** **i** Which two numbers multiply to give 15 and add to give 8?
ii Complete $x^2 + 8x + 15 =$ (_______)(_______).
b **i** Which two numbers multiply to give −10 and add to give 3?
ii Complete $x^2 + 3x - 10 =$ (_______)(_______).
c **i** Which two numbers multiply to give 8 and add to give −6?
ii Complete $x^2 - 6x + 8 =$ (_______)(_______).

If two numbers multiply to give a negative, they will need to have opposite signs.



Example 8 Factorising trinomials of the form $x^2 + bx + c$

Factorise:

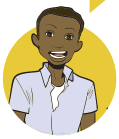
a $x^2 + 7x + 12$ **b** $x^2 + x - 6$ **c** $x^2 - 5x + 6$

SOLUTION	EXPLANATION
a $x^2 + 7x + 12 = (x + 4)(x + 3)$	$3 \times 4 = 12$ and $3 + 4 = 7$ Check: $(x + 4)(x + 3) = x^2 + 3x + 4x + 12 = x^2 + 7x + 12$
b $x^2 + x - 6 = (x - 2)(x + 3)$	Since the numbers must multiply to −6, one number must be positive and one must be negative. $-2 \times 3 = -6$ and $-2 + 3 = 1$ Check: $(x - 2)(x + 3) = x^2 + 3x - 2x - 6 = x^2 + x - 6$
c $x^2 - 5x + 6 = (x - 3)(x - 2)$	To multiply to a positive and add to a negative, both numbers must be negative. $-3 \times (-2) = 6$ and $-3 + (-2) = -5$ Check: $(x - 3)(x - 2) = x^2 - 2x - 3x + 6 = x^2 - 5x + 6$

4 Factorise these quadratic trinomials.

a $x^2 + 7x + 6$ **b** $x^2 + 5x + 6$ **c** $x^2 + 6x + 9$
d $x^2 + 7x + 10$ **e** $x^2 + 7x + 12$ **f** $x^2 + 11x + 18$
g $x^2 + 5x - 6$ **h** $x^2 + x - 6$ **i** $x^2 + 2x - 8$
j $x^2 + 3x - 4$ **k** $x^2 + 7x - 30$ **l** $x^2 + 9x - 22$
m $x^2 - 7x + 10$ **n** $x^2 - 6x + 8$ **o** $x^2 - 7x + 12$
p $x^2 - 2x + 1$ **q** $x^2 - 9x + 18$ **r** $x^2 - 11x + 18$
s $x^2 - 4x - 12$ **t** $x^2 - x - 20$ **u** $x^2 - 5x - 14$
v $x^2 - x - 12$ **w** $x^2 + 4x - 32$ **x** $x^2 - 3x - 10$

For $x^2 + bx + c$, look for factors of c that add to give b.



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Example 9 Factorising perfect squares

Factorise $x^2 - 8x + 16$ to form a perfect square.

SOLUTION	**EXPLANATION**
$x^2 - 8x + 16 = (x - 4)(x - 4)$	$-4 \times (-4) = 16$ and $-4 + (-4) = -8$
$= (x - 4)^2$	$(x - 4)(x - 4) = (x - 4)^2$ is a perfect square.

5 Factorise these perfect squares.

- **a** $x^2 - 4x + 4$
- **b** $x^2 + 6x + 9$
- **c** $x^2 + 12x + 36$
- **d** $x^2 - 14x + 49$
- **e** $x^2 - 18x + 81$
- **f** $x^2 - 20x + 100$
- **g** $x^2 + 8x + 16$
- **h** $x^2 + 20x + 100$
- **i** $x^2 - 30x + 225$

Factorise perfect squares just like any trinomial but finish by writing in the form $(x + a)^2$.

PROBLEM-SOLVING AND REASONING

6–7(½) 6–7(½), 8

Example 10 Factorising by first taking out a common factor

Factorise $2x^2 - 10x - 28$ by first taking out a common factor.

SOLUTION	**EXPLANATION**
$2x^2 - 10x - 28 = 2(x^2 - 5x - 14)$	First take out the common factor of 2.
$= 2(x - 7)(x + 2)$	$-7 \times 2 = -14$ and $-7 + 2 = -5$

6 Factorise by first taking out the common factor.

- **a** $2x^2 + 14x + 20$
- **b** $3x^2 + 21x + 36$
- **c** $2x^2 + 22x + 36$
- **d** $5x^2 - 5x - 10$
- **e** $4x^2 - 16x - 20$
- **f** $3x^2 - 9x - 30$
- **g** $-2x^2 - 14x - 24$
- **h** $-3x^2 + 9x - 6$
- **i** $-2x^2 + 10x + 28$
- **j** $-4x^2 + 4x + 8$
- **k** $-5x^2 - 20x - 15$
- **l** $-7x^2 + 49x - 42$

Factor out the coefficient of x^2. Include the negative in parts **g–l**.

7 Factorise these as perfect squares after first taking out the common factor.

- **a** $2x^2 + 44x + 242$
- **b** $3x^2 - 24x + 48$
- **c** $5x^2 - 50x + 125$
- **d** $-3x^2 + 36x - 108$
- **e** $-2x^2 + 28x - 98$
- **f** $-4x^2 - 72x - 324$

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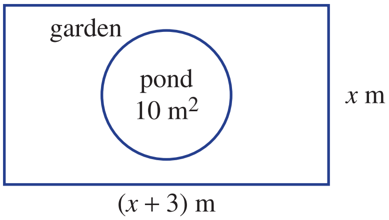
8 A rectangular garden has length 3 m more than its breadth, x m. There is a pond of area 10 m^2 in the centre.



a Find an expression for:
  i the entire area (expand your answer)
  ii the garden area, excluding the pond

b Factorise your answer from part **a ii**.

c What is the area of the garden, excluding the pond, if:
  i $x = 5$? **ii** $x = 7$?

ENRICHMENT	–	9(½)

Algebraic fractions

9 Some algebraic fractions can be simplified using factorisation.
Here is an example,

$$\frac{x^2 - x - 12}{x - 4} = \frac{\cancel{(x - 4)}(x + 3)}{\cancel{x - 4}} = x + 3$$

Use this idea to simplify these fractions.

a $\dfrac{x^2 - 3x - 54}{x - 9}$ **b** $\dfrac{x^2 + x - 12}{x + 4}$ **c** $\dfrac{x^2 - 6x + 9}{x - 3}$

d $\dfrac{x + 2}{x^2 + 9x + 14}$ **e** $\dfrac{x - 3}{x^2 - 8x + 15}$ **f** $\dfrac{x + 1}{x^2 - 5x - 6}$

g $\dfrac{x^2 - 4x + 4}{x - 2}$ **h** $\dfrac{x^2 + 2x + 1}{x + 1}$ **i** $\dfrac{x^2 - 16x + 64}{x - 8}$

First factorise the numerator or denominator, then cancel.

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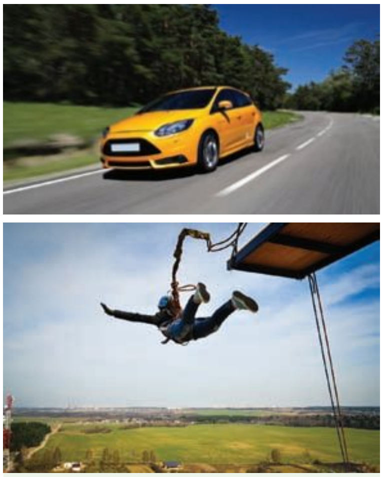
10D Solving equations of the form $ax^2 = c$

Interactive
Widgets
HOTsheets
Walkthrough

A quadratic equation can be expressed in the general form $ax^2 + bx + c = 0$, where a, b and c are real numbers with $a \neq 0$. In a quadratic equation the highest power is 2. The simplest quadratic equation can be expressed in the form $x^2 = c$ and these will be considered in this section.

We will see that since $5^2 = 5 \times 5 = 25$ and $(-5)^2 = -5 \times (-5) = 25$, there are two possible solutions to the equation $x^2 = 25$; i.e. $x = 5$ or $x = -5$. However, note that $x^2 = -25$ has no solutions.

This simplest form of a quadratic equation arises in many circumstances, including in Pythagoras' theorem and in area and volume formulas. Formulas involving motion, including the velocity of a constantly accelerating object and the time taken for an object to fall due to gravity, also give rise to quadratic equations.


The velocity of an accelerating car and an object falling to earth can be modelled using quadratic equations.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: How many possible solutions?

- List all the pairs of numbers that multiply to 16.
- List all the pairs of numbers that multiply to −16.
- What do you notice about the signs of your pairs of numbers that multiply to 16? What about the signs of the numbers that multiply to −16?
- How many of your listed pairs satisfy $x \times x = 16$?
- Are there any pairs that satisfy $x \times x = -16$?
- From what you have found above, how many values of x would make the following true?

a $x^2 = 9$ **b** $x^2 = -9$

Key ideas

- A **quadratic equation** is an equation in which the highest power is 2. For example: $x^2 = 9$, $2x^2 - 6 = 0$ and $x^2 - 2x = 8$.
  - A quadratic equation may have 0, 1 or 2 possible solutions.
- The square of a number is always positive or 0; i.e. $x^2 \geqslant 0$ for all values of x. For example: $(2)^2 = 2 \times 2 = 4$ and $(-3)^2 = -3 \times (-3) = 9$.
- The inverse operation of squaring is the square root, $\sqrt{\ }$.
  - $\sqrt{4} = 2$ since $2 \times 2 = 4$
  - $\sqrt{7} \times \sqrt{7} = 7$
- If $x^2 = c$, then $x = \pm\sqrt{c}$ provided that $c \geqslant 0$.
  - $\pm$ represents two possible solutions: $+\sqrt{c}$ and $-\sqrt{c}$.
  - $c = 0$ gives just one solution since $\sqrt{0} = 0$.

Quadratic equation
An equation in which the highest power is 2

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Key ideas

- If $x^2 = c$ and $c < 0$, there are no real solutions.
- Square roots that do not reduce to whole numbers are called surds and can be left in this exact form; i.e.$\sqrt{2}$, $\sqrt{10}$, ... etc.
  For example: $\sqrt{25}$ is not a surd as 25 is a square number and $\sqrt{25} = 5$.
- To solve equations of the form $ax^2 = c$, make x^2 the subject and then take the square root of both sides to solve for x.
- In practical problems such as those involving measurement, it may make sense to reject the negative solution obtained.

Exercise 10D

UNDERSTANDING AND FLUENCY

1, 2–3(½), 4, 5–6(½) | 4, 5–7(½)

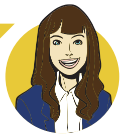
1 List the first 12 square numbers.

Start at $1^2 = 1$, $2^2 = \dots$

2 Evaluate the following.

a 4^2 **b** 7^2 **c** 9^2 **d** 11^2
e $(-3)^2$ **f** $(-5)^2$ **g** $(-8)^2$ **h** $(-12)^2$

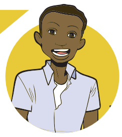
$4^2 = 4 \times 4 = \dots$
$(-3)^2 = -3 \times (-3) = \dots$



3 Evaluate the following.

a $\sqrt{36}$ **b** $\sqrt{64}$ **c** $-\sqrt{49}$ **d** $-\sqrt{25}$
e $-\sqrt{100}$ **f** $-\sqrt{1}$ **g** $\sqrt{0}$ **h** $\sqrt{121}$

$\sqrt{4} = 2$ since $2^2 = 4$.



4 Complete the following. The equation $x^2 = c$ has:

a two solutions if _________
b one solution if _________
c no solutions if _________

Example 11 Solving equations of the form $ax^2 = c$

Find all possible solutions to the following equations.

a $x^2 = 16$ **b** $3x^2 = 12$ **c** $x^2 = -25$

SOLUTION	EXPLANATION
a $x^2 = 16$ $\therefore x = \pm\sqrt{16}$ $x = \pm 4$	Take the square root of both sides to solve for x. If $x^2 = c$, where $c > 0$, then $x = \pm\sqrt{c}$. Since 16 is a square number, $\sqrt{16}$ is a whole number. $\pm$ represents two solutions: $+4$ since $(+4)^2 = 16$ and -4 since $(-4)^2 = 16$.
b $3x^2 = 12$ $x^2 = 4$ $\therefore x = \pm\sqrt{4}$ $x = \pm 2$	First make x^2 the subject by dividing both sides by 3. Take the square root of both sides to solve for x. This gives two possible values for x: $+2$ and -2.
c $x^2 = -25$ There are no solutions.	Since $x^2 \geqslant 0$ for all values of x, there are no values of x that will make $x^2 = -25$.

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5 Find the possible solutions for x in the following equations.

a $x^2 = 25$ **b** $x^2 = 81$

c $x^2 = 36$ **d** $x^2 = 49$

e $x^2 = -16$ **f** $x^2 = -100$

g $x^2 = 400$ **h** $x^2 = 144$

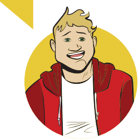
i $2x^2 = 50$ **j** $3x^2 = 48$

k $-5x^2 = -5$ **l** $-5x^2 = 20$

m $\frac{x^2}{2} = 32$ **n** $\frac{x^2}{3} = 27$

o $\frac{1}{2}x^2 = 18$ **p** $\frac{1}{4}x^2 = -25$

When taking the square root, don't forget ±.



$\frac{1}{2}x^2$ is the same as $\frac{x^2}{2}$.

Example 12 Solving equations with answers that are surds

Find all possible solutions to the following equations.

a $x^2 = 10$ (Give your answer in exact surd form.)

b $3x^2 = 9$ (Give your answer to 1 decimal place.)

SOLUTION	EXPLANATION
a $x^2 = 10$	Take the square root of both sides.
$\therefore x = \pm\sqrt{10}$	Since 10 is not a square number, leave your answer in exact surd form $\pm\sqrt{10}$, as required.
b $3x^2 = 9$	Divide both sides by 3.
$x^2 = 3$	Take the square root of both sides.
$\therefore x = \pm\sqrt{3}$ $x = \pm 1.7$	Use a calculator to evaluate $\pm\sqrt{3} = 1.73205\ldots$ and round your answer to 1 decimal place, as required.

6 **a** Solve the following equations, where possible, leaving your answer in exact surd form.

i $x^2 = 14$ **ii** $x^2 = 22$

iii $x^2 = 17$ **iv** $x^2 = -7$

v $3x^2 = 15$ **vi** $4x^2 = 24$

vii $\frac{x^2}{3} = 7$ **viii** $\frac{x^2}{2} = 3$

$\sqrt{14}$ is exact surd form.

b Solve these equations, giving your answers to 1 decimal place.

i $x^2 = 12$ **ii** $x^2 = 35$

iii $3x^2 = 90$ **iv** $\frac{x^2}{9} = 7$

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Example 13 Solving equations of the form $ax^2 + b = c$

Find the exact solution(s), where possible, to the following equations.

a $x^2 - 9 = 0$ **b** $x^2 + 12 = 0$ **c** $\frac{x^2}{2} - 3 = 4, x > 0$ **d** $7 - x^2 = 6, x < 0$

SOLUTION	EXPLANATION
a $x^2 - 9 = 0$ $x^2 = 9$ $\therefore x = \pm\sqrt{9}$ $x = \pm 3$	Make x^2 the subject by adding 9 to both sides. Solve for x by taking the square root of both sides.
b $x^2 + 12 = 0$ $x^2 = -12$ There is no real solution.	Make x^2 the subject by subtracting 12 from both sides. Since x^2 is positive for all values of x, $x^2 = c$, where c is negative has no real solution.
c $\frac{x^2}{2} - 3 = 4$ $\frac{x^2}{2} = 7$	Solve for x^2 by adding 3 to both sides and then multiplying both sides by 2.
$x^2 = 14$ $\therefore x = \pm\sqrt{14}$	Take the square root of both sides to solve for x. $\sqrt{14}$ is the exact form of the answer.
$x = \sqrt{14}$ since $x > 0$.	Note the restriction that x must be a positive value (i.e. > 0), so reject the solution $x = -\sqrt{14}$.
d $7 - x^2 = 6$ $-x^2 = -1$ $x^2 = 1$ $\therefore x = \pm\sqrt{1}$	Subtract 7 from both sides and then divide both sides by -1. Alternatively, add x^2 to both sides to give $7 = x^2 + 6$ and then solve.
$x = \pm 1$	$\sqrt{1} = 1$ since $1^2 = 1$.
$x = -1$ since $x < 0$.	Reject the solution $x = 1$ because $x < 0$.

7 Find the exact solution(s), where possible, of these equations.

- **a** $x^2 - 4 = 0$
- **b** $x^2 - 81 = 0$
- **c** $x^2 + 16 = 0$
- **d** $x^2 + 10 = 0$
- **e** $x^2 + 6 = 15$
- **f** $x^2 - 5 = 10$
- **g** $2x^2 - 6 = 0, x > 0$
- **h** $3x^2 + 10 = 13$
- **i** $\frac{x^2}{2} + 4 = 5, x > 0$
- **j** $10 - x^2 = 3, x < 0$
- **k** $5 - x^2 = 7$

First get your equation in the form $x^2 = c$.

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PROBLEM-SOLVING AND REASONING

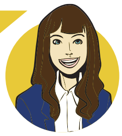
8(½), 9, 10, 11(½) | 8(½), 11(½), 12–16

8 Solve these equations by first collecting like terms.

- **a** $3x^2 = 2x^2 + 16$
- **b** $4x^2 = 2x^2 + 18$
- **c** $4x^2 - 11 = x^2 + 16$
- **d** $x^2 = 50 - x^2$
- **e** $2x^2 + 5 = 17 - x^2$
- **f** $4x^2 + 8 = 2x^2 + 5$

Rewrite the equation in the form $x^2 = c$ by collecting x^2 terms on one side and the number on the other.

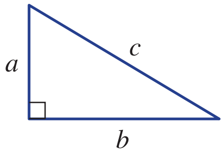
$$\begin{tikzcd} 3x^2 = 2x^2 + 16 \arrow[d, bend right, "-2x^2"'] \arrow[d, bend left, "-2x^2"] \\ x^2 = 16 \end{tikzcd}$$



9 The area of a square is 36 m^2, what is its perimeter?

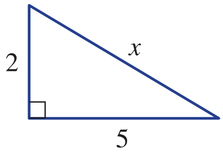
10 The distance, d metres, that an object has fallen t seconds after being dropped is given by $d = 5t^2$. How long does the object take to fall 80 m?

11 Recall Pythagoras' theorem, $c^2 = a^2 + b^2$.

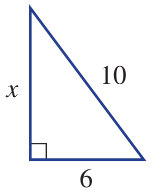


Use this to find the unknown side length in the following triangles. Give your answers in exact form.

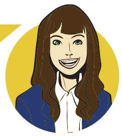
a



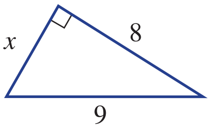
b



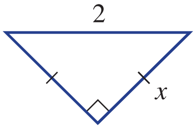
Set up the Pythagorean equation first.



c

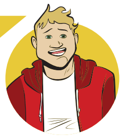


d



12 The volume of a cylinder is $V = \pi r^2 h$, where r is the radius and h is the height of the cylinder. If the volume of a cylindrical water tank is 285 m^3 and its height is 15 m, determine its radius to 1 decimal place.

$\pi r^2(15)$ can be written as $15\pi r^2$.



13 **a** Solve the equation $\pi r^2 = 24$, to find two possible values for r, rounded to 1 decimal place.

b Given that $A = \pi r^2$ is the formula for the area of a circle of radius r, what restriction does this place on your answer to part **a** if the area of the circle is 24 units^2?

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14 Determine for which values of b the equation $x^2 - b = 0$ has:

- **a** two solutions
- **b** one solution
- **c** no solutions

For Questions **14** & **15**, first solve for x^2.

15 Determine for which values of b the equation $x^2 + b = 0$ has:

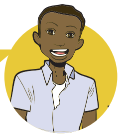
- **a** two solutions
- **b** one solution
- **c** no solutions

16 **a** Solve the equation $x^2 - 25 = 0$.

b Hence, determine the range of values of x for which:

i $x^2 - 25 < 0$ **ii** $x^2 - 25 > 0$

In part **b**, make use of your answer to part **a**.



ENRICHMENT		–	17(½)

Square powers and brackets

17 Consider the following example.

$$\begin{aligned} \text{Solve } (x+1)^2 &= 16 \\ x+1 &= \pm\sqrt{16} && \text{(Take the square root of both sides.)} \\ x+1 &= \pm 4 \\ x+1 = 4 \quad &\text{or} \quad x+1 = -4 && \text{(Write each equation separately.)} \\ x = 3 \quad &\text{or} \quad x = -5 && \text{(Subtract 1 from both sides.)} \end{aligned}$$

Use this method to solve these equations.

- **a** $(x + 1)^2 = 9$
- **b** $(x + 3)^2 = 49$
- **c** $(x - 2)^2 = 4$
- **d** $(x - 5)^2 = 16$
- **e** $(2x + 1)^2 = 25$
- **f** $(2x - 1)^2 = 1$
- **g** $(3x - 2)^2 = 4$
- **h** $(4x - 3)^2 = 81$

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10E Solving $x^2 + bx + c = 0$ using factors

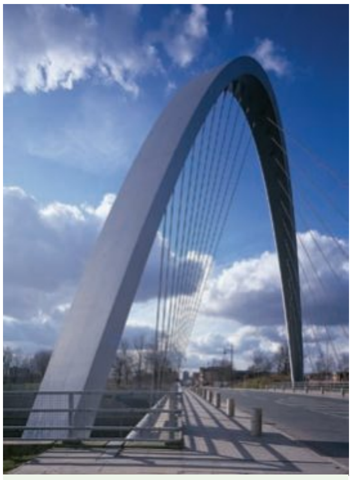
Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

In previous chapters, you would have solved linear equations such as $3x = 9$ and $2x - 1 = 5$, and you may have used 'back tracking' or inverse operations to solve them.

For quadratic equations such as $x^2 - x = 0$ or $x^2 - x - 20 = 0$, we need a new method, because there are different powers of x involved and 'back tracking' isn't useful.

The result of multiplying a number by zero is zero. Therefore, if an expression equals zero then at least one of its factors must be zero. This is called the null factor law and it provides us with an important method that can be utilised to solve a range of mathematical problems involving quadratic equations.



Parabolic arches, like this one used in the Hulme Arch Bridge in Manchester, can be modelled by quadratic equations.

Let's start: How does the null factor law work?

Start this investigation by completing this table.

x	−5	−4	−3	−2	−1	0	1	2
$(x - 1)(x + 4)$	6							

- Which values of x made $(x - 1)(x + 4) = 0$? Why?
- Could you work out what values of x make $(x - 1)(x + 4) = 0$ without doing a table? Explain.
- What values of x make $(x - 2)(x + 3) = 0$ or $(x + 5)(x - 7) = 0$?

Key ideas

- The **null factor law** states that if the product of two numbers is zero then either or both of the two numbers is zero.
  - If $a \times b = 0$ then $a = 0$ and/or $b = 0$.
- To solve a quadratic equation, write it in standard form ($ax^2 + bx + c = 0$) and factorise. Then use the null factor law.

  For example:
  $$\begin{aligned} x^2 - 2x - 8 &= 0 \\ (x - 4)(x + 2) &= 0 \\ x - 4 = 0 &\text{ or } x + 2 = 0 \\ x = 4 &\text{ or } \quad x = -2 \end{aligned}$$
  - If the coefficients of all the terms have a common factor, then first divide by that common factor.

Null factor law If two numbers multiply to give zero, then one or both of those numbers must be zero

Exercise 10E

UNDERSTANDING AND FLUENCY

1(½), 2, 3, 4–7(½)

3, 4–7(½)

1 Determine the value of x that makes each of the following true.

a $x - 1 = 0$ **b** $x + 3 = 0$
c $x + 7 = 0$ **d** $x - 5 = 0$
e $2x = 0$ **f** $-5x = 0$
g $2x + 4 = 0$ **h** $2x - 7 = 0$

2 **a** Complete this table for the given values of x.

x	−3	−2	−1	0	1	2
$(x + 2)(x - 1)$						

b What values of x made $(x + 2)(x - 1) = 0$?
c What values of x would make $(x + 3)(x - 2) = 0$?

3 Copy and complete.

a
$x(x - 2) = 0$
$x = 0$ or $\_\_\_ = 0$
$x = 0$ or $x = \_\_\_$

b
$(x - 1)(x + 4) = 0$
$x - 1 = 0$ or $\_\_\_ = 0$
$x = \_\_\_$ or $x = \_\_\_$

c
$(x + 6)(2x - 7) = 0$
$\_\_\_ = 0$ or $\_\_\_ = 0$
$x = \_\_\_$ or $2x = \_\_\_$
$x = \_\_\_$ or $x = \_\_\_$

Example 14 Using the null factor law

Use the null factor law to solve these equations.

a $x(x - 1) = 0$ **b** $(x - 1)(2x + 5) = 0$

SOLUTION	EXPLANATION
a $x(x - 1) = 0$ $x = 0$ or $x - 1 = 0$ $x = 0$ or $x = 1$	Set each factor equal to zero. For $x - 1 = 0$, add one to both sides to finish.
b $(x - 1)(2x + 5) = 0$ $x - 1 = 0$ or $2x + 5 = 0$ $x = 1$ or $2x = -5$ $x = 1$ or $x = -\frac{5}{2}$	Set each factor equal to zero and then solve each linear equation.

4 Use the null factor law to solve these equations.

a $x(x + 1) = 0$ **b** $x(x - 5) = 0$
c $2x(x - 4) = 0$ **d** $(x - 3)(x + 2) = 0$
e $(x + 5)(x - 4) = 0$ **f** $(x + 1)(x - 1) = 0$
g $(2x - 4)(x + 1) = 0$ **h** $(3x - 2)(x - 7) = 0$
i $3x(4x + 5) = 0$ **j** $(2x - 1)(3x + 7) = 0$
k $(4x - 5)(5x + 2) = 0$ **l** $(8x + 3)(4x + 3) = 0$

Null factor law: If $a \times b = 0$, then either $a = 0$ or $b = 0$.

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Example 15 Solving quadratic equations with a common factor

Solve $x^2 - 2x = 0$.

SOLUTION

$$\begin{aligned} x^2 - 2x &= 0 \\ x(x - 2) &= 0 \\ x = 0 \text{ or } x - 2 &= 0 \\ x = 0 \text{ or } \quad x &= 2 \end{aligned}$$

EXPLANATION

Factorise by taking out the common factor x. Apply the null factor law; i.e. if $a \times b = 0$ then $a = 0$ or $b = 0$.

Solve for x.

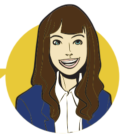
5 Solve the following quadratic equations.

a $x^2 - 4x = 0$ **b** $x^2 - 3x = 0$

c $x^2 + 2x = 0$ **d** $3x^2 - 12x = 0$

e $2x^2 - 10x = 0$ **f** $4x^2 + 8x = 0$

First take out the common factor, then use the null factor law.



Example 16 Solving with difference of two squares

Solve $x^2 - 16 = 0$ by factorising the difference of two squares.

SOLUTION

$$\begin{aligned} x^2 - 16 &= 0 \\ (x + 4)(x - 4) &= 0 \\ x + 4 = 0 \quad \text{or } x - 4 &= 0 \\ x = -4 \text{ or } \quad x &= 4 \end{aligned}$$

EXPLANATION

Note that $x^2 - 16$ is a difference of two squares.

$x^2 - 16 = x^2 - 4^2 = (x + 4)(x - 4)$

Solve each linear factor equal to zero to finish.

6 Solve the following by factorising the difference of two squares.

a $x^2 - 25 = 0$ **b** $x^2 - 36 = 0$

c $x^2 - 100 = 0$ **d** $4x^2 - 9 = 0$

e $9x^2 - 16 = 0$ **f** $49x^2 - 81 = 0$

$4x^2 = (2x)^2$

Example 17 Solving quadratic equations

Solve the following quadratic equations.

a $x^2 - 5x + 6 = 0$ **b** $x^2 + 2x + 1 = 0$

SOLUTION

a
$$\begin{aligned} x^2 - 5x + 6 &= 0 \\ (x - 3)(x - 2) &= 0 \\ x - 3 = 0 \text{ or } x - 2 &= 0 \\ x = 3 \text{ or } \quad x &= 2 \end{aligned}$$

b
$$\begin{aligned} x^2 + 2x + 1 &= 0 \\ (x + 1)(x + 1) &= 0 \\ (x + 1)^2 &= 0 \\ x + 1 &= 0 \\ x &= -1 \end{aligned}$$

EXPLANATION

Factorise by finding two numbers that multiply to 6 and add to -5: $-3 \times (-2) = 6$ and $-3 + (-2) = -5$.

Apply the null factor law and solve for x.

$1 \times 1 = 1$ and $1 + 1 = 2$.

$(x + 1)(x + 1) = (x + 1)^2$ is a perfect square.

This gives one solution for x.

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7 Solve the following quadratic equations.

a $x^2 + 3x + 2 = 0$ **b** $x^2 + 5x + 6 = 0$ **c** $x^2 - 6x + 8 = 0$
d $x^2 - 7x + 10 = 0$ **e** $x^2 + 4x - 12 = 0$ **f** $x^2 + 2x - 15 = 0$
g $x^2 - x - 20 = 0$ **h** $x^2 - 5x - 24 = 0$ **i** $x^2 - 12x + 32 = 0$
j $x^2 + 4x + 4 = 0$ **k** $x^2 + 10x + 25 = 0$ **l** $x^2 - 8x + 16 = 0$
m $x^2 - 14x + 49 = 0$ **n** $x^2 - 24x + 144 = 0$ **o** $x^2 + 18x + 81 = 0$

Parts **j** to **o** are perfect squares, so you will find only one solution.

PROBLEM-SOLVING AND REASONING

8(½), 9 | 8(½), 9, 10(½)

8 How many different solutions for x will these equations have?

a $(x - 2)(x - 1) = 0$ **b** $(x + 7)(x + 3) = 0$ **c** $(x + 1)(x + 1) = 0$
d $(x - 3)(x - 3) = 0$ **e** $\left(x + \sqrt{2}\right)\left(x - \sqrt{2}\right) = 0$ **f** $(x + 8)(x - \sqrt{5}) = 0$
g $(x + 2)^2 = 0$ **h** $(x + 3)^2 = 0$ **i** $3(2x + 1)^2 = 0$

9 The height, in metres, of a paper plane above floor level is given by $-\frac{1}{5}t(t - 10)$, where t is in seconds.

a Find the height of the plane after:
  i 2 seconds **ii** 6 seconds

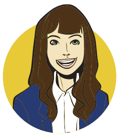
b Solve $-\frac{1}{5}t(t - 10) = 0$ for t.

c How long does it take for the plane to hit the ground after it is launched?

10 Solve by first taking out a common factor.

a $2x^2 + 16x + 24 = 0$
b $2x^2 - 20x - 22 = 0$
c $3x^2 - 18x + 27 = 0$
d $5x^2 - 20x + 20 = 0$

First take out the common factor, then factorise before using the null factor law.

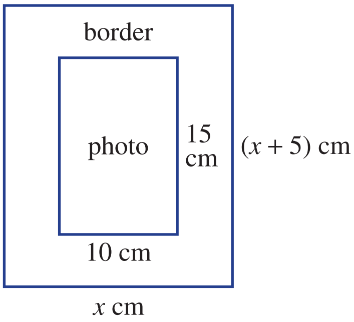


ENRICHMENT

– | 11

Photo albums

11 A printer produces photo albums. Each page has a length that is 5 cm more than the breadth, and includes a spot in the middle for a standard 10 cm by 15 cm photo.



a Find the area of the photo.

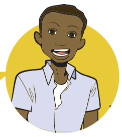
b Find an expression for:
  i the total area of a page
  ii the border area of a page (i.e. excluding the photo)

c Factorise your expression for the border area.

d For what value of x is the border area equal to zero?

e For what value of x is the border area equal to 350 cm^2?

In part **e**, you will need to set your equation equal to 0 before factorising.



10F Using quadratic equations to solve problems EXTENSION

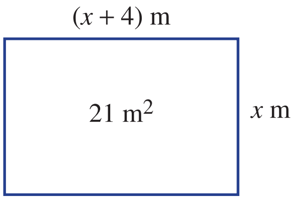
Defining variables, setting up equations, solving equations and interpreting solutions are all important elements of applying quadratics in problem solving. For example, the area of a rectangular paddock that can be fenced off using a limited length of fencing can be found by setting up a quadratic equation, solving it and then interpreting the solutions.

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Rectangular quadratics

The length of a rectangular room is 4 m longer than its breadth, which is x metres. Its area is 21 m^2.

- Write an expression for the area, using the variable x.
- Use the 21 m^2 fact to set up an equation equal to zero.
- Factorise and solve the equation to find x and then find the dimensions of the rectangle.



Key ideas

- When applying quadratic equations:
  - Define a variable; i.e. 'Let x be …'.
  - Write an equation.
  - Solve the equation.
  - Choose the solution(s) that solves the equation and answers the question.
  - Ensure that the solution is reasonable.

Exercise 10F EXTENSION

UNDERSTANDING AND FLUENCY		
	1–3, 4, 5	3–7

1 Write expressions for each of the following.

a The length of a rectangle if it is 4 more than its breadth, x.

b The length of a rectangle if it is 10 more than its breadth, x.

c The length of a rectangle if it is 7 less than its breadth, x.

d The height of a triangle if it is 2 less than its base, x.

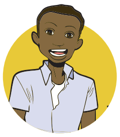
e The height of a triangle if it is 6 more than its base, x.

2 Rearrange these equations so that there is a zero on the right-hand side. Do not try to solve the equation.

a $x^2 + 2x = 3$

b $x^2 - 3x = 5$

c $x^2 + 7x = 4$



Subtract from both sides to give a zero on the right side.

3 Factorise and solve these equations. Only give the positive answer for x.

a $x^2 - x - 6 = 0$ **b** $x^2 - 3x - 10 = 0$ **c** $x^2 + 2x - 24 = 0$

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Example 18 Setting up and solving a quadratic equation

The area of a rectangle is fixed at 28 m^2 and its length is 3 metres more than its breadth. Find the dimensions of the rectangle.

SOLUTION

Let x m be the breadth of the rectangle.

Length = $(x + 3)$ m

Area = 28

$l \times b = 28$

$x(x + 3) = 28$

$x^2 + 3x - 28 = 0$

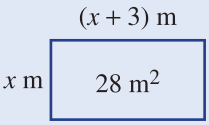
$(x + 7)(x - 4) = 0$

$x + 7 = 0$ or $x - 4 = 0$

$x = -7$ or $x = 4$

Rectangle has breadth = 4 m and length = 7 m.

EXPLANATION

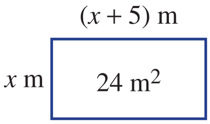


Write an equation using the given information. Then write with a zero on the right by subtracting 28 from both sides. Solve for x by applying the null factor law.

Disregard $x = -7$ because x must be greater than zero.

Answer the question in full.

4 A rectangle has an area of 24 m^2. Its length is 5 m longer than its breadth.



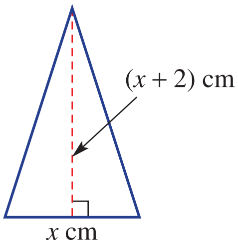
- **a** Copy this sentence: 'Let x m be the breadth of the rectangle.'
- **b** Write an expression for the rectangle's length.
- **c** Write an equation using the rectangle's area.
- **d** Write your equation from part **c** with a zero on the right-hand side, and solve for x.
- **e** Find the dimensions of the rectangle.

5 Repeat all the steps in Question **4** to find the dimensions of a rectangle with the following properties.

- **a** Its area is 60 m^2 and its length is 4 m more than its breadth.
- **b** Its area is 63 m^2 and its length is 2 m less than its breadth.
- **c** Its area is 154 mm^2 and its length is 3 mm less than its breadth.

Carefully set out each step as in **Example 18** and **Question 4.**

6 A triangle's area is 4 cm^2 and its height is 2 cm more than its base.



- **a** Write an expression for the area of the triangle using $A = \frac{1}{2}bh$.
- **b** Write an equation using the 4 cm^2 area fact.
- **c** Multiply both sides by 2 and write your equation with a zero on the right-hand side.
- **d** Solve your equation to find the base and height dimensions of the triangle.

7 Find the height and base lengths of a triangle that has an area of 7 m^2 and height 5 m less than its base.

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PROBLEM-SOLVING AND REASONING	8, 9	9–11

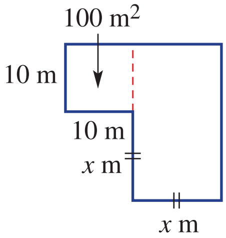
8 The product of two consecutive whole numbers (x and $x + 1$) is 132, so $x(x + 1) = 132$.

- **a** Expand the equation and make equal to zero on the right-hand side.
- **b** Solve the equation to find two values of x.
- **c** List the two pairs of consecutive numbers that multiply to 132.

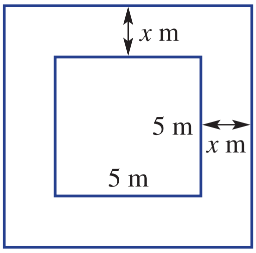
'Product' means times. 'Consecutive' means next to; e.g. 4 and 5 are consecutive whole numbers.

9 The product of two consecutive numbers is 72. Use a quadratic equation to find the two sets of numbers.

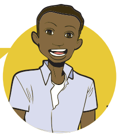
10 A 100 m² hay shed is to be extended to give 475 m² of floor space in total, as shown in the diagram. Find the value of x.



11 A square hut with side lengths of 5 m is to be surrounded by a verandah of breadth x metres. Find the breadth of the verandah if its area is to be 24 m².



What is the side length of the verandah?



ENRICHMENT	–	12, 13

Projectile maths

12 A ball is thrust vertically upwards from a machine on the ground. The height (h metres) after t seconds is given by $h = t(4 - t)$.

- **a** Find the ball's height after 1.5 seconds.
- **b** Find when the ball is at a height of 3 m.
- **c** Why are there two solutions to part **b**?
- **d** Find when the ball is at ground level.
- **e** Find when the ball is at a height of 4 m.
- **f** Why is there only one solution for part **e**?
- **g** Is there a time when the ball is at a height of 5 m? Explain.

13 The height h (in metres) of a rocket is given by $h = -x^2 + 100x$, where x metres is the horizontal distance from where the rocket was launched.

- **a** Find the values of x when $h = 0$.
- **b** Interpret your answer from part **a**.
- **c** Find how far the rocket has travelled horizontally if the height is 196 m

10G Exploring parabolas

Interactive
Widgets
HOTsheets
Walkthrough

Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

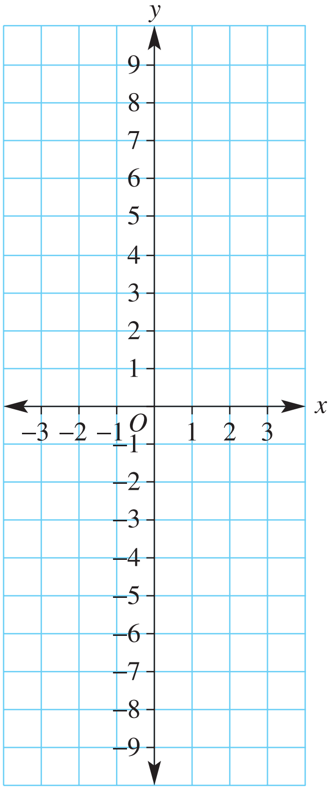
One of the simplest and most important non-linear graphs is the parabola. When a ball is thrown or water streams up and out from a garden hose or fountain, the path followed has a parabolic shape. The parabola is the graph of a quadratic relation with the basic rule $y = x^2$. Quadratic rules, such as $y = (x - 1)^2$ and $y = 2x^2 - x - 3$, also give graphs that are parabolas and are transformations of the graph of $y = x^2$.

Let's start: To what effect?

To see how different quadratic rules compare to the graph of $y = x^2$, complete this table and plot the graph of each equation on the same set of axes.

x	-3	-2	-1	0	1	2	3
$y_1 = x^2$	9	4					
$y_2 = -x^2$	-9						
$y_3 = (x - 2)^2$	☒	☒	9				
$y_4 = x^2 - 3$	6						

- For all the graphs, find features such as the:
  - turning point
  - axis of symmetry
  - y-intercept
  - x-intercepts
- Discuss how each of the graphs of y_2, y_3 and y_4 compare to the graph of $y = x^2$. Compare the rule with the position of the graph.



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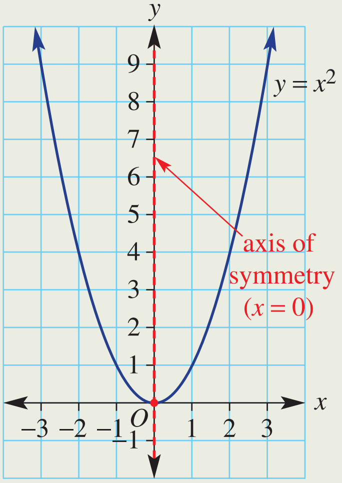
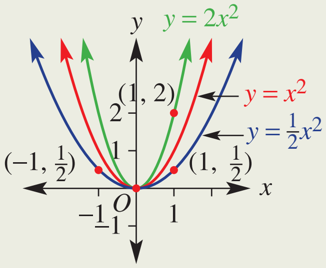
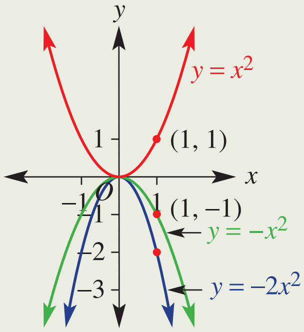
- A **parabola** is the graph of a quadratic relation. The basic parabola has the rule $y = x^2$.
  - The vertex (or turning point) is (0, 0).
  - It is a minimum turning point.
  - Axis of symmetry is $x = 0$.
  - y-intercept is 0.
  - x-intercept is 0.



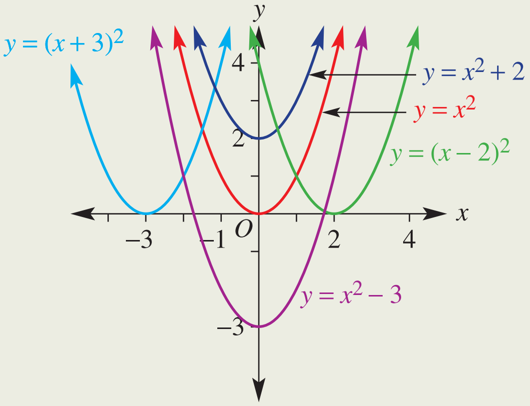
- Simple transformations of the graph of $y = x^2$ include:
  - **dilation**



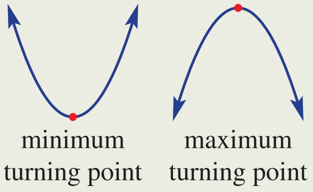
  - **reflection**



  - **translation**



  - Turning points can be a maximum or a minimum.



Parabola
A smooth U-shaped curve with the basic rule $y = x^2$

Dilation
A transformation where a curve is enlarged or reduced but the centre is not changed

Reflection
A transformation where a curve is flipped across a line on the number plane

Translation
A transformation where a curve is moved a certain distance on the number plane

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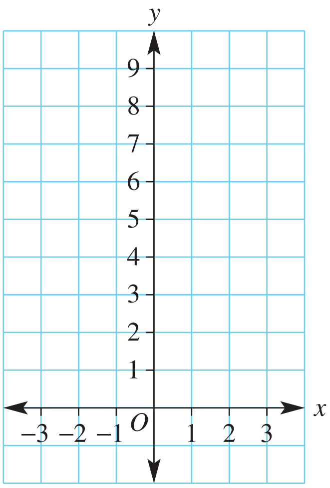
Exercise 10G

UNDERSTANDING AND FLUENCY 1, 2, 3(½), 4–6 | 3(½), 4–6

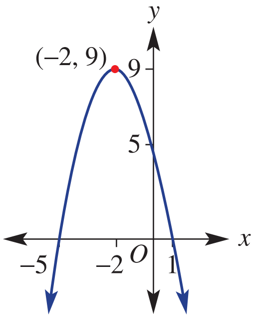
1 Complete this table to plot the graph of $y = x^2$.

x	−3	−2	−1	0	1	2	3
y	9						



Recall: $(-3)^2 = -3 \times (-3)$
$= 9$

2 Write the missing features for this graph.



a The parabola has a __________ (maximum or minimum).

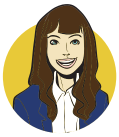
b The coordinates of the turning point are _____.

c The y-intercept is $y =$ _____.

d The x-intercepts are $x =$ _____ and $x =$ _____.

e The axis of symmetry is ______.

The axis of symmetry is the vertical line passing through the turning point.



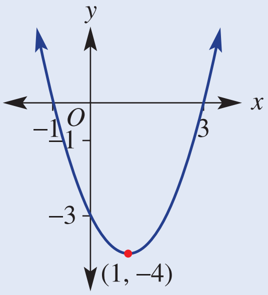
Example 19 Identifying key features of parabolas

Determine the following key features of each of the given graphs.

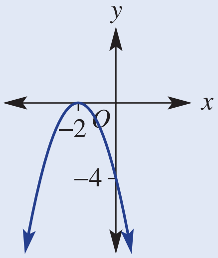
i turning point and whether it is a maximum or minimum

ii axis of symmetry **iii** x-intercepts **iv** y-intercept

a



b



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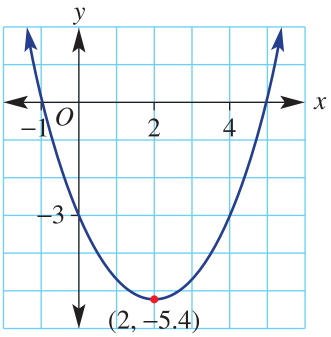
SOLUTION	EXPLANATION
a **i** Turning point is a minimum at (1, −4).	Lowest point of graph is at (1, −4).
ii Axis of symmetry is $x = 1$.	Line of symmetry is through the x-coordinate of the turning point.
iii x-intercepts at −1 and 3.	x-intercepts lie on the x-axis (i.e. when $y = 0$) and the y-intercept lies on the y-axis (i.e. when $x = 0$).
iv y-intercept at −3.	
b **i** Turning point is a maximum at (−2, 0).	Graph has a highest point at (−2, 0).
ii Axis of symmetry is $x = -2$.	Line of symmetry is through the x-coordinate of the turning point.
iii x-intercept at −2.	Turning point is also the one x-intercept.
iv y-intercept at −4.	

3 Determine these key features of the following graphs.

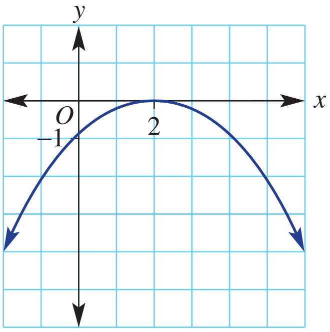
- **i** turning point and whether it is a maximum or minimum
- **ii** axis of symmetry
- **iii** x-intercepts
- **iv** y-intercept

An axis of symmetry is described by a rule such as $x = 2$ or $x = -3$.

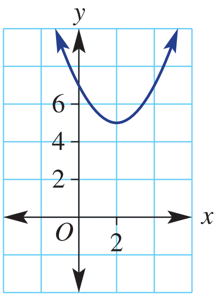
a



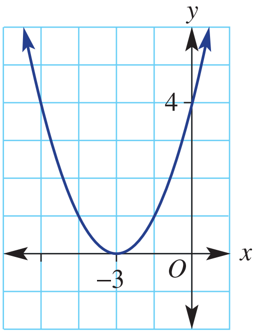
b



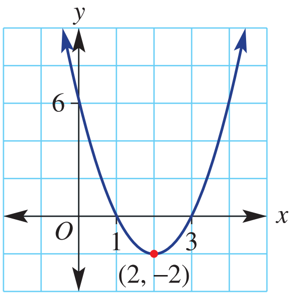
c



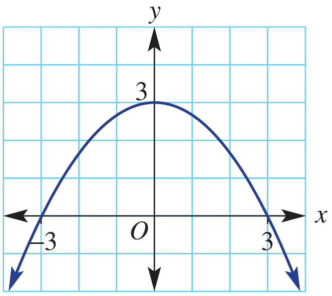
d



e



f



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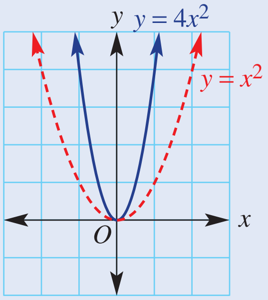
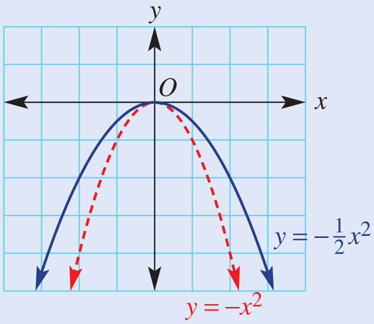
Example 20 Identifying key features of parabolas

Copy and complete the table for the following graphs.

a



b



	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 4x^2$					
b	$y = -\frac{1}{2}x^2$					

SOLUTION

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 4x^2$	minimum	no	(0, 0)	4	narrower
b	$y = -\frac{1}{2}x^2$	maximum	yes	(0, 0)	$-\frac{1}{2}$	wider

EXPLANATION

Read features from graphs and consider the effect of each change in equation on the graph.

4 Copy and complete the table below for the graphs on the next page.

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 3x^2$					
b	$y = \frac{1}{2}x^2$					
c	$y = 2x^2$					
d	$y = -4x^2$					
e	$y = -\frac{1}{3}x^2$					
f	$y = -2x^2$					

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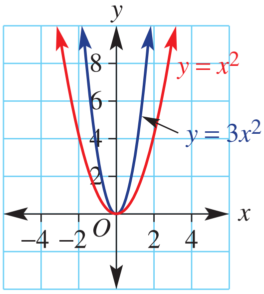
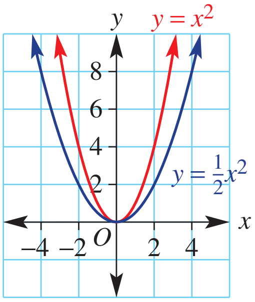
a



b



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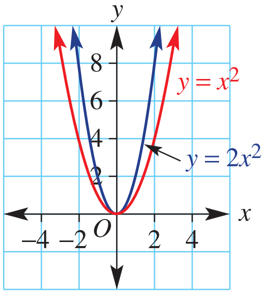

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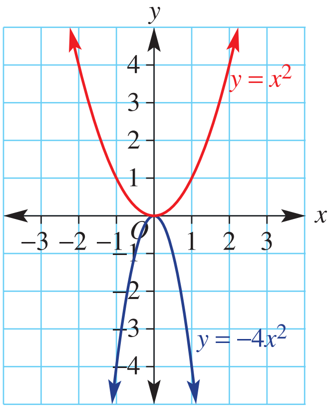
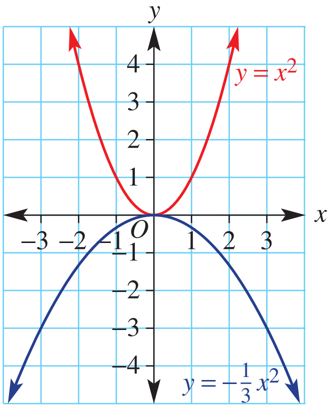


e



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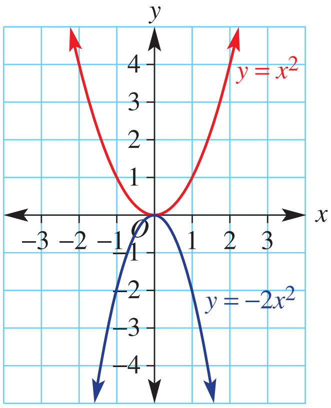
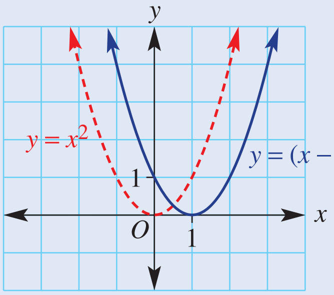


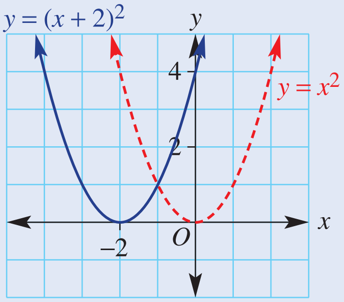
Example 21 Translating horizontally

Copy and complete the table for the following graphs.

a



b



	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = (x - 1)^2$					
b	$y = (x + 2)^2$					

SOLUTION

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = (x - 1)^2$	minimum	no	(1, 0)	0	same
b	$y = (x + 2)^2$	minimum	no	(−2, 0)	9	same

EXPLANATION

The effect is to shift right or left; right for part **a** and left for part **b**.

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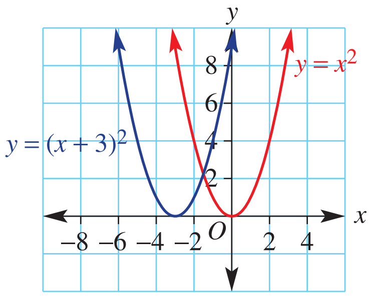
5 Copy and complete the table below for the graphs that follow.

	Formula	Turning point	Axis of symmetry	y-intercept ($x = 0$)	x-intercept
a	$y = (x + 3)^2$				
b	$y = (x - 1)^2$				
c	$y = (x - 2)^2$				
d	$y = (x + 4)^2$				

a



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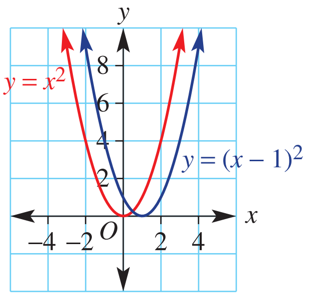
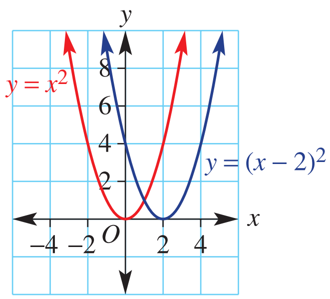


c



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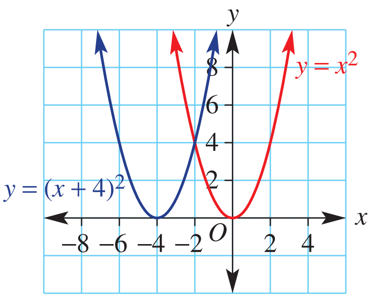
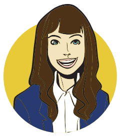


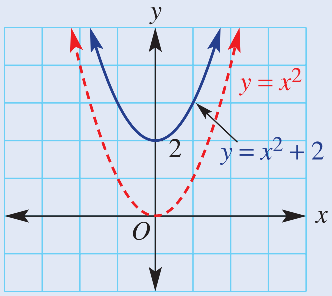


The axis of symmetry is a vertical line passing through the turning point of a parabola. The equation is given by the x coordinate of the turning point.

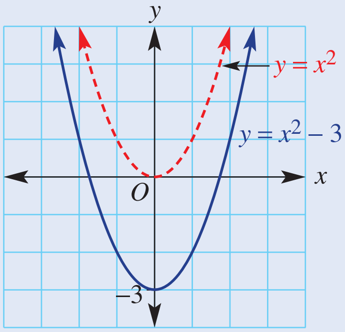
Example 22 Translating vertically

Copy and complete the table for the following graphs.

a



b



	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = x^2 + 2$					
b	$y = x^2 - 3$					

SOLUTION

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = x^2 + 2$	minimum	no	(0, 2)	3	same
b	$y = x^2 - 3$	minimum	no	(0, –3)	–2	same

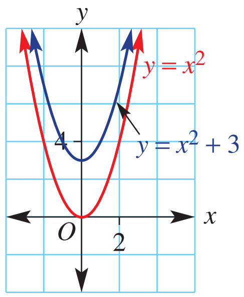
EXPLANATION

The effect is to shift up or down; up for $y = x^2 + 2$ and down for $y = x^2 - 3$.

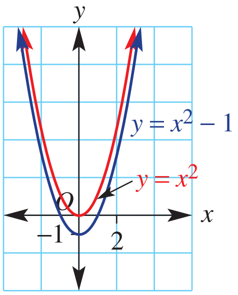
6 Copy and complete the table for the graphs that follow.

	Formula	Turning point	y-intercept ($x = 0$)	y value when $x = 1$
a	$y = x^2 + 3$			
b	$y = x^2 - 1$			
c	$y = x^2 + 2$			
d	$y = x^2 - 4$			

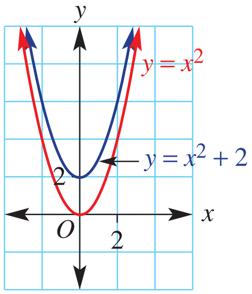
a



b



c



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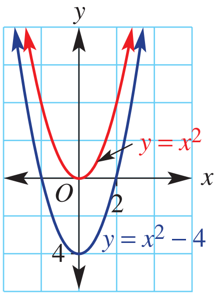
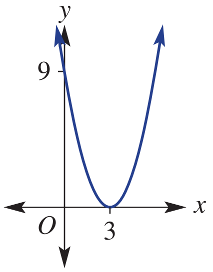


PROBLEM-SOLVING AND REASONING 7, 8 7–9

7 Match each of the following equations (**a**–**f**) to one of the graphs (**A**–**F**).

a $y = 2x^2$
b $y = x^2 - 6$
c $y = (x + 2)^2$
d $y = -5x^2$
e $y = (x - 3)^2$
f $y = x^2 + 4$

A



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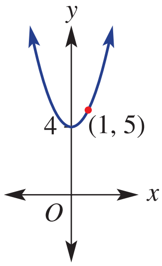

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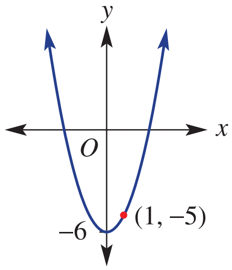

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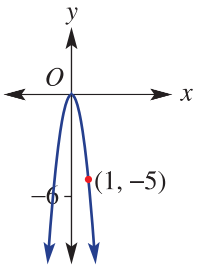
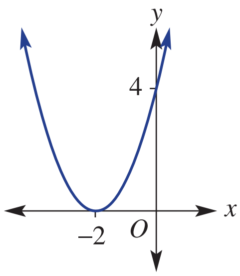
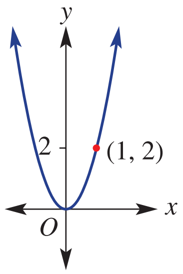


E



F



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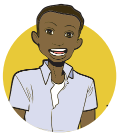
8 Write a rule for a parabola with each feature.

- **a** same shape as $y = x^2$, minimum turning point $(0, 2)$
- **b** same shape as $y = x^2$, maximum turning point $(0, 0)$
- **c** same shape as $y = x^2$, minimum turning point $(-1, 0)$
- **d** same shape as $y = x^2$, minimum turning point $(5, 0)$



What turns $y = x^2$ into a graph with a maximum turning point?

9 **a** The points $(x, 5)$ lie on a parabola. The equation of the parabola is $y = x^2 - 9$. Find the exact values of x.

- **b** The points $(x, 0)$ lie on a parabola with the equation $y = 2x^2 - 18$. Find the values of x.
- **c** Explain why there is no point on the curve $y = x^2 - 9$, which has a y value of -10.

ENRICHMENT – 10– 12

Parabolas with technology

10 **a** Using technology, plot the following pairs of graphs on the same set of axes for $-5 \leqslant x \leqslant 5$ and compare their graphs.

- **i** $y = x^2$ and $y = 4x^2$
- **ii** $y = x^2$ and $y = \frac{1}{3}x^2$
- **iii** $y = x^2$ and $y = 6x^2$
- **iv** $y = x^2$ and $y = \frac{1}{4}x^2$
- **v** $y = x^2$ and $y = 7x^2$
- **vi** $y = x^2$ and $y = \frac{2}{5}x^2$

b Suggest how the constant a in $y = ax^2$ transforms the graph of $y = x^2$.

11 **a** Using technology, plot the following sets of graphs on the same set of axes for $-5 \leqslant x \leqslant 5$ and compare the turning point of each.

- **i** $y = x^2, y = (x + 1)^2, y = (x + 2)^2, y = (x + 3)^2$
- **ii** $y = x^2, y = (x - 1)^2, y = (x - 2)^2, y = (x - 3)^2$

b Explain how the constant h in $y = (x + h)^2$ transforms the graph of $y = x^2$.

12 **a** Using technology, plot the following sets of graphs on the same set of axes for $-5 \leqslant x \leqslant 5$ and compare the turning point of each.

- **i** $y = x^2, y = x^2 + 1, y = x^2 + 2, y = x^2 + 3$
- **ii** $y = x^2, y = x^2 - 1, y = x^2 - 3, y = x^2 - 5$

b Explain how the constant k in $y = x^2 + k$ transforms the graph of $y = x^2$.

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10H Graphs of circles and exponentials

Interactive

Widgets

HOTsheets

Walkthrough

We know the circle as being a common shape in geometry. We can also describe a circle using a rule and as a graph on the Cartesian plane.

We can also use graphs to illustrate exponential relationships. The population of the world, for example, or the balance of an investment account, can be described using exponential rules that include indices. The rule $A = 100\,000(1.05)^t$ describes the account balance of \$100 000 invested at 5% p.a. compound interest for t years.

The population of the world can be modelled using an exponential equation.

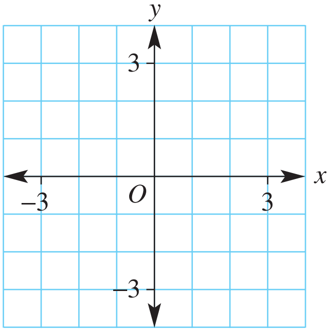
Stage
5.3#
5.3
5.3§
5.2
5.2◊
5.1
4

Let's start: Plotting non-linear curves

A graph has the rule $x^2 + y^2 = 9$.

- If $x = 0$ what are the two values of y?
- If $x = 1$ what are the two values of y?
- If $x = 4$ are there any values of y? Discuss.
- Complete this table of values.

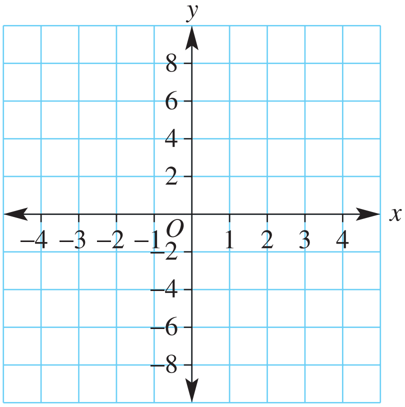
x	−3	−2	−1	0	1	2	3
y		$\pm\sqrt{5}$					



- Now plot all your points on a number plane and join them to form a smooth curve.
- What shape have you drawn and what are its features?
- How does the radius of your circle relate to the equation?

Complete this table and graph the rule $y = 2^x$ before discussing the points below.

x	−3	−2	−1	0	1	2	3
$y = 2^x$	$\frac{1}{8}$			1		4	



- Discuss the shape of the graph.
- Where does the graph cut the y-axis?
- Does the graph have an x-intercept? Why not?

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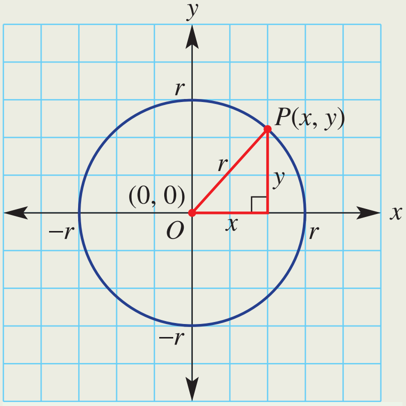
Key ideas

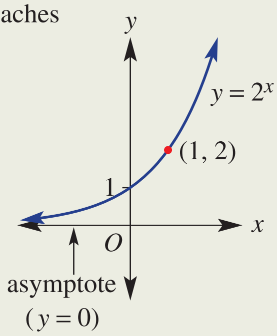
- The Cartesian equation of a circle with centre (0, 0) and radius r is given by $x^2 + y^2 = r^2$.



Using Pythagoras' theorem:
$a^2 + b^2 = c^2$ gives $x^2 + y^2 = r^2$.

- A simple **exponential** rule is of the form $y = a^x$, where $a > 0$ and $a \neq 1$.
  - y-intercept is 1.
  - $y = 0$ is the equation of the asymptote.

- An **asymptote** is a line that a curve approaches but never touches. The curve gets closer and closer to the line so that the distance between the curve and the line approaches zero, but the curve never meets the line so the distance is never zero.



Exponential (notation)
A way of representing repeated multiplication of the same number

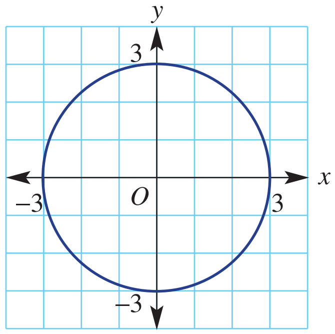
Asymptote
A line whose distance to a curve approaches zero, and the curve never touches it

Exercise 10H

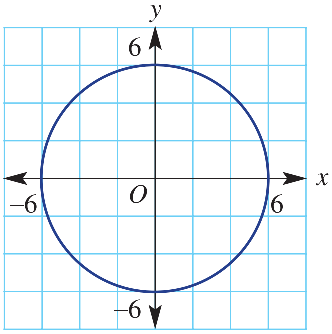
UNDERSTANDING AND FLUENCY 1–3, 4(½), 5, 7 4(½), 6–8

1 Write the coordinates of the centre and give the radius of these circles.

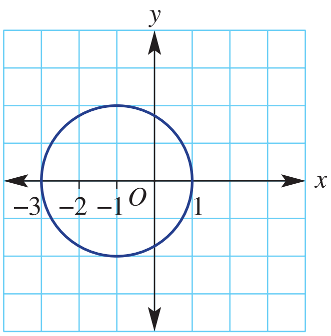
a



b



c



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2 Solve these equations for the unknown variable, correct to 1 decimal place where necessary.

a $x^2 + 2^2 = 9$

b $x^2 + 3^2 = 25$

c $5^2 + y^2 = 36$

There are two answers for each. ±4 means the answers are +4 and −4.

3 A circle has equation $x^2 + y^2 = r^2$. Complete these sentences.

a The centre of the circle is ________.

b The radius of the circle is ________.

4 Evaluate:

a 2^0	**b** 2^1
c 2^4	**d** 3^0
e 3^1	**f** 3^3
g 4^0	**h** 4^2
i 5^0	**j** 5^2

Example 23 Sketching a circle

Complete the following for the equation $x^2 + y^2 = 4$.

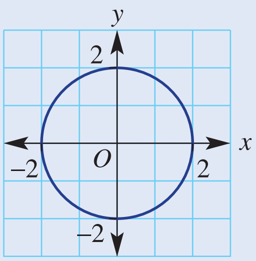
a State the coordinates of the centre.

b State the radius.

c Find the values of y when $x = 1$, correct to 1 decimal place.

d Find the values of x when $y = 0$.

e Sketch a graph showing intercepts.

SOLUTION	EXPLANATION
a (0, 0)	(0, 0) is the centre for all circles $x^2 + y^2 = r^2$.
b $r = 2$	$x^2 + y^2 = r^2$ so $r^2 = 4$.
c $x^2 + y^2 = 4$ $1^2 + y^2 = 4$ $y^2 = 3$ $y = \pm 1.7$	Substitute $x = 1$ and solve for y. $y^2 = 3$, so $y = \pm\sqrt{3}$ $\sqrt{3} \approx 1.7$
d $x^2 + 0^2 = 4$ $x^2 = 4$ $x = \pm 2$	Substitute $y = 0$. Solve for x. Both $(-2)^2$ and $2^2 = 4$.
e 	Draw a circle with centre (0, 0) and radius 2. Label intercepts.

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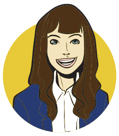
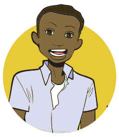
5 A circle has equation $x^2 + y^2 = 9$. Complete the following.
- **a** State the coordinates of the centre.
- **b** State the radius.
- **c** Find the values of y when $x = 2$, correct to 1 decimal place.
- **d** Find the values of x when $y = 0$.
- **e** Sketch a graph showing intercepts.

If $x^2 + y^2 = r^2$, then r is the radius.



If $y^2 = 5$, then $y = \pm\sqrt{5}$.



6 Complete the following for the equation $x^2 + y^2 = 25$.
- **a** State the coordinates of the centre.
- **b** State the radius.
- **c** Find the values of y when $x = 4$.
- **d** Find the values of x when $y = 0$.
- **e** Sketch a graph showing intercepts.

Example 24 Plotting an exponential graph

For the rule $y = 2^x$:
- **a** Complete this table.
- **b** Plot the points to form its graph.

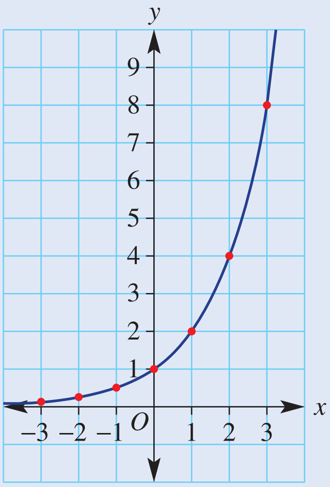
x	−3	−2	−1	0	1	2	3
y	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$				

SOLUTION

a

x	−3	−2	−1	0	1	2	3
y	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	8

b



EXPLANATION

$2^0 = 1$, $2^1 = 2$, $2^2 = 4$, $2^3 = 8$.

Plot each point and join them to form a smooth curve.

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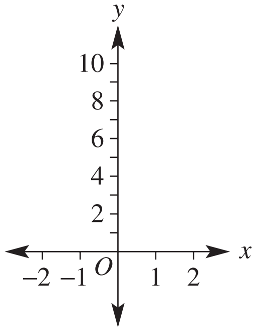
7 Consider the exponential rule $y = 3^x$.

a Complete this table.

x	−2	−1	0	1	2
y	$\frac{1}{9}$	$\frac{1}{3}$			

b Plot the points in the table to form the graph of $y = 3^x$.

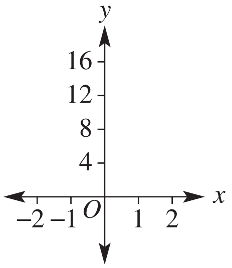


8 Consider the exponential rule $y = 4^x$.

a Complete this table.

x	−2	−1	0	1	2
y	$\frac{1}{16}$	$\frac{1}{4}$			

b Plot the points in the table to form the graph of $y = 4^x$.



PROBLEM-SOLVING AND REASONING

9, 10(½), 11 10(½), 11–13

9 **a** Sketch the graph of the following on the same set of axes, labelling the y-intercept and the point where $x = 1$.

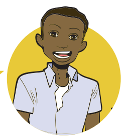
- **i** $y = 2^x$
- **ii** $y = 4^x$
- **iii** $y = 5^x$

b What do you notice about the y-intercept on each graph?

c What does increasing the base number do to each graph?

Use this table to help.

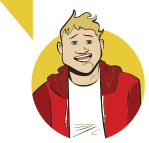
x	−1	0	1	2
$y = 2^x$	$\frac{1}{2}$	1		
$y = 4^x$	$\frac{1}{4}$			
$y = 5^x$	$\frac{1}{5}$			



10 Give the radius of the circles with these equations.

a $x^2 + y^2 = 36$
b $x^2 + y^2 = 81$
c $x^2 + y^2 = 144$
d $x^2 + y^2 = 5$
e $x^2 + y^2 = 14$
f $x^2 + y^2 = 20$

Remember: $x^2 + y^2 = r^2$

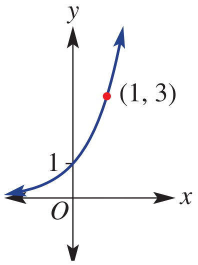


11 Write the equation of a circle with centre (0, 0) and radius 7.

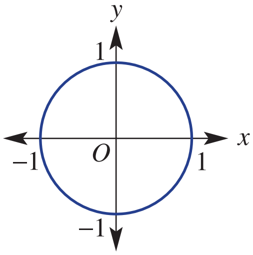
12 Match equations **a**–**c** with graphs **A**–**C**.

a $y = -x - 2$
b $y = 3^x$
c $x^2 + y^2 = 1$

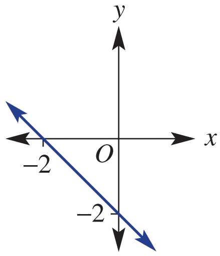
A



B



C



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13 A study shows that the population of a town is modelled by the rule $P = 2^t$, where t is in years and P is in thousands of people.

a State the number of people in the town at the start of the study (i.e. when $t = 0$).

b State the number of people in the town after:

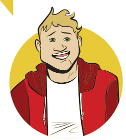
  i 1 year **ii** 3 years

c When is the town's population expected to reach:

  i 4000 people? **ii** 16 000 people?

d Sketch a graph of P versus t for $t \geqslant 0$.

If $P = 3$, there are 3000 people.



ENRICHMENT	–	14, 15

Graphs of hyperbolas

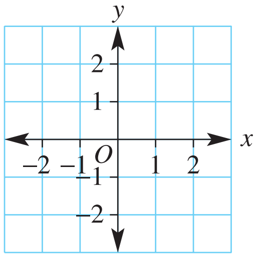
Another type of graph is called a hyperbola, and it comes from the rule $y = \frac{1}{x}$.

14 A hyperbola has the rule $y = \frac{1}{x}$.

a Complete this table.

x	-2	-1	$-\frac{1}{2}$	$\frac{1}{2}$	1	2
y						

b Plot the points to form the graph of $y = \frac{1}{x}$.

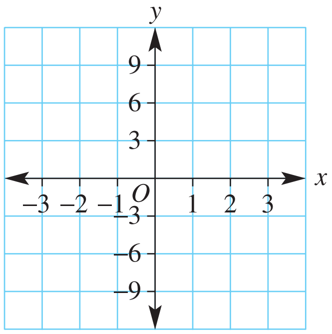


15 A hyperbola has the rule $y = \frac{3}{x}$.

a Complete this table.

x	-3	-1	$-\frac{1}{3}$	$\frac{1}{3}$	1	3
y						

b Plot the points to form the graph of $y = \frac{3}{x}$.



1 'I am a beautiful curve!' Solve the equations and then match the letters to the answers to find out what I am.

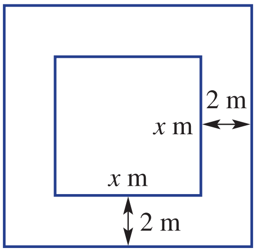
O	B	A	L	P	R
2^3	radius of $x^2 + y^2 = 16$	solution to $(x - 3)^2 = 0$	$x^2 - x$	$-2(x - 1)$	solution to $x^2 - 2x - 8 = 0$

____	____	____	____	____	____	____	____
$-2x + 2$	3	4, −2	3	4	8	$x(x - 1)$	3

2 A square pool with side lengths of x metres is surrounded by a tiled edge of breadth 2 m.

a Find an expression for the total area.

b For what value of x is the total area equal to 100 m^2?



3 A book's length is 6 cm longer than its breadth and its total cover area is 280 cm^2. What are its dimensions?

4 The product of two consecutive even numbers is 168. Find the two numbers.

5 A father's age is the square of his son's age (x). In 20 years' time the father will be 3 times as old as his son. What are the ages of the father and son?

6 A rectangular painting is to have a total area (including the frame, which has a uniform width) of 1200 cm^2. The painting is 30 cm long and 20 cm wide. Find the breadth of the frame.

7 Simplify these expressions.

a $4x - 3(2 - x)$

b $(x - 1)^2 - (x + 1)^2$

c $\dfrac{x^2 - x - 6}{x + 2}$

8 A cyclist in a charity ride cycles 300 km at a constant average speed. If the average speed had been 5 km/h faster, then the ride would have taken 2 hours less. What was the average speed of the cyclist?

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Chapter summary

Quadratic expressions and quadratic equations

Factorising $x^2 + bx + c$

2 numbers × to b
and + to c

e.g. $x^2 - 7x - 18 = (x - 9)(x + 2)$
$-9 \times 2 = -18$
$-9 + 2 = -7$

Factorising and difference of perfect squares

Always take out common factors first; e.g. $2x + 6 = 2(x + 3)$

Difference of perfect squares

$a^2 - b^2 = (a - b)(a + b)$

e.g. **1** $x^2 - 4 = x^2 - 2^2$
$= (x + 2)(x - 2)$

2 $4x^2 - 9 = (2x)^2 - (3)^2$
$= (2x - 3)(2x + 3)$

Expanding brackets

$a(b + c) = ab + ac$
$(a + b)(c + d) = ac + ad + bc + bd$
$(a + b)(a - b) = a^2 - b^2$
$(a + b)^2 = a^2 + 2ab + b^2$
$(a - b)^2 = a^2 - 2ab + b^2$

Solving quadratic equations

Null factor law:
If $ab = 0$, then $a = 0$ or $b = 0$.
Write each quadratic in standard form $ax^2 + bx + c = 0$, factorise and then apply the null factor law to solve.

e.g. **1** $x^2 - 4x = 0$
$x(x - 4) = 0$
$x = 0$ or $x - 4 = 0$
$x = 0$ or $x = 4$

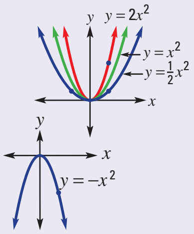
2 $x^2 - 3x + 10 = 0$
$(x - 5)(x + 2) = 0$
$x - 5 = 0$ or $x + 2 = 0$
$x = 5$ or $x = -2$

Applications

1. Define the variable.
2. Set up the equation.
3. Solve by factorising and use the null factor law.
4. Determine the suitable answer(s).

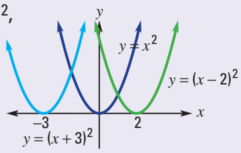
Transformations of a parabola

$y = ax^2$ dilates graph compared to $y = x^2$
$0 < a < 1$ graph is wider
$a > 1$ graph is narrower
$a < 0$ graph is inverted (reflected in x-axis)



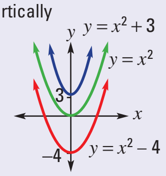
$y = (x - h)^2$ translates $y = x^2$, h units horizontally

$h > 0$ move right
$h < 0$ move left

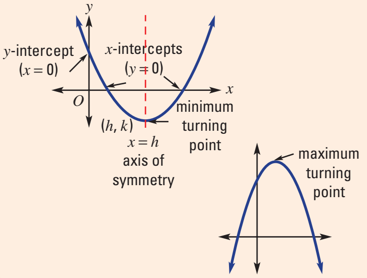


$y = x^2 + k$ translates $y = x^2$, k units vertically

$k > 0$ move up
$k < 0$ move down



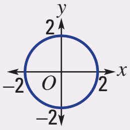
A parabola's rule is a quadratic equation



Other non-linear relationships

Circles

$x^2 + y^2 = r^2$ is a circle centred at (0, 0) or O with radius r.

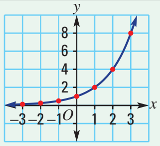


$x^2 + y^2 = 4$
$r^2 = 4$
$\therefore r = 2$

Exponential graphs

$y = 2^x$

x	−3	−2	−1	0	1	2	3
y	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4	8



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Multiple-choice questions

1 $-2x(1 - x)$ expands to:

A $-2 + 2x^2$ **B** $-2x - 2x^2$ **C** $2x + 2x^2$
D $-3x^2$ **E** $-2x + 2x^2$

2 $(x + 5)^2$ is the same as:

A $x^2 + 25$ **B** $x^2 + 5x$ **C** $x^2 + 5x + 25$
D $x^2 + 10x + 25$ **E** $x^2 + 50$

3 $(2x - 1)(x + 4)$ is equal to:

A $2x^2 + 11x - 2$ **B** $2x^2 + 7x - 4$ **C** $4x^2 + 14x - 8$
D $4x^2 + 9x - 2$ **E** $2x^2 + 5x + 4$

4 $4x^2 - 25$ in factorised form is:

A $4(x - 5)(x + 5)$ **B** $(2x - 5)^2$ **C** $(2x - 5)(2x + 5)$
D $(4x + 5)(x - 5)$ **E** $2(2x + 1)(x - 25)$

5 The solutions to $(2x - 1)(x + 1) = 0$ are:

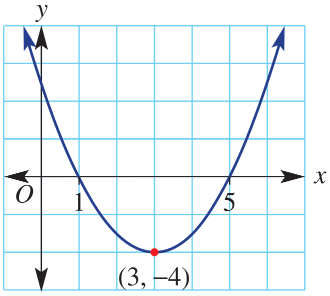
A $x = 0, x = 1$ **B** $x = -1, x = \frac{1}{2}$ **C** $x = -1, x = 2$
D $x = -1, x = -2$ **E** $x = 1, x = \frac{1}{2}$

6 The solutions to $2x^2 - 8x = 0$ are:

A $x = 0, x = -4$ **B** $x = 2$ **C** $x = 0, x = 4$
D $x = 4$ **E** $x = 0, x = 2$

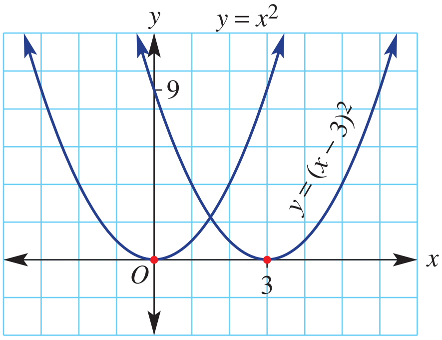
7 The equation of the axis of symmetry of the graph shown is:

A $y = -4$
B $x = 3$
C $x = -4$
D $y = 3$
E $y = 3x$



8 Compared to the graph of $y = x^2$, the graph of $y = (x - 3)^2$ is:

A 3 units down
B 3 units left
C in the same place
D 3 units right
E 3 units up



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9 The solution(s) to the equation $x^2 - 6 = 0$ are:

A no solution **B** $x = 3$ **C** $x = \sqrt{6}$ **D** $x = \pm\sqrt{6}$ **E** $x = \pm 3$

10 The equation of a circle centred at the origin with radius 4 units is:

A $y = 4x^2$ **B** $x^2 + y^2 = 4$ **C** $x^2 + y^2 = 8$ **D** $y = 4^x$ **E** $x^2 + y^2 = 16$

11 The graph of $y = 3^x$ has y-intercept with coordinates:

A $(0, 3)$ **B** $(3, 0)$ **C** $(0, 1)$ **D** $(1, 3)$ **E** $\left(0, \frac{1}{3}\right)$

Short-answer questions

1 Expand the following and simplify where possible.

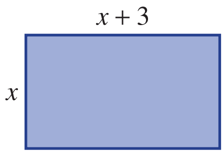
a $-2(x + 1)$ **b** $x(x + 3)$ **c** $(x + 2)(x - 1)$

d $(x + 5)(3x - 4)$ **e** $(x + 4)(x - 4)$ **f** $(5x - 2)(5x + 2)$

g $(x + 2)^2$ **h** $(x - 6)^2$ **i** $(3x - 2)(4x - 5)$

2 Write, in expanded form, an expression for the shaded areas.

a



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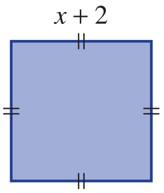
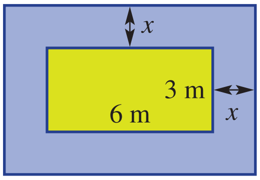


c



3 Factorise by removing a common factor.

a $3x - 9$ **b** $-4x - 16$ **c** $x^2 + 2x$

d $ab - b$ **e** $7x - 14x^2$ **f** $-a^2b - 6ab$

4 Factorise the following, using difference of perfect squares. Remember to look for a common factor first.

a $x^2 - 49$ **b** $9x^2 - 16$

c $4x^2 - 1$ **d** $3x^2 - 75$

e $2x^2 - 18$ **f** $4x^2 - 81$

5 Factorise these quadratic trinomials. Some are perfect squares.

a $x^2 + 5x + 6$ **b** $x^2 - x - 6$ **c** $x^2 - 8x + 12$

d $x^2 + 10x - 24$ **e** $x^2 + 5x - 50$ **f** $x^2 - 12x + 32$

g $x^2 - 6x + 9$ **h** $x^2 + 20x + 100$ **i** $x^2 + 40x + 400$

6 Solve the following equations for x, finding all possible solutions in exact form.

a $x^2 = 36$ **b** $x^2 = 15$

c $3x^2 = 75$ **d** $2x^2 = -32$

e $x^2 + 10 = 0$ **f** $x^2 - 22 = 0$

g $\frac{x^2}{2} - 3 = 5$ **h** $4 - x^2 = 2$

7 Solve, using the null factor law.

a $(x + 1)(x - 2) = 0$ **b** $(x - 3)(x + 7) = 0$ **c** $(2x - 1)(x + 4) = 0$

d $x(x - 3) = 0$ **e** $-4x(x + 6) = 0$ **f** $7x(2x - 5) = 0$

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8 Solve these quadratic equations by factorising and applying the null factor law.

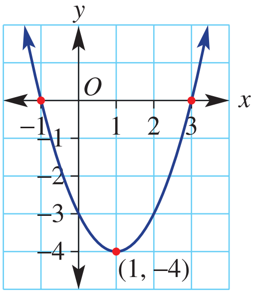
a $x^2 + 4x = 0$
b $3x^2 - 9x = 0$
c $x^2 - 25 = 0$
d $9x^2 - 16 = 0$
e $x^2 + 8x + 15 = 0$
f $x^2 - 10x + 21 = 0$
g $x^2 - 8x + 16 = 0$
h $x^2 + 10x + 25 = 0$
i $x^2 + 5x - 36 = 0$

9 The area of a circle is 30 cm^2. Find the radius of the circle (to 1 decimal place) if the area (A) of a circle is given by $A = \pi r^2$, where r is the radius.

10 A large rectangular sandpit is 2 m longer than it is wide. If it occupies an area of 48 m^2, determine the dimensions of the sandpit by solving a suitable equation.

11 State the following features of the quadratic graph shown.

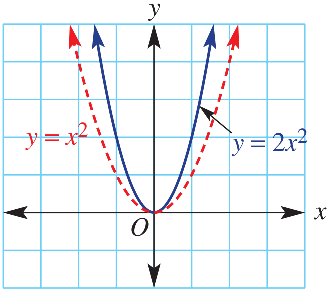
a turning point and whether it is a maximum or a minimum
b axis of symmetry
c x-intercepts
d y-intercept



12 Copy and complete the table for the following graphs.

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 2x^2$					
b	$y = -\frac{1}{2}x^2$					
c	$y = (x - 2)^2$					
d	$y = x^2 - 2$					

a



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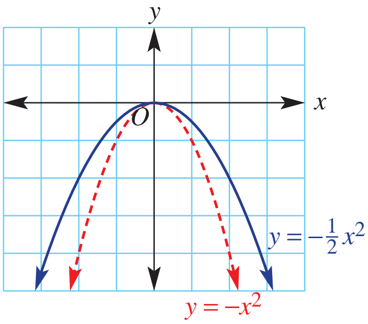

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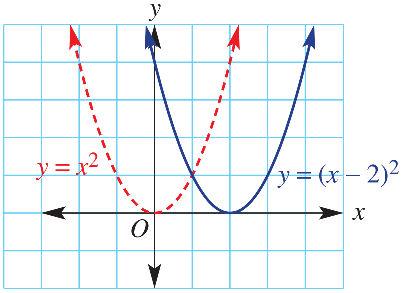

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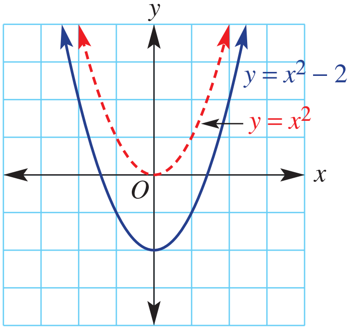


13 Sketch these circles. Label the centre and axes intercepts.

a $x^2 + y^2 = 25$

b $x^2 + y^2 = 4$

14 Sketch the following graphs, labelling the y-intercept and the point where $x = 1$.

a $y = 2^x$

b $y = 4^x$

Extended-response questions

1 A square spa is to be built in the middle of a 10 m by 10 m paved area. The builder does not yet know the size of the spa, so on the plan the spa size is variable. Its side length is x metres.

a Write expressions for the area of:

- **i** the spa
- **ii** paving

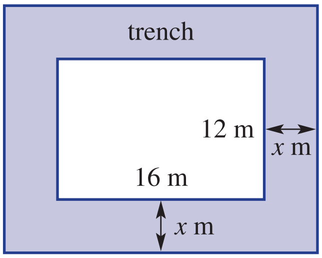
b Factorise your expression from part **a ii**.

c What will be the area of the paving if:

- **i** $x = 2$?
- **ii** $x = 4$?

d What value of x makes the paving area equal to 75 m^2?

2 A zoo enclosure for a rare tiger is rectangular in shape and include a trench of width x m all the way around it to ensure that the tiger doesn't get far if it tries to escape. The dimensions are as shown.



a Write an expression in terms of x for:

- **i** the length of the enclosure
- **ii** the breadth of the enclosure

b Use your answers from part **a** to find the total area of the enclosure, in expanded form.

c Hence, find an expression for the area of the trench alone.

d Zoo restrictions state that the trench must have an area of at least 128 m^2. Find the minimum width of the trench.

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Chapter 6: Linear relationships

Multiple-choice questions

1 If a straight line has a gradient of −3 and a y-intercept of 5, its equation is:

A $y = 5$ **B** $y = 3x + 5$ **C** $y = 5x - 3$ **D** $y = -3x + 5$ **E** $m = -3$

2 The gradient of the line joining (0, 6) and (2, −4) is:

A −2 **B** 6 **C** 5 **D** $\frac{1}{5}$ **E** −5

3 The midpoint of the line segment between (−3, 8) and (7, 2) has coordinates:

A (4, 10) **B** (2, 5) **C** (2.5, 4.5) **D** (0.5, 9) **E** (−5, 3)

4 The equation and gradient of the vertical line through the point (1, 3) are:

A $x = 1$; gradient undefined **B** $x = 1$; gradient zero
C $y = 3$; gradient positive **D** $y = 3$; gradient negative
E $y = 3$; gradient undefined

5 A landscape company charges $80 delivery plus $73 per cubic metre of soil. If $$C$ is the cost of n cubic metres of soil, then:

A $C = 80n + 73$ **B** $C = 73n - 80$ **C** $n = 73C + 80$
D $C = 73n + 80$ **E** $C = 80n - 73$

Short-answer questions

1 This distance–time graph shows the journey of a cyclist from home to a location and back again.

a How many km had the cyclist travelled after:

i 1 hour? **ii** 1.5 hours? **iii** 3 hours?

b Calculate the cyclist’s speed over the first 2 hours.

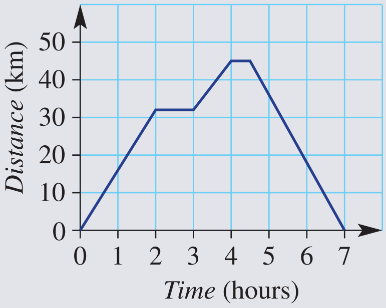
c What was the total time in rest breaks?

d What was the cyclist’s greatest distance from home?

e How long did the return trip take?

f Calculate the cyclist’s speed for the return journey.

g What was the total distance cycled?

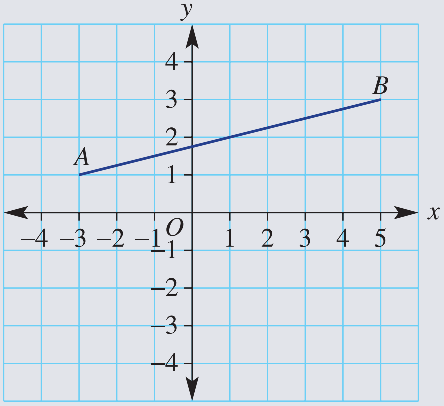


2 Copy and complete this table for the rule $y = 2x - 1$, then sketch its graph.

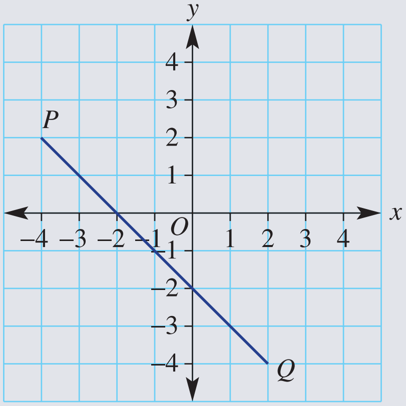
x	−2	−1	0	1	2	3
y						

3 For each of the graphs below, find the midpoint of the line segment.

a



b



4 Plot and join each pair of points and for the line segment joining these points, find:

i its gradient, m

ii its length (as a square root)

a $A(3, 2)$ and $B(5, 6)$

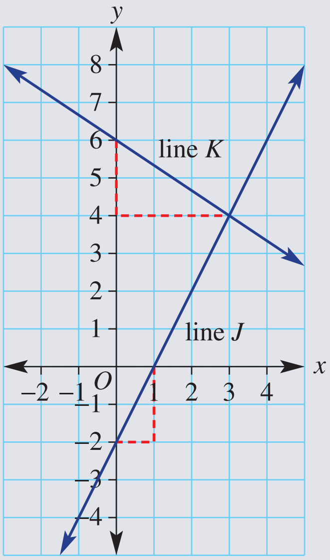
b $K(1, -3)$ and $L(-2, 6)$

c $P(3, 4)$ and $Q(-1, 9)$

d $R(-4, 2)$ and $M(1, 10)$

5 **a** For each of the lines J and K graphed here, write the equation of the line in the form $y = mx + b$.

b State the coordinates of the point of intersection of lines J and K.



6 Sketch each of these lines by considering the y-intercept and gradient.

a $y = -3x + 4$

b $y = \frac{2}{3}x + 1$

c $y = -2$

d $x = -3$

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7 Find the x- and y-intercepts for each of these lines and sketch. Label all axis intercepts.

a $y = 2x - 6$

b $2x - 3y = 12$

8 Find the equation of a line for each given description.

a A line passes through (0, 0) and is parallel to the line with rule $y = 3x - 8$.

b A line passes through (0, −2) and is parallel to the line with rule $y = -x + 3$.

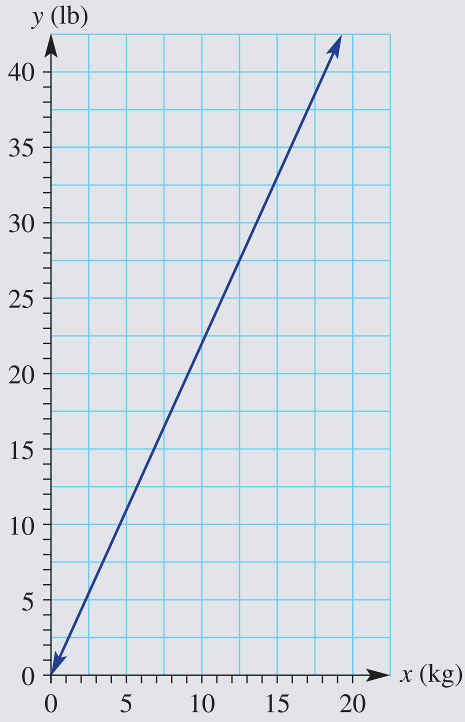
c A line passes through (0, 1) and is perpendicular to the line with rule $y = x - 4$.

d A line passes through (0, −5) and is perpendicular to the line with rule $y = -2x - 3$.

e A line passes through (1, 3) and is perpendicular to the line with rule $y = \frac{1}{2}x - 4$.

f A line passes through (5, −3) and is perpendicular to the line with rule $y = 5x + 2$.

9 This graph shows the direct proportional relationship between weight in kilograms (kg), and weight in pounds (lb).



a Use the graph to convert 6 kg to pounds (lb).

b Use the graph to convert 35 lb to kg.

c Find 20 lbs in kg and use this to find the conversion rate in lb/kg, to 1 decimal place.

d Determine the constant of proportionality k, to 1 decimal place.

e Write the direct proportion equation.

f Use this equation to find the number of lbs in 40 kg.

g Use this equation to find the number of kg in 143 lbs.

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Extended-response question

1 You have a \$100 gift voucher for downloading movies from the internet. Each movie costs \$2.40. After downloading n movies you have a balance of \$$B$ on your voucher.

- a Write a rule for the balance, B, on your voucher in terms of n.
- b Use your rule to find:
  - i the balance on the voucher after 10 movies are downloaded
  - ii the number of movies bought that will leave a balance of \$28
- c Copy and complete this table.

Number of movies (n)	0	5	10	15	20
Balance (B)					

- d Sketch a graph of B versus n, using the values in the table above.
- e What is the maximum number of movies you could buy and how much would be left on your voucher?

Chapter 7: Properties of geometrical figures

Multiple-choice questions

1 If two lines are parallel, then co-interior angles will:

A be equal	B sum to 90°	C sum to 180°
D sum to 360°	E sum to 270°	

2 The sum of the internal angles of a hexagon is:

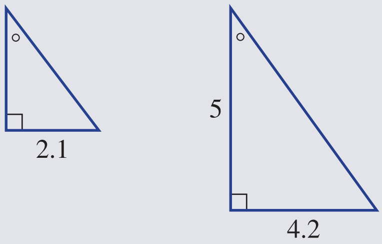
A 360°	B 540°	C 1080°	D 900°	E 720°

3 Which of the following is not a test for congruent triangles?

A SSS	B SAS	C AAA	D AAS	E RHS

4 The scale factor for these similar triangles is:

A 2	B 4	C 5	D 0.1	E 0.4



5 The length ratio for two similar solid objects is 2 : 3. The volume ratio is:

A 16 : 81	B 2 : 3	C 4 : 9	D 8 : 27	E 1 : 5

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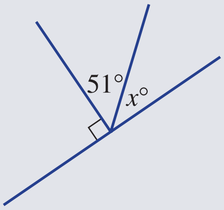
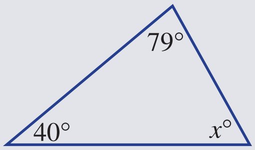
Short-answer questions

1 Find the value of x in these diagrams.

a



b



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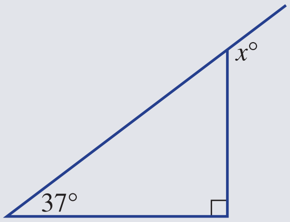

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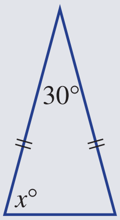

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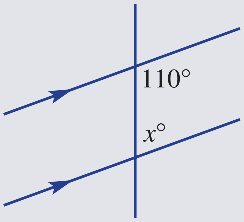

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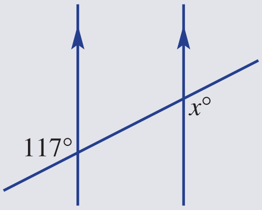

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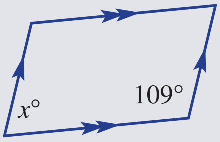

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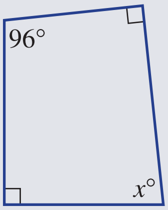

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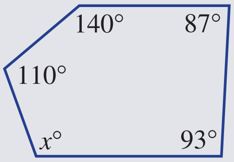

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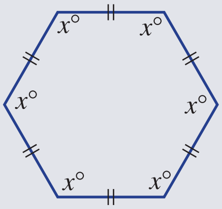

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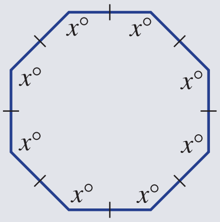

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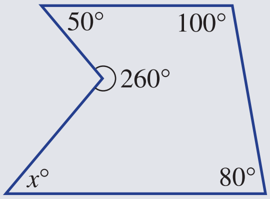
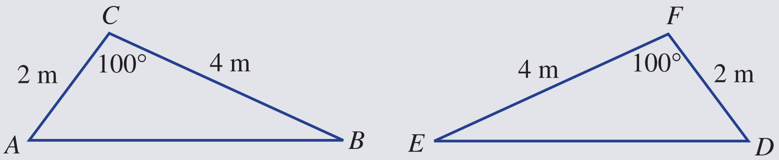


2 Write a congruence statement and the test to prove congruence in these pairs of triangles.

a



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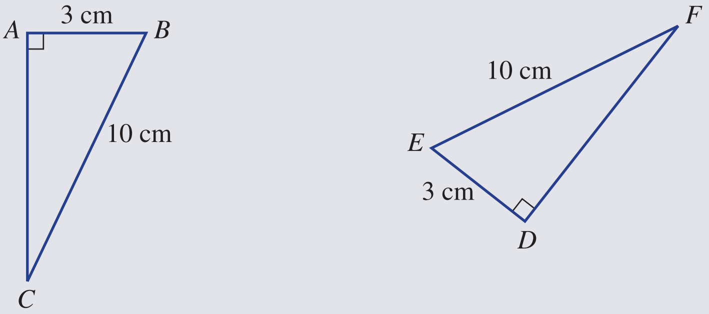

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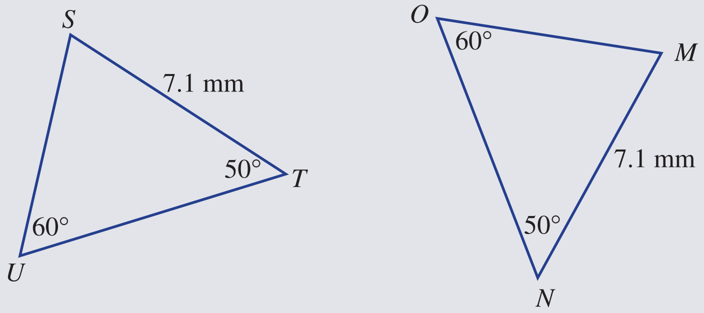

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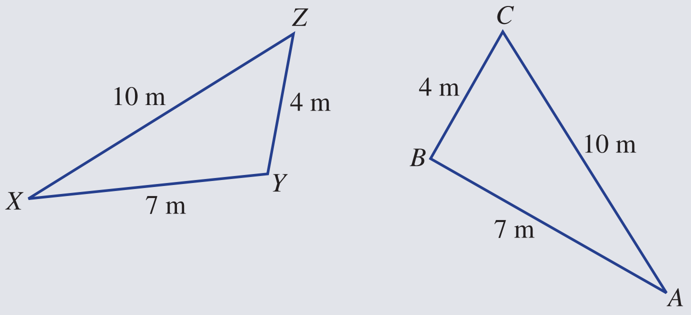
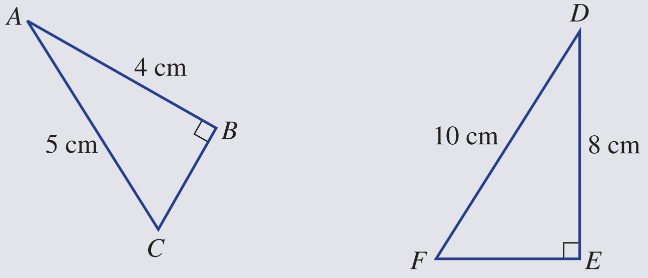


3 Decide whether or not the pairs of triangles are similar.

a



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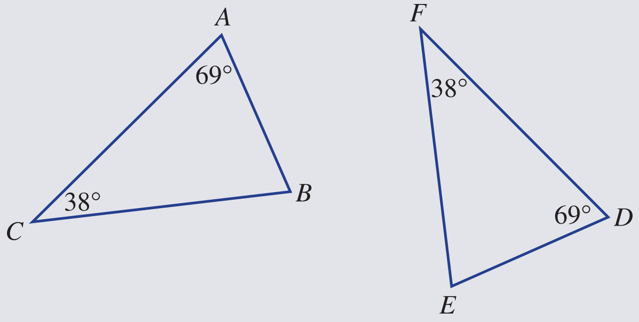

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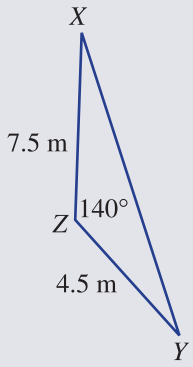

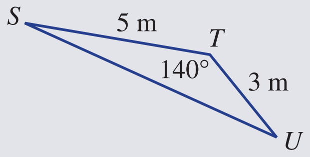

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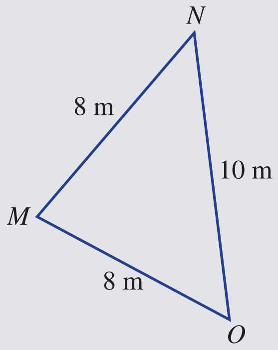
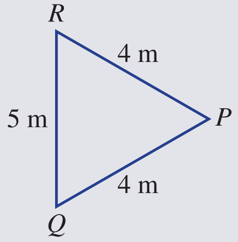
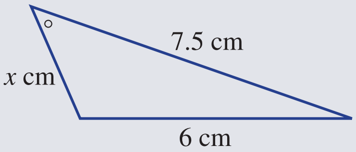
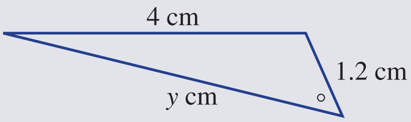




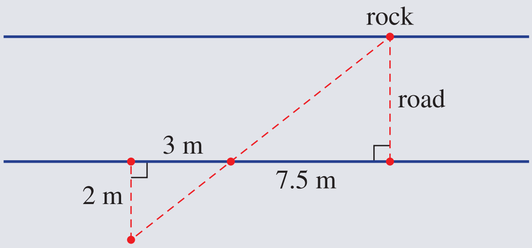
4 The given pair of triangles are known to be similar. Find the value of *x* and *y*.





Extended-response question

1 A chicken wants to know the distance across the road without having to cross it. The chicken places four pebbles in various positions on its own side of the road, as shown. There is a rock on the other side of the road aligned with one of the pebbles.



a What reason would be given to explain why the two triangles are similar?

b Find the scale factor.

c What is the distance across the road?

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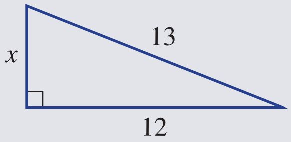
Chapter 8: Right-angled triangles

Multiple-choice questions

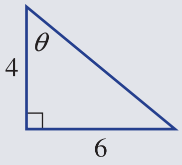
1 The value of x in the triangle shown is:

A 1 **B** 11 **C** 4
D 10 **E** 5



2 In which of the following triangles does $\cos\theta = \frac{2}{3}$?

A



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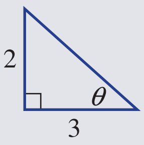
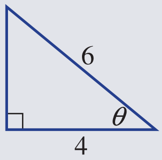
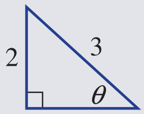


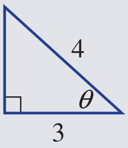
C



D



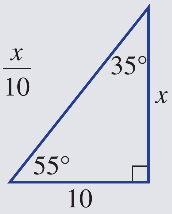
E



3 Choose the correct trigonometric statement for the diagram shown.

A $\tan 55° = \frac{x}{10}$ **B** $\tan 35° = \frac{x}{10}$ **C** $\sin 55° = \frac{x}{10}$

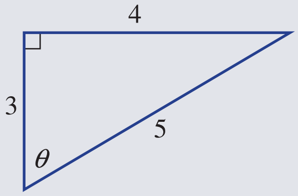
D $\sin 35° = \frac{x}{10}$ **E** $\cos 35° = \frac{x}{10}$



4 For the triangle shown, $\sin\theta$ is equal to:

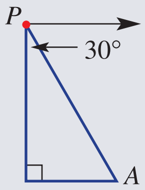
A $\frac{3}{5}$ **B** $\frac{4}{5}$ **C** $\frac{5}{3}$

D $\frac{3}{4}$ **E** $\frac{4}{3}$

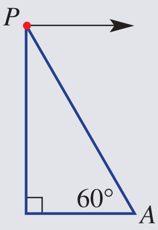


5 In which diagram is the angle of depression of A from P equal to 30°?

A



B



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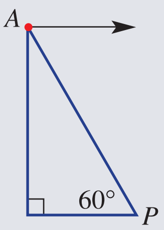
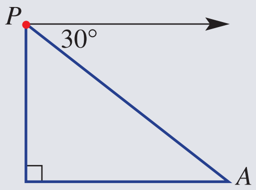
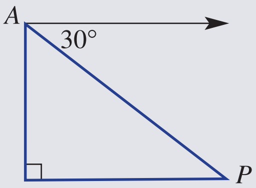


D



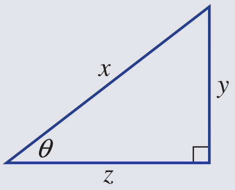
E



Short-answer questions

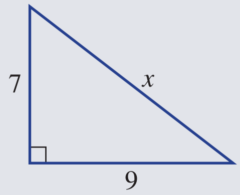
1 Use the triangle shown to help you write a fraction for:

a sin θ **b** cos θ **c** tan θ



2 Find the value of each pronumeral, correct to 1 decimal place.

a



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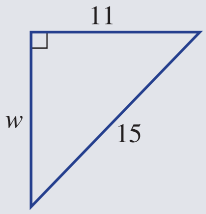

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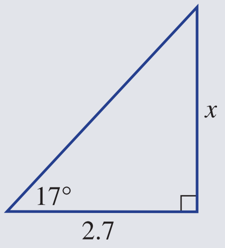

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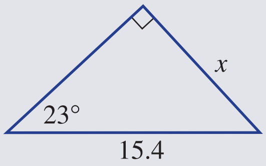

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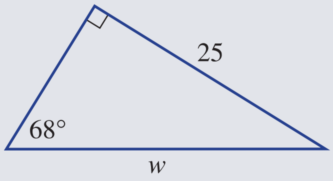

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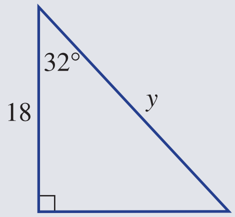
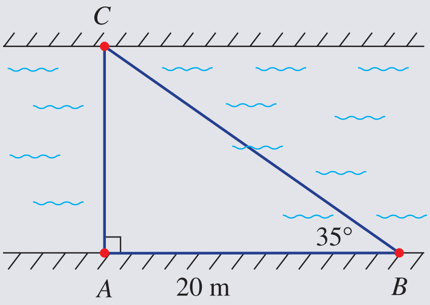
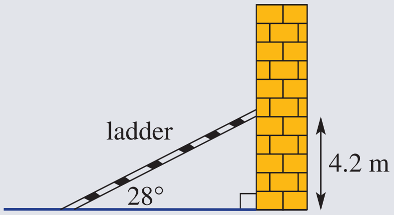


3 Kara wants to measure the breadth of a river. She places two markers, *A* and *B*, 20 m apart along one side. *C* is a point directly opposite marker *A*. Kara measures angle *ABC* as 35°. How broad is the river, to the nearest metre?



4 A ladder is inclined at an angle of 28° to the ground. If the ladder reaches 4.2 m up the wall, what is the length of the ladder, correct to 2 decimal places?



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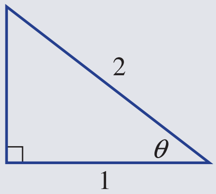
5 Find the angle θ in the following triangles, correct to the nearest degree.

a



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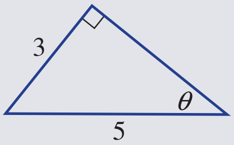

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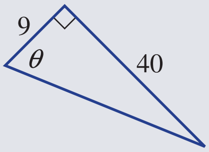
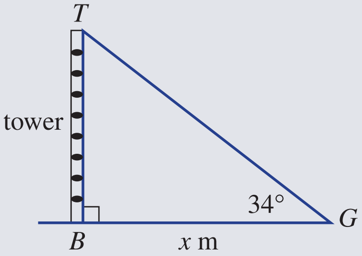
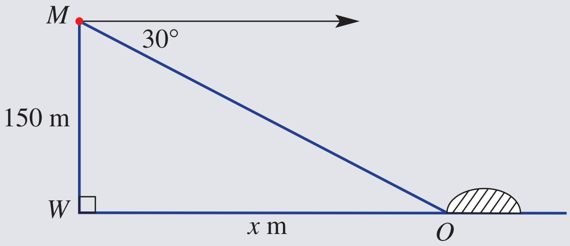


6 Geoff measures the angle of elevation to the top of a 120 m tower to be 34°. How many metres is Geoff from the base of the tower? Round your answer to 1 decimal place.



7 Malcolm is sitting on top of a bridge 150 m above the water level of the river. He notices an object floating on the river some distance away. If the angle of depression to the object is thought to be 30°, how many metres (x) from the bridge is the object? Round your answer to 1 decimal place.



Extended-response question

1 A plane flies from the airport on a bearing of 136° for 450 km.

- **a** Draw a diagram showing the plane's flight.
- **b** How far east of the airport is the plane? Round your answer to 1 decimal place.
- **c** How far south of the airport is the plane? Round your answer to 1 decimal place.
- **d** What is the bearing of the airport from the plane, correct to the nearest degree?

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Chapter 9: Equations, formulas and inequalities

Multiple-choice questions

1 Which of the following is *not* an equation?

A $x - 3 = 5$ **B** $2x + 4 = 5x - 11$ **C** $y + 7x - 4$

D $y = 3x - 5$ **E** $y = 8$

2 A number is decreased by 8 and then doubled. The result is equal to 24. This can be written as:

A $2x - 8 = 24$ **B** $x - 8 \times 2 = 24$ **C** $x - 8 = 2 \times 24$

D $2(x - 8) = 24$ **E** $\dfrac{x-8}{2} = 24$

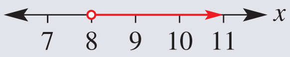
3 The solution to $\dfrac{x-9}{3} = 6$ is:

A $x = 27$ **B** $x = 45$ **C** $x = 9$ **D** $x = 11$ **E** $x = 3$

4 The solution to $3(x - 1) = 5x + 7$ is:

A $x = -4$ **B** $x = -5$ **C** $x = 5$ **D** $x = 3$ **E** $x = 1$

5 The inequality shown on the number line below is:



A $x < 8$ **B** $x \geq 8$ **C** $x \leq 8$ **D** $x < 11$ **E** $x > 8$

Short-answer questions

1 Solve the following equations.

a $2p + 3 = 7$ **b** $3a - 10 = 2$ **c** $\dfrac{x}{2} + 3 = 9$ **d** $3 = \dfrac{x-8}{4}$

2 Solve the following equations.

a $2(x - 4) = 8$ **b** $3(k - 2) + 4k = 15$

c $m + 5 = 3m - 13$ **d** $\dfrac{3x+1}{2} = 8$

e $\dfrac{3a-2}{7} = -2$ **f** $4x + 7 + 3x - 12 = 5x + 3$

3 For each of the following statements, write an equation and then solve it for the pronumeral.

a If 5 is subtracted from x, the result is 8.

b If 8 is added to the product of 4 and x, the result is 20.

c When 6 less than 3 lots of x is doubled, the result is 18.

4 Find the value of the unknown in each of the following formulas.

a $A = \dfrac{1}{2}bh$, find b when $A = 120$ and $h = 24$.

b For $I = PRN$, find P when $I = 80$, $R = 0.05$ and $N = 4$.

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5 Solve each of the following inequalities and graph the solution on a number line.

a $\frac{x}{3} \le 2$ **b** $3x - 2 > 4$ **c** $-3x \ge 12$ **d** $1 - 2x > 9$

6 Find the point of intersection (x, y) of each pair of equations below by plotting an accurate graph. First draw x- and y-axes each labelled from -5 to 5.

a $x = 3, y = 2$

b $y = 2x - 4$ and $3x + 2y = 6$

7 Solve the following pairs of simultaneous equations by using the substitution method; i.e. find the point of intersection.

a $y = 2x$
$x + y = 3$

b $x + y = 12$
$y = x + 6$

c $y = 3 - x$
$3x + 2y = 5$

8 Solve the following pairs of simultaneous equations by using the elimination method; i.e. find the point of intersection.

a $x + 2y = 3$
$-x + 3y = 2$

b $3x + y = 10$
$x + y = 6$

c $2x - 3y = 3$
$3x - 2y = 7$

9 Oliver is older than Ruby. The sum of their ages is 45 years and the difference of their ages is 7 years.

a Define pronumerals to represent each person's age.

b Set up a pair of simultaneous equations based on the given information.

c Solve the simultaneous equations to find Oliver and Ruby's ages.

Extended-response question

1 Ishan and Mia normally had an electricity bill of \$200 per month.

Now that they have installed solar panels (which cost \$6000 including installation), the solar energy has provided for all their power usage with some left over. Their excess power is sold to the town's electricity supplier. On average, they receive a cheque for \$50 per month for the sale of this solar-generated power.

a Copy and complete this table, which compares the total cost of normal town electricity to solar power.

Number of months, n	0	6	12	18	24	30	36	42	48
Total cost of electricity (at \$200 per month), E	0								
Total cost of solar power (reducing by \$50 per month), S	\$6000								

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b Draw a graph of the information in your table.

c On the graph, show where the total cost of solar power is the same as the total cost of electricity for that period of time. State the value of n and the cost.

d Write an equation for E (total cost of electricity) in terms of n and another equation for S (total cost of solar power) in terms of n.

e Solve the equations in part **d** for n, when $E = S$ (i.e. when the total cost of each power supply is equal).

f After 4 years, how much money has been saved by using solar power?

g Suppose that, in a wet climate, the cheque for excess power sold to the town supply was reduced to \$25 per month. Using equations, find how many months it takes for the total costs to be equal. (Round your answer to the nearest month.)

Chapter 10: Quadratic expressions, quadratic equations and non-linear relationships

Multiple-choice questions

1 $-x(x - 1) + 2x^2$ simplifies to:

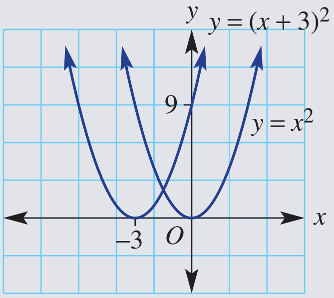
A $x^2 - 1$ **B** $x^2 + x$ **C** $3x^2 + 1$

D $3x^2 - x$ **E** $3x^2 + 3$

2 Compared to the graph of $y = x^2$, the graph of $y = (x + 3)^2$ is:

A 3 units down **B** 3 units up **C** 3 units left

D in the same place **E** 3 units right



3 The solutions to $(2x - 1)(x + 3) = 0$ are:

A $x = -\frac{1}{2}, x = -3$

B $x = 2, x = 3$

C $x = 2, x = -3$

D $x = \frac{1}{2}, x = 3$

E $x = \frac{1}{2}, x = -3$

4 The radius of the circle with equation $x^2 + y^2 = 25$ is:

A 5 **B** 25 **C** -5

D 0 **E** 1

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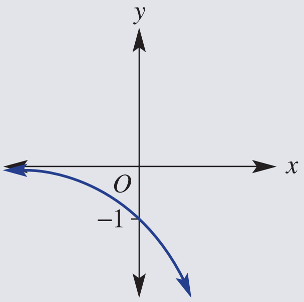
5 The graph of $y = 2^x$ could be:

A



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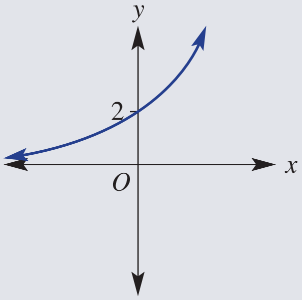

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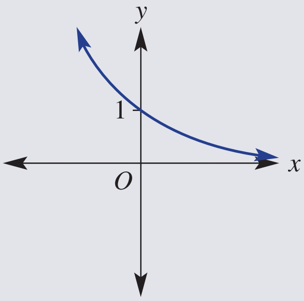

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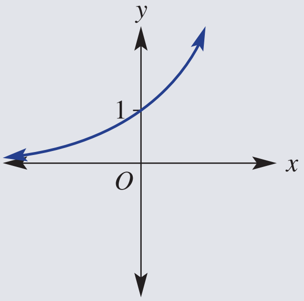
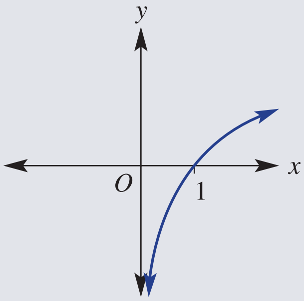


E



Short-answer questions

1 Expand the following expressions.

a	$-2(x - 1)$	**b**	$(x + 2)(x - 3)$
c	$(2x - 7)(x + 3)$	**d**	$(x + 2)(x - 2)$
e	$(x - 3)^2$	**f**	$(2x + 1)^2$

2 Factorise these expressions.

a	$3x - 12$	**b**	$-2x - x^2$
c	$x^2 - 25$	**d**	$9x^2 - 100$
e	$x^2 + 7x + 12$	**f**	$x^2 - x - 6$
g	$x^2 + 2x - 8$	**h**	$x^2 - 8x + 16$
i	$x^2 + 6x + 9$		

3 Solve these equations.

a $x(x - 3) = 0$

b $x^2 + 2x = 0$

c $x^2 - 4 = 0$

d $4x^2 - 9 = 0$

e $(x - 3)(2x - 1) = 0$

f $x^2 - x - 20 = 0$

g $x^2 + 10x + 21 = 0$

h $x^2 + 8x + 16 = 0$

i $x^2 - 14x + 49 = 0$

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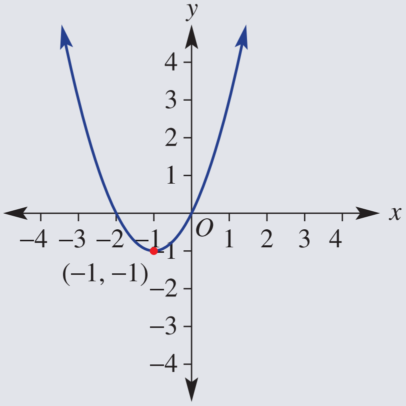
4 State the following features of the quadratic graph shown.

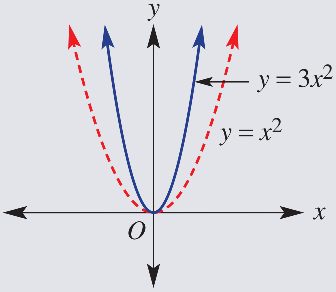
- **a** turning point and whether it is a minimum or a maximum
- **b** equation of the axis of symmetry
- **c** x-intercepts
- **d** y-intercept



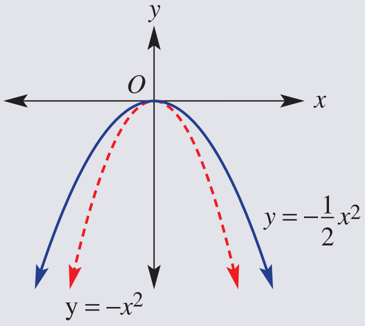
5 Copy and complete the table for these parabolas.

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 3x^2$					
b	$y = -\frac{1}{2}x^2$					
c	$y = (x + 2)^2$					
d	$y = x^2 - 3$					

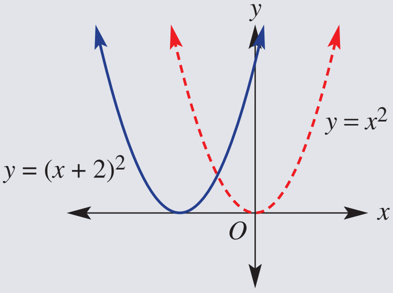
a



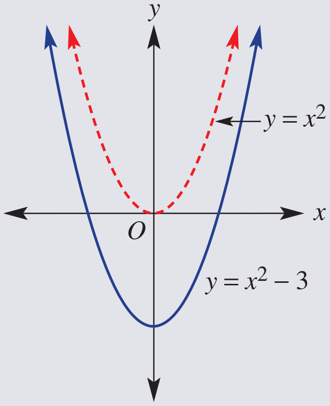
b



c



d



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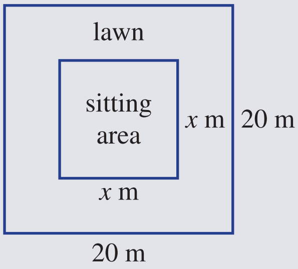
6 Solve the following equations for x, finding all possible solutions in exact form.

a $x^2 = 64$
b $x^2 = -25$
c $2x^2 = 32$
d $\frac{x^2}{3} = 5$
e $x^2 - 17 = 0$
f $x^2 + 5 = 0$
g $2x^2 - 3 = 7, x > 0$
h $15 - x^2 = 12, x < 0$

Extended-response question

1 In a garden, a square-shaped sitting area paved with stone is to be placed in the centre of a square area of lawn that is 20 m by 20 m.

- **a** Write expressions for the area of:
  - **i** the sitting area
  - **ii** the remaining lawn
- **b** Factorise your expression from part **a ii**.
- **c** What will be the lawn area if:
  - **i** $x = 4$?
  - **ii** $x = 9$?
- **d** What value of x makes the lawn area equal to:
  - **i** 175 m^2?
  - **ii** 75% of the total area?



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Chapter 1

Pre-test

1 a $99.62 b $1612 c $2742
d $84.51 e $1683.85
2 a 0.5 b 0.25 c 0.2 d 0.28 e $0.\dot{3}$
3 a $\frac{50}{100}$ b $\frac{75}{100}$ c $\frac{20}{100}$ d $\frac{68}{100}$ e $\frac{45}{100}$
4 a 16.79 b 7.35 c 45.34 d 6.84 e 102.90
5 a $4519.28 b $50 509.20 c $29 572
d $54 878 e $97 903.46
6 a $65 312 b $187 200 c $49 686 d $35 800
7 a $40 b $250 c $2
d $211 e $2.56 f $750
8 a $20 b $300 c $64
9 a $18 b $323 c $264
d $112 e $57.92
10 a $50 b $56 c $550

Exercise 1A

1 a $\frac{40}{100}$ b $\frac{85}{100}$ c $\frac{98}{100}$ d $\frac{28}{100}$ e $\frac{90}{100}$
2 a 100 b 90 c 60
3 a $0.75 b $80 c $49
d $501 e $103 f $1.20
g $37.50 h $400 i $4.50
4 a 50% b 20% c 25% d 10%
e 1% f 28% g 30% h 75%
i $62\frac{1}{2}$% j 76% k 99% l 94%
5 a 17% b 73% c 48% d 9%
e 6% f 13% g 113% h 101%
i 80% j 90% k 99% l 17.5%
6 a $\frac{71}{100}$ b $\frac{4}{5}$ c $\frac{1}{4}$ d $\frac{11}{20}$
e $\frac{2}{5}$ f $\frac{22}{25}$ g $\frac{3}{20}$ h $\frac{33}{200}$
i $\frac{7}{40}$ j $\frac{9}{400}$ k $\frac{21}{400}$ l $\frac{21}{40}$
7 a 0.61 b 0.83 c 0.75 d 0.45
e 0.09 f 0.9 g 0.5 h 0.165
i 0.073 j 2 k 4.3 l 0.005
8 a $25 b $150 c $60
d $90 e $21.60 f 344 grams
g $50.40 h $107.80 i 350 m
9 a $\frac{15}{300} = \frac{1}{20}$ b 5%
10 68 kg
11 47.52 minutes
12 16.67%
13 $11\frac{1}{9}$%
14 $205.97
15 a 1.5% b i 32.0% c 93°
2.2% ii 25.8%
1.6% iii 10.4%
0.6%
0.8%
0.9%
0.2%
2.1%
1.6%

Exercise 1B

1 a 110% b 120% c 150%
d 102% e 118%
2 a 95% b 70% c 85%
d 50% e 83%
3 a *P*:$5 b *P*:$2.50 c L: $16
d *P*:$11 e L: $2.20
4 a $94.50 b $440 c $66 d $529.20
e $56 f $7210 g $56.43 h $3.60
5 a $1425 b $360 c $376 d $68
e $412.50 f $47.03 g $101.58 h $35.80
6

a	$6	60%
b	$60	25%
c	$3	20%
d	$7.50	3%
e	$2325	75%
f	$0.99	18%

7 a $52.25 b $261.25
8 a $1225 b $24.50
9 a $120, $12, $132 b $50, $5, $55
c $80, $8, $88 d $90, $9, $99
e $145, $14.50, $159.50
10 a $67.96 b $11.99
11 a $2140.25 b $305.75
12 a $221.40 b $147.60
13 a $84.13 b $94.87
14 $104.71
15 a $106.15 b $37.15
16 a $2.20 b 122.22%
c $66 d 122.22%
17 a $13 b $6.30
c $69.30 d 38.6%
18 a $1952.24 b $211.24
c 12.13% d $57.03

Exercise 1C

1 a $15 b $22.50 c $30 d $29 640
2 $5600 a month by $200
3 $36 842

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4

	Gross income	Net income
a	$570	$415
b	$984	$764
c	$604.90	$304.90
d	$3430	$2920
e	$930.15	$746.15

5 **a** $1186.24 **b** $30842.24 **c** $2570.19

6 $3437.50

7 **a** $1960 **b** $2460

8 **a** $519.23 **b** $150 **c** $669.23 **d** $38425

9 **a** $1057.50 **b** $157.50

10 $3760

11 3%

12 $365.70

13 $437.50

14 $2000

15 **a** Kuger Incorporated
b Mathsville Credit Union, 00754031
c $72454 **d** fortnightly
e $4420 **f** $26.45 **g** $600.60
h $16016 tax, net = $49793.90

Exercise 1D

1 Taxable income = gross income minus deductions

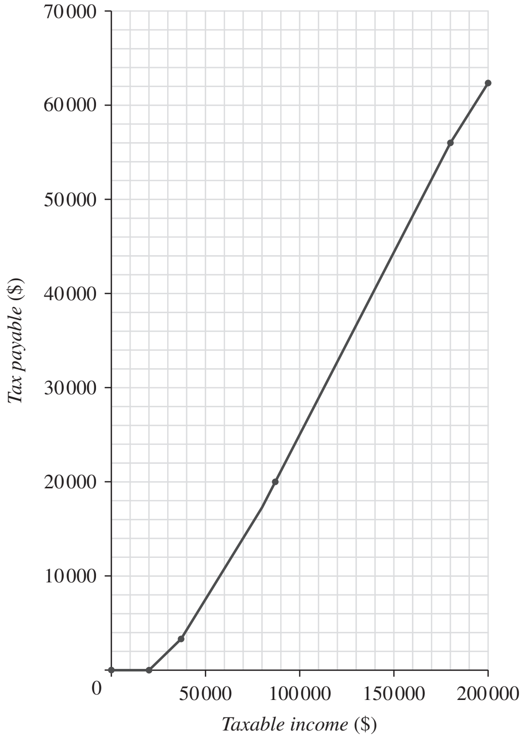
2 false

3 Anything from $0 to $18200

4 37c

5 **a** $2242 **b** $11047 **c** $43132 **d** $63232

6



7 $6172

8 **a** $65625 **b** $12875.13
c $1312.50 **d** $14187.63
e 21.6% (to 1 dp.)
f Not enough paid; owes $1117.63

9 $87500

10 $6595.06

11 $95000

12 Gross income is the total income earned before tax is deducted. Taxable income is found by subtracting tax deductions from gross income.

13 If a person pays too much tax during the year they will receive a tax refund. If they do not pay enough tax during the year they will have a tax liability to pay.

14 They only pay 45 cents for every dollar over $180000.

15 **a** The tax-free threshold has been increased from $6000 to $18200. In the second tax bracket, the rate has changed from 15c to 19c. In the third tax bracket, the rate has changed from 30c to 32.5c.

b

	2011/ 2012	2012/ 2013	
Ali	$0	$0	No change
Xi	$1350	$0	$1350 less tax to pay
Charlotte	$3600	$2242	$1358 less tax to pay
Diego	$8550	$7797	$753 less tax to pay

16

	Resident	Non-resident	
Ali	$0	$1625	Non-residents pay a lot more tax than residents.
Xi	$0	$4875	
Charlotte	$2242	$9750	
Diego	$7797	$16250	

17 **a** Answers will vary.
b **i** $17547
ii $32.50, so this means that the $100 donation really only cost you $67.50.

Exercise 1E

1 $124.28

2 $2162

3 $47

4 **a** $13750
b $11250
c No, only $48 per week

5 $60.88

6 **a** $33068 **b** 73.5%

7 **a** $7756 **b** $3878 **c** $149.15

8 **a** $82708 **b** $1590.54 **c** 24%

9 **a** 13.43% **b** 29.56 L

10 **a** $342.55 **b** $2137.51 **c** 11.68%

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11 a

food	$86.40
recreation	$43.20
transport	$56.16
savings	$86.40
taxation	$108.00
clothing	$51.84

b $56.16 **c** 30% **d** $673.92 **e** 10%

12 200 tea bags

13 daily

14 a Mon–Thurs – $87

Fri–Sat – $93.50

weekly – $71.43

b weekly

15 a 200 mL bottle $0.011 75, 500 mL bottle $0.01 048

b 500 mL bottle **c** $2.10 **d** $0.25

e cost of packaging

16 a $248 **b** $240, 6 containers

Exercise 1F

1 a 1 **b** 6 **c** 52 **d** 4 **e** 3 **f** 30

2 a $120 **b** $420 **c** $30

3 a $420 **b** $840 **c** $35

4 a $140 **b** $420 **c** $192.50

d $46.88 **e** 3% p.a **f** 4% p.a.

5 a $6650 **b** $184.72 per month

6 a $5192.25 **b** $16 692.25 **c** $198.72

7 a $7600 **b** $17 600 **c** $366.67

8 a $228 **b** $684 **c** $4684

9 $1008

10 16%

11 12.5 years

12 $66 667

13 $7500

14 a $1250, $2500 **b** $1968.75, $1920.00

c $220.31, $331.11 **d** Answers will vary.

Exercise 1G

1 a $50 **b** $550 **c** $55

d $605 **e** $605

2 a $1102.50 **b** $1102.50

c $1157.63 **d** $1157.63

3 a $700(1.08)^2$ **b** $1000(1.15)^6$ **c** $850(1.06)^4$

4 a 6, 0.03 **b** 60, 0.01 **c** 52, 0.00173

d 14, 0.02625 **e** 32, 0.0375 **f** 120, 0.008

5 a

2	4200	210	4410
3	4410	220.50	4630.50
4	4630.50	231.53	4862.03
5	4862.03	243.10	5105.13

b

1	4000	200	3800
2	3800	190	3610
3	3610	180.5	3429.5
4	3429.5	171.48	3258.03
5	3258.03	162.90	3095.13

6 a $5105.13 **b** $11 946.33

c $13 652.22 **d** $9550.63

7 a $106 000 **b** $112 360

c $119 101.60 **d** $133 822.56

e $179 084.77 **f** $239 655.82

8 a $2254.32 **b** $87 960.39 **c** $1461.53

d $789.84 **e** $591.63

9 $8874.11

10 Every year the car has an opening value of A. During the year it loses 15% of A. A is more than 15% of A. Therefore, A – 15% of A will not be zero.

11 a i $3239.42 **ii** $3348.15 **iii** $3446.15

iv $3461.88 **v** $3465.96

b $226.54

12 a $3000

b twice

c 8% p.a.

d $1440.73

13 5.3% compounded bi-annually

14 a i approx. 6 years **ii** approx. 12 years

iii approx. 9 years **iv** approx. 5 years

v approx. 7 years **vi** approx. 4 years

b Same answer as part **a**.

c yes

Exercise 1H

1 a $2640 **b** $3960 **c** $13 200

2 $124.50

3 a $1.20 **b** $1.71 **c** $3 **d** $0.09

4 a $18 600 **b** $8600

5 a $5580 **b** $80

6 a 360 **b** $624 960 **c** $374 960

7 a $2550 **b** $10 200 **c** $10 620

d $13 170 **e** $420

8 a $4.50 **b** $1.26

9 a

May	June	July	August	September	October
$2.40	$3.00	$0.12	$5.00	$2.08	$0.73

b $13.33

10 a i $0 **ii** $0 **iii** $7500

b $6375

c $1125

11 a i $5250 **ii** $20 250 **iii** $281.25

b i $8400 **ii** $32 400 **iii** $270

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12 a

Date	Deposit	Withdrawal	Balance
1 May			$3010
3 May	$490		$3500
5 May		$2300	$1200
17 May	$490		$1690
18 May		$150	$1540
20 May		$50	$1490
25 May		$218	$1272
31 May	$490		$1762

b $4.90 **c** $1759.55 **d** wages

13 a i $73.13 **ii** $69.72 **iii** $75.17

b $1700 over 3 years

14 a $403.80

b $393.80

c 24 cents a day

15 a $98 822.90 **b** $0.23 **c** $8.00

d $2400 **e** $378.50 **f** $246 025

Exercise 1I

1 B

2 $P = 750$, $R = 0.075$, $n = 5$

3 $I = 225 \quad P = 300 \quad R = 0.03 \quad N = 25$

4 a i $7146.10 **ii** $6955.64 **iii** $6858.57

iv $7260 **v** $7916.37

b $6000 at 5.7% p.a. for 5 years

5 a i $7080 **ii** $7080 **iii** $7428

iv $7200 **v** $7710

b 6000 at 5.7% p.a., for 5 years

6 a i I $240, $240 **II** $480, $494.40

III $1200, $1352.90 **IV** $2400, $3163.39

ii I $240, $243.60 **II** $480, $502.04

III $1200, $1375.67 **IV** $2400, $3224.44

iii I $240, $246.71 **II** $480, $508.64

III $1200, $1395.40 **IV** $2400, $3277.59

b compound interest

c simple interest

7 a

Principal	Rate	Overall time	Interest	Amount
$7000	5%	5 years	$1750	$8750
$7000	10%	5 years	$3500	$10 500
$3300	10%	3 years	$990	$4290
$8000	10%	3 years	$2400	$10 400
$9000	8%	2 years	$1440	$10 440
$18 000	8%	2 years	$2880	$20 880

b i interest is doubled

ii no change

iii interest is doubled

8

Principal	Rate	Period	Overall time	Interest	Amount
$7000	4.56%	annually	5 years	$1750	$8750
$7000	8.45%	annually	5 years	$3500	$10 500
$9000	8%	fortnightly	2 years	$1559.00	$10 559.00
$18 000	8%	fortnightly	2 years	$3118.01	$21 118.01

9 a 8.45% **b** 8.19% **c** 8.12%

The more often interest is calculated, the lower the required rate.

10 a i 4.2% **ii** 8.7%

b It increases by more than this factor

Puzzles and games

1 commission, fortnightly, overtime, piecework, annual, gross, net, monthly, casual, salary

2 You take away his credit card

3 7 years 4 months

4 59 games

Multiple-choice questions

1 E **2** D **3** D **4** C **5** B

6 E **7** B **8** B **9** C **10** E

Short-answer questions

1 $1395 **2** $1084.16 **3** $4557

4 a $11.40 **b** $3.80

5 $4200 **6** $576.92

7 a $7400 **b** $616.67 **c** $142.31

8 a $287.32 **b** $43.10 **c** 10.79%

9 a $12 525 **b** approx. 37%

10 a $346.68 **b** $290.65

11 $7095.65

12 $35.55

13 a $1050 **b** $12 000 **c** $6050

14 a $1600 **b** $1166.67 **c** $624.32 **d** $1022.53

Extended-response questions

1 a $5624.32 **b** $624.32

c 4.16% **d** $636.36

2 a

Date	Deposit	Withdrawal	Balance
1st			217.63
7th		64.00	153.63
9th	140.00		293.63
11th		117.34	176.29
15th		0.51	175.78
20th	20.00	12.93	182.85
30th	140.00		322.85

b $153.63 **c** $0.08

Chapter 2

Pre-test

1 a circle **b** square **c** parallelogram
d triangle **e** rectangle **f** trapezium
g semicircle **h** rhombus
2 a 1000 **b** 100 **c** 10
d 1000 **e** 500 **f** 25
3 a 12 cm **b** 32 m **c** 5.9 mm
4 a 10 cm^2 **b** 70 m^2 **c** 36 km^2
5 a 4 cm^2 **b** 14 m^2 **c** 6 km^2
6 $C = 31.42$ m
$A = 78.54$ m^2

Exercise 2A

1 a 1000 **b** 10 **c** 100
2 a 100 **b** 10 000 **c** 1 000 000
3 a 1000 **b** 1 000 000 000 **c** 1 000 000
4 a millimetre **b** milligram **c** gigalitre
d millisecond **e** microsecond **f** nanosecond
5 a 43.2 mm **b** 0.327 km **c** 8.34 m
d 96 mm **e** 0.2975 km **f** 1.27 cm
6 a 7000 g **b** 7 km **c** 15 000 000 t
d 4000 W **e** 0.0089 Mt **f** 5×10^{-9} s
g 600 000 µ*g* **h** 10 min **i** 1 285 000 ms
j 0.00068 Mt **k** 4000 cm **l** 8×10^{9} bytes
m 8.5 s **n** 3 s **o** 9 g
7 a 300 000 mm^2 **b** 5000 cm^2 **c** 5 000 000 m^2
d 29 800 cm^2 **e** 53 700 mm^2 **f** 230 cm^2
8 a 2000 mm^3 **b** 200 000 cm^3 **c** 5.7 cm^3
d 15 000 000 m^3 **e** 0.0283 km^3 **f** 0.762 m^3
9 5500 m
10 a 23.4 m **b** 22 m
11 a 118 mm **b** 147.3 cm **c** 453.258 km
d 15.5 cm^2 **e** 3251 cm^2 **f** 3739 m^2
g 484 500 mm^3 **h** 537 300 m^3
12 21.5 cm
13 For a high level of accuracy
14 2 million
15 10.448 s
16 a 9.002×10^{6} B or 9002 kB
b 9.002 MB
c No, two separate emails will be needed.
17 a 1000 **b** 250
18 a 8.85 km **b** 4.5 feet **c** 26.67 cm
d 1.243 miles **e** 57 000 m^2 **f** 0.247 L
g 8200 mL **h** 5 500 000 mL **i** 1000 sq. feet
j 2000 L **k** 100 ha **l** 0.152 m^3

Exercise 2B

1 from 3.35 to under 3.45 (i.e. 3.43, 3.39 etc.)
2 a 347 cm **b** 3 m
3 6.65
4 a 1 cm **b** 0.1 mm **c** 1 m
d 0.1 kg **e** 0.1 g **f** 1 m
g 1 h **h** 0.01 m or 1 cm
i 0.01 km or 10 m **j** 0.001 km or 1 m
5 a 4.5 m to 5.5 m **b** 7.5 cm to 8.5 cm
c 77.5 mm to 78.5 mm **d** 4.5 ns to 5.5 ns
e 1.5 km to 2.5 km **f** 34.15 cm to 34.25 cm
g 3.85 kg to 3.95 kg **h** 19.35 kg to 19.45 kg
i 457.85 t to 457.95 t **j** 18.645 m to 18.655 m
k 7.875 km to 7.885 km **l** 5.045 s to 5.055 s
6 a 30 m **b** 145 g **c** 4.6 km
7 a 149.5 cm to 150.5 cm **b** 145 cm to 155 cm
c 149.95 cm to 150.05 cm
8 a 24.5 cm to 25.5 cm
b i 245 cm **ii** 255 cm
9 a 9.15 cm **b** 9.25 cm
c 36.6 cm to 37 cm
10 a If they all choose a different level of accuracy, then they will have different answers. Also, human error plays a part.
b Johan: nearest kg; Amy: nearest 100 g; Thomas: nearest 10 g.
c Yes; however, the more decimal places being considered then the more accurate that the measurement will be when used in further calculations, if they are required.
11 a distances between towns, cities airplane rides, length of major rivers
b house plans, plumbing plans and building, in general
c mixing chemicals, administering cough mixture to children, matching paint colours, paying for petrol
d filling a swimming pool, describing the fuel tank of a car or plane
12 a square:
i 5.3 cm **ii** 53 mm
rectangle:
i 6.5 cm by 4.7 cm **ii** 65 mm by 47 mm
triangle:
i 6 cm, 8 cm, 10 cm
ii 60 mm, 80 mm, 100 mm
b square: $P = 212$ mm, $A = 2809$ mm^2
rectangle: $P = 224$ mm, $A = 3055$ mm^2
triangle: $P = 240$ mm, $A = 2400$ mm^2
c Answers will vary. **d** Answers will vary

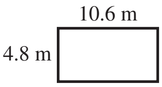
Exercise 2C

1 perimeter
2 a $x = 6$ **b** $x = 7.1$ **c** $x = 4.3$
3 a 12 cm **b** 23 m **c** 11 km
d 12 m **e** 19.2 cm **f** 10 m
4 a 6.7 cm **b** 65 mm **c** 18 m
d 810 m **e** 9.4 km **f** 220 cm

5 **a** $x = 4$ **b** $x = 2$ **c** $x = 6$

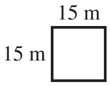
6 **a** $x = 3$ **b** $x = 8.8$ **c** $x = 0.1$

7 **a** **i**



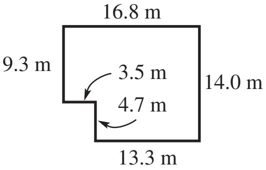
ii 30.8 m

b **i**



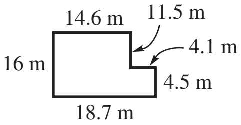
ii 60 m

c **i**



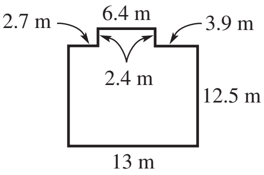
ii 61.6 m

d **i**



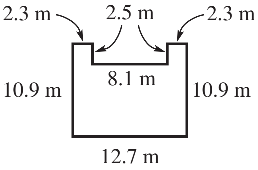
ii 69.4 m

e **i**



ii 55.8 m

f **i**



ii 52.2 m

8 20 m

9 15 cm

10 **a** $P = 4s$ **b** $P = 2l + 2b$ **c** $P = x + y + z$

d $P = a + 2b$ **e** $P = 4l$ **f** $P = 3s$

11 13 **12** 3

Exercise 2D

1 **a** $\frac{1}{2}$ **b** $\frac{1}{4}$ **c** $\frac{3}{4}$

2 **a** 8.6 m **b** 1.8 cm

3 **a** 18.85 m **b** 31.42 m **c** 31.42 km

d 113.10 cm **e** 61.07 mm **f** 3.36 km

4 **a** 1.6 cm **b** 9.4 cm **c** 3.1 cm

5 **a** 27.42 m **b** 16.28 cm **c** 6.71 mm

d 12.22 cm **e** 14.71 m **f** 59.70 cm

6 **a** 9.42 m **b** $423.90

7 **a** **i** 3.14 m **ii** 47.12 m

b 3.14 km

8 319 times

9 **a** 12.25 **b** 53.03 **c** 1.37

d 62.83 **e** 19.77 **f** 61.70

10 **a** $r = \frac{C}{2\pi}$

b **i** 5.57 cm **ii** 0.29 m **iii** 0.04 km

11 **a** 3.5 cm

b **i** 21.99 cm **ii** 65.97 cm **iii** 109.96 cm

c 12.73 cm

Exercise 2E

1 **a** E **b** B **c** F **d** C **e** D **f** A

2 **a** 2 cm **b** 4 m **c** 4.3 cm

d 4 km **e** 7.8 m **f** 10 cm

3 **a** 4 m^2 **b** 18 cm^2 **c** 11.76 m^2

d 21 m^2 **e** 22.5 mm^2 **f** 2 m^2

4 **a** 25 cm^2 **b** 54.6 m^2 **c** 1.82 km^2

d 0.03 mm^2 **e** 1.12 m^2 **f** 100 cm^2

5 **a** 0.96 m^2 **b** 9600 cm^2

6 27 m^2

7 **a** 13.6 m^2 **b** $149.60

8 **a** 7.56 m^2 **b** $491.40

9 1 and 24, 2 and 12, 3 and 8, 4 and 6

10 **a** 252.05 m^2 **b** 177.86 m^2

11 **a** $b = 2.88$ **b** $s = 14.35$ **c** $h = 1.44$

d $a = 1.05$ **e** $h = 1.87$ **f** $x = 8.89$

12 All answers $= 3$

Exercise 2F

1 E

2 C

3 **a** $\frac{1}{2}$ **b** $\frac{1}{4}$ **c** $\frac{1}{3}$

d $\frac{1}{12}$ **e** $\frac{7}{12}$ **f** $\frac{5}{6}$

4 **a** 50.27 cm^2 **b** 201.06 m^2 **c** 72.38 m^2

d 38.48 m^2 **e** 0.82 mm^2 **f** 124.69 km^2

5 **a** 39.27 m^2 **b** 4.91 m^2 **c** 84.82 m^2

d 13.09 m^2 **e** 69.81 cm^2 **f** 8.03 m^2

6 157.1 cm^2

7 **a** 14.28 cm^2 **b** 178.54 m^2 **c** 32.14 mm^2

8 43.24 m^2

9 **a** 34.8 cm^2 **b** 63.5 m^2 **c** 8.7 m^2

d 103.3 mm^2 **e** 578.5 km^2 **f** 5.0 m^2

10 **a** 20 **b** 565.49 cm^2

c 154.51 cm^2 **d** 5

Exercise 2G

1 **a** 6 **b** 3

2 **a** 35 cm^2 **b** 21 cm^2

c 12 cm^2 **d** 96 cm^2

3 **a** 90 cm^2 **b** 34 mm^2 **c** 46 m^2

4 **a** 360 m^2 **b** 168 m^2 **c** 1176 cm^2

5 **a** 8.64 cm^2 **b** 96 mm^2 **c** 836.6 m^2

6 384 cm^2

7 3880 cm^2

8 3520 cm^2

9 **a** 5.116 L **b** 10.232 L
10 **a** waterproof 13.76 L; smooth paint 22.86 L
b $553.46
11 **a** 105 cm^2 **b** 5 cm^2 **c** 16 m^2
12 Yes, only 5 L required.

Exercise 2H

1 **a** circle **b** $2\pi rh$
2 **a** **i** 4 m **ii** 7 m
b 25.13 m **c** 276.46 m^2
3 **a** 100.53 m^2 **b** 376.99 cm^2
c 1225.22 cm^2 **d** 74.64 mm^2
4 **a** 2557.3 cm^2 **b** 502.9 m^2
5 **a** 6.3 m^2 **b** 6283.2 cm^2
6 24.0 m^2
7 628.3 cm^2
8 75.4 m^2
9 **a** 173.9 cm^2 **b** 217.8 m^2
c 31.6 m^2 **d** 52.9 cm^2
10 **a** 25.13 m^2 **b** 251.33 m^2 **c** 6.28 m
d 159.15 times **e** 4000 m^2

Exercise 2I

1 **a** C **b** A **c** B
2 **a** 1000 **b** 1000
3 **a** 10 cm^3 **b** 9 m^2
4 **a** 240 m^3 **b** 480 cm^3 **c** 0.18 m^3
5 **a** 113.10 cm^3 **b** 19.63 m^3 **c** 4.83 mm^3
6 **a** 20 cm^2 **b** 90 cm^3
7 **a** 36 m^3 **b** 15 cm^3 **c** 0.572 mm^3
8 5890.49 cm^3
9 **a** 72 L **b** 2 L **c** 2 L
10 **a** 1583.36 m^3 **b** 30 km^3 **c** 196 cm^3
d 30 m^3 **e** 10 cm^3 **f** 2.15 m^3
11 **a** 25 cm^2 **b** 4 cm
12 **a** 17 150 cm^3 **b** 384.85 cm^3
c 35 **d** 3680.42 cm^3
13 **a** 83.3 m^3 **b** 1500 m^3 **c** 20.9 cm^3

Exercise 2J

1 **a** rectangular prism, cylinder
b triangular prism, cylinder
c rectangular prism, cube
2 **a** 5 m **b** 13 cm **c** 15 mm
3 **a** 288 m^2 **b** 510 cm^2 **c** 920 mm^2
4 **a** **i** $A = 171.40$ m^2
ii $V = 139.40$ m^3
b **i** $A = 976.99$ cm^2
ii $V = 1942.48$ cm^3
c **i** $A = 66.85$ cm^2
ii $V = 25.42$ cm^3
5 **a** 45.70 L **b** 3570.80 L
6 **a** 406 cm^2 **b** 326 cm^3
7 **a** **i** 16 m^2 **ii** 2 L
b **i** 100.53 m^2 **ii** 11 L
c **i** 520 m^2 **ii** 52 L
8 5.7 m^2
9 17.6 cm^2
10 cube
11 **a** approx. 120 cm^3 **b** cylinder
12 **a** **i** 64 cm^3 **ii** 72 cm^3 **iii** 48 cm^3
b 2 cm cut-out
c yes (close to 1.7 cm)
d cut-out length of $\frac{5}{3}$ cm

Puzzles and games

1 PRISM
2 no
3 21.46%
4 11
5 $r = 2$
6 9.42 cm^2
7 27 cm^3

Multiple-choice questions

1 E **2** B **3** C **4** A **5** A **6** B
7 E **8** D **9** B **10** C **11** C

Short-answer questions

1 **a** 5300 m **b** 2.7 m^2 **c** 40 mm^3
d 86 400 s **e** 125 ms **f** 0.089 TB
2 **a** 5.5 cm to 6.5 cm
b 4.15 kg to 4.25 kg
c 16.205 m to 16.215 m
3 **a** 13 **b** 24 cm **c** 38 m
4 **a** 18.85 m **b** 28.27 m^2
5 **a** **i** 19.42 m **ii** 26.14 m^2
b **i** 19.50 m **ii** 21.87 m^2
c **i** 14.28 m **ii** 12.28 m^2
6 **a** 10 **b** 25.9 **c** 17.5
7 **a** 828 m^2 **b** 136 cm^2
8 376.99 m^2
9 **a** 40 cm^3 **b** 125.66 m^3 **c** 21 cm^3
10 cylinder
11 **a** $A = 329.1$ cm^2 **b** $V = 385.6$ cm^3

Extended-response questions

1 **a** 50.27 m^2 **b** 150.80 m^2
c 100.53 m^3 **d** 100 530.96 L
2 **a** 5 m **b** 135 m^2
c $810 **d** 154 m^3

Chapter 3

Pre-test

1 a $3x$ **b** $a + 1$ **c** $2m - 5$ **d** $4(x + y)$
2 a 20 **b** 17 **c** 23 **d** 22
3 a no **b** yes **c** yes **d** no
4 a $8m$ **b** $5ab$ **c** $6x + 8y$
d $8x$ **e** $15ab$ **f** $3y$
5 a $2x + 10$ **b** $3y - 6$ **c** $8x - 12$ **d** $3x^2 + x$
6 a 4 **b** 6 **c** $7a$
d $2x$ **e** x
7 a $\frac{31}{40}$ **b** $\frac{11}{21}$ **c** $\frac{2}{15}$ **d** $\frac{3}{2}$
8 a 7^4 **b** m^3 **c** x^2y^3 **d** 3^5a^5
9 a 49 **b** 27 **c** 16 **d** 64
10 a 3^7 **b** 3^2 **c** 3^{10}
d 3^0 **e** 3^{-2}
11 a 38 **b** 2310 **c** 0.172
d 18 **e** 1000 **f** 10 000

Exercise 3A

1 a expression **b** constant term
c coefficient **d** term
2 a 7 **b** 15 **c** 5
d 9 **e** 6
3 a -6 **b** -20 **c** -6 **d** -7
e 9 **f** 18 **g** -6 **h** 7
i -7 **j** -13 **k** -4 **l** -5
4 a 3 **b** -14 **c** 6 **d** 16
e 18 **f** -30 **g** 12 **h** -4
i 36 **j** -36 **k** 36 **l** 0
5 a i 3 **ii** 8 **iii** 5
b i 4 **ii** 2 **iii** -3
c i 3 **ii** -4 **iii** 1
6 a $x + 2$ **b** $y - 4$ **c** $ab + y$ **d** $2x - 3$
e $5x$ **f** $2m$ **g** $3r$ **h** $\frac{1}{2}x$
i $\frac{3}{4}m$ **j** $\frac{x}{y}$ **k** $\frac{a + b}{4}$ **l** x^2y
7 a 12 **b** 3 **c** 9 **d** 10
e 10 **f** -2 **g** 1 **h** 4
i -6 **j** 10 **k** -2 **l** -9
8 a $5x$ cents **b** $35y$ cents **c** $\frac{\$500}{n}$
d $\frac{\$11}{m}$ **e** $11 + x$
9 a $\$(3.40 + 2d)$ **b i** \$23.40 **ii** \$47.40
10 a i $2x$ **ii** $2x - 3$ **iii** $3(2x - 3)$
b 21
11 a $x + 1$ and $x - 1$ **b** no
c i $(x + 1)(x - 1)$
ii Less by one square metre.
12 a 21 sq. units **b** 1, 2, 3, 6, 9, 18
13 a i $4x$ **ii** x^2
b i $2x + 2y$ **ii** xy
c i $x + y + 5$ **ii** $\frac{5x}{2}$
d i $4ab$ **ii** a^2b^2
e i $2a^2 + 2b$ **ii** a^2b
f i $mn + 9$ **ii** $2mn$

Exercise 3B

1 a Y **b** Y **c** N
d N **e** Y **f** Y
2 a $10g$ **b** $5f$ **c** $8e$
d 0 **e** $6x$ **f** $17st$
g $3ts$ **h** $3ab$ **i** xy
3 a $6x$ **b** $12a$ **c** $10m$ **d** $-18y$
4 a $\frac{a}{2}$ **b** $4b$ **c** $3c$
d $\frac{2d}{3}$ **e** $\frac{2e}{3}$ **f** $\frac{7f}{3}$
g $\frac{3g}{4}$ **h** $\frac{2h}{5}$ **i** $\frac{5i}{6}$
5 a $3ac$ and $-2ac$ **b** $4pq$ and $3qp$
c $7x^2y$ and $4yx^2$, $-3xy^2$ and $2xy^2$
d $2r^2$ and $-r^2$ **e** $-2ab$ and $4ba$
f $3p^2q$ and $4qp^2$ **g** $\frac{1}{3}lm$ and $\frac{lm}{4}$
h x^2y and yx^2, $-xy$ and yx
6 a $7t + 10$ **b** $4g + 1$ **c** $7x - 5$
d $m + 2$ **e** $3x + 3y$ **f** $2x + 6y$
g $5a - 2b$ **h** $-3m - 2n$ **i** $5de + 7de^2$
j $3kl - 10k^2l$ **k** $7x^2y + xy^2$ **l** $3fg - fg^2$
7 a $6rs$ **b** $6hu$ **c** $16wh$ **d** $6r^2s$
e $-8es$ **f** $-10hv$ **g** $12cm^2$ **h** $35fl$
i $8x^2y$ **j** $24a^2b$ **k** $3xy^2$ **l** $-16a^2b$
m $-12m^2n^2$ **n** $20x^2y^2$ **o** $20a^2b^2$ **p** $-48x^2y^2$
8 a $\frac{x}{2}$ **b** $3a$ **c** $\frac{a}{3}$ **d** $\frac{ab}{4}$
e $2b$ **f** $3x$ **g** $\frac{y}{2}$ **h** $\frac{4a}{5}$
i $\frac{2x}{5}$ **j** $\frac{2xy}{3}$ **k** $3ab$ **l** $\frac{n}{3}$
9 a $8x$ **b** $3x^2$
10 a $5x$ **b** $8y$ **c** $4a$
d $-6x$ **e** $2x$ **f** $10a^2b$
11 a $P = 4x + 6, A = 6x$ **b** $P = 4y + 16x, A = 16xy$
c $P = 20a, A = 25a^2$
12 $3x$
13 a $6x$ **b** $8a + 7$ **c** $4b$ **d** $11x$
e $3x^2$ **f** $15xy$ **g** $8x^2$ **h** $-29x^2$

Exercise 3C

1 a $4x$ **b** 8 **c** $4x + 8$
d $x + 2$ **e** $4 \times (x + 2)$ **f** $4x + 8$

2 a -8 **b** -18 **c** $-3x$ **d** $-8x$ **e** -20
f $-16x$ **g** 15 **h** 24 **i** $6x$

3 a $3(x + 4) = 3 \times x + 3 \times 4$
$= 3x + 12$
b $2(x - 5) = 2 \times x + 2 \times (-5)$
$= 2x - 10$
c $2(4x + 3) = 2 \times 4x + 2 \times 3$
$= 8x + 6$
d $x(x - 3) = x \times x + x \times (-3)$
$= x^2 - 3x$

4 a $6x$ **b** $8xy$ **c** $15x^2$
d $2x + 9$ **e** $7x + 5$ **f** $3x - 4$
5 a $2x + 8$ **b** $3x + 21$ **c** $4y - 12$ **d** $5y - 10$
e $6x + 4$ **f** $8x + 20$ **g** $9a - 12$ **h** $14y - 35$
i $10a + 5b$ **j** $12a - 9b$ **k** $2x^2 + 10x$ **l** $3x^2 - 12x$
m $6a^2 + 4ab$ **n** $6xy - 8y^2$ **o** $6ab - 15b^2$

6 a $-2x - 6$ **b** $-5m - 10$ **c** $-3w - 12$
d $-4x + 12$ **e** $-2m + 14$ **f** $-7w + 35$
g $-x - y$ **h** $-x + y$ **i** $-6x^2 - 8x$
j $-6x^2 - 15x$ **k** $-8x^2 + 8x$ **l** $-6y^2 + 27y$
m $-6x^2 + 10xy$ **n** $-9x^2 - 6xy$ **o** $-12xy - 18y^2$

7 a $5x + 17$ **b** $7x + 17$ **c** $2x - 1$ **d** $1 - 2x$
e $1 - 5x$ **f** $1 + 6x$ **g** $6x + 11$ **h** $14 - 4x$
i $27 - 6x$ **j** $7x + 18$ **k** $7p - 11$ **l** $10x - 4$
m $4s + 5$ **n** 4 **o** $2x - 7$
8 a 2 **b** 4 **c** $3x$
d $3x$ **e** $y, 1$ **f** $2x, 3y$
9 a $2x - 10$ **b** $x^2 + 3x$ **c** $2x^2 + 8x$ **d** $6x^2 - 3x$
10 $2x^2 + 4x$
11 a $x - 18200$ **b** $0.1x - 1820$
12 a $x^2 + 7x + 12$ **b** $x^2 + 4x + 3$ **c** $x^2 + 7x + 10$
d $x^2 - 2x - 8$ **e** $x^2 + 3x - 10$ **f** $2x^2 + 11x + 12$
g $2x^2 - x - 6$ **h** $x^2 + x - 12$ **i** $4x^2 + 18x - 10$

Exercise 3D

1 a 2 **b** 4 **c** 9 **d** 6 **e** 7 **f** 12
2 a x **b** $2x$ **c** $3x$ **d** $2b$ **e** $4x$ **f** $3y$
3 a C
b They have no common factor.
4 a 6 **b** 5 **c** 4 **d** 9
e $5a$ **f** $2m$ **g** $7x$ **h** $8a$
i $3a$ **j** $2x$ **k** $8y$ **l** $5xy$
5 a $3(x + 3)$ **b** $4(x - 2)$ **c** $10(y - 2)$
d $6(a + 5)$ **e** $5(x + y)$ **f** $4(3a + b)$
g $9(2m - 3n)$ **h** $12(3x - 4y)$ **i** $4(2x + 11y)$
j $6(4a - 3b)$ **k** $11(11m + 5n)$ **l** $7(2k - 9l)$
6 a $7x(2 + 3y)$ **b** $3b(2a - 5)$ **c** $8y(4 - 5x)$
d $5x(x - 1)$ **e** $x(x + 7)$ **f** $2a(a + 4)$
g $6a(2a + 7b)$ **h** $9y(y - 7)$ **i** $2x(3x + 7)$
j $3x(3x - 2)$ **k** $8y(2y + 5)$ **l** $10m(1 - 4m)$
7 a $-2(x + 3)$ **b** $-4(a + 2)$ **c** $-3(x + 2y)$
d $-7a(1 + 2b)$ **e** $-x(1 + 10y)$ **f** $-3b(1 + 4a)$
g $-x(x + 7)$ **h** $-4x(x + 3)$ **i** $-2y(y + 5)$
j $-2x(4x + 7)$ **k** $-4x(3x + 2)$ **l** $-5a(3a + 1)$
8 a $ab(7a + 1)$ **b** $4a^2(b + 5)$ **c** $xy(1 - y)$
d $x^2y(1 + 4y)$ **e** $6mn(1 + 3n)$ **f** $5xy(x + 2y)$
g $-y(y + 8z)$ **h** $-3ab(a + 2)$ **i** $-ab(b + a)$
9 a $4(x + 5)$ **b** $8(x + 2)$ **c** $2(3x + 4)$
10 $(x + 3)$ metres
11 a $2(x + 2y + 3z)$ **b** $3(x^2 + 4x + 2)$ **c** $4(x^2 + 2xy + 3)$
d $3x(2x + y - 3)$ **e** $5x(2y - z + 1)$ **f** $2y(2y - 9 + 7x)$
12 a $(x + 2)(4 + x)$ **b** $(x + 3)(x + 2)$ **c** $(x + 4)(x - 7)$
d $(2x + 1)(x - 3)$ **e** $(y - 3)(2x + 4)$ **f** $(x - 1)(2x - 3)$

Exercise 3E

1 a $\frac{2}{3}$ **b** $\frac{3}{4}$ **c** $\frac{2x}{5}$ **d** $\frac{2x}{5}$
e $\frac{x + 1}{2}$ **f** $\frac{x - 2}{2}$ **g** $\frac{x + 4}{3}$ **h** $\frac{x + 3}{5}$
2 a $\frac{4}{15}$ **b** $\frac{2}{5}$ **c** $\frac{1}{12}$ **d** $\frac{4}{5}$
3 a $\frac{2}{3}$ **b** $\frac{3}{5x}$ **c** $\frac{1}{7}$ **d** $\frac{4}{x + 3}$
4 a $3(x + 2)$ **b** $2(x + 2)$ **c** $4(2x + 3)$ **d** $8(2 - x)$
e $x(x + 3)$ **f** $2x(2x + 5)$ **g** $-2(x + 3)$ **h** $-x(x + 5)$
5 a $\frac{y}{2}$ **b** $\frac{2a}{5}$ **c** $\frac{x}{5}$ **d** $5x$
e $x + 1$ **f** $x - 5$ **g** $\frac{x + 1}{2}$ **h** 5
i 4 **j** $\frac{1}{2}$ **k** 3 **l** $\frac{3}{2}$
6 a $x + 2$ **b** $a - 5$ **c** $2y - 3$ **d** $2b - 3$
e 3 **f** 4 **g** 3 **h** 4
i $x + 2$ **j** $x - 5$ **k** $x + 3$ **l** x
m x **n** $2x$ **o** $3x$ **p** $2x$
7 a $\frac{2}{3}$ **b** $\frac{3}{2}$ **c** $\frac{3}{4}$ **d** $\frac{5x}{3}$
e $\frac{3y}{2}$ **f** $\frac{5}{6}$ **g** $\frac{4}{9}$ **h** 10
i $\frac{15}{2}$ **j** $\frac{8}{5}$ **k** $\frac{4}{3x}$ **l** 12
8 a 3 **b** 6 **c** $8a$ **d** $\frac{x}{4}$
e $\frac{8}{15a}$ **f** $\frac{4}{x}$ **g** 3 **h** $\frac{5}{2}$
i $\frac{3}{4}$ **j** $\frac{1}{25}$ **k** 10 **l** $\frac{5}{4}$
9 a Must factorise first, $x + 2$.
b Factorise first, $x + 2$.
c Need to multiply by the reciprocal of the fraction after division sign, $\frac{6}{25}$.
d x is not a common factor, cannot cancel, $\frac{x + 4}{5x}$.
10 a $\frac{1 + 2a}{3}$ **b** $\frac{4}{5}$ **c** $\frac{x}{4}$
d $\frac{2}{5}$ **e** $\frac{7}{18}$ **f** $\frac{2x}{3}$
g $\frac{5}{4}$ **h** $\frac{x}{9}$ **i** $\frac{x + 5}{9}$

11 a -3 **b** -2 **c** $-x$

d $\frac{x+2}{3}$ **e** $x-6$ **f** $2x-3$

12 a $\frac{x+1}{2}$ **b** $\frac{2(x+1)}{3}$ **c** $\frac{x-2}{2}$

d $\frac{x+2}{8}$ **e** $\frac{x-3}{12}$ **f** $\frac{5(2x+1)}{8}$

Exercise 3F

1 a 12 **b** 18 **c** 8

d 12 **e** 20 **f** 30

2 a $\frac{5}{6}$ **b** $\frac{31}{40}$ **c** $\frac{13}{12}=1\frac{1}{12}$

d $\frac{5}{21}$ **e** $\frac{3}{16}$ **f** $\frac{7}{18}$

3 a $3x$ **b** $5x$ **c** $6x$

d $12x$ **e** 3 **f** 5

4 a $7x+8$ **b** $5x-12$ **c** $2x+4$

d $7x+18$ **e** $7x+4$ **f** $7x+10$

5 a $\frac{7x}{12}$ **b** $\frac{7x}{10}$ **c** $\frac{2x}{9}$

d $\frac{2x}{35}$ **e** $\frac{13x}{15}$ **f** $\frac{7x}{6}$

g $\frac{7x}{18}$ **h** $\frac{13x}{40}$ **i** $\frac{-5x}{14}$

j $\frac{-3x}{10}$ **k** $\frac{-x}{30}$ **l** $\frac{-6x}{5}$

6 a $\frac{2x+3}{4}$ **b** $\frac{3x+10}{15}$ **c** $\frac{8x+21}{60}$

d $\frac{5x-8}{20}$ **e** $\frac{6x-5}{9}$ **f** $\frac{10-3x}{12}$

7 a $\frac{5x+4}{6}$ **b** $\frac{13x+12}{15}$ **c** $\frac{5x-4}{8}$

d $\frac{x+8}{6}$ **e** $\frac{x+10}{10}$ **f** $\frac{3x+14}{24}$

g $\frac{9x+22}{20}$ **h** $\frac{11x+13}{14}$ **i** $\frac{5x+7}{12}$

j $\frac{11x+14}{12}$ **k** $\frac{3x-2}{10}$ **l** $\frac{14x-13}{24}$

8 a Need to multiply numerators also when getting common denominator, $\frac{17x}{12}$.

b Need common denominator before subtracting, $\frac{x}{10}$.

c $3(x+2)=3x+6$ and $5(x+4)=5x+20$, $\frac{8x+26}{15}$.

d $-$ sign changed to $+$, $\frac{4x+9}{6}$.

9 a $\frac{x+16}{30}$ **b** $\frac{2x+22}{15}$ **c** $\frac{x-23}{20}$ **d** $\frac{x+9}{4}$

10 a $\frac{12+2x}{3x}$ **b** $\frac{3x+8}{4x}$ **c** $\frac{2x+15}{5x}$

d $\frac{3x-14}{7x}$ **e** $\frac{x-20}{5x}$ **f** $\frac{24-5x}{8x}$

11 a $\frac{3x+10}{4x}$ **b** $\frac{x+15}{6x}$ **c** $\frac{6x-5}{20x}$

d $\frac{3x+5}{x^2}$ **e** $\frac{4x+1}{x^2}$ **f** $\frac{3-5x}{x^2}$

g $\frac{3x+4}{2x^2}$ **h** $\frac{12x+7}{3x^2}$ **i** $\frac{3x-14}{4x^2}$

Exercise 3G

1 a base, index or exponent or power

b power **c** index

d multiply **e** expanded

2 a $8\times8\times8$ **b** $7\times7\times7\times7\times7$

c $x\times x\times x\times x\times x\times x$ **d** $ab\times ab\times ab\times ab$

3 a 9^4 **b** 3^6 **c** 15^3 **d** 5^2x^3

e 4^3a^4 **f** $7b^4$ **g** x^3y^2 **h** a^2b^4

i $3^3x^2y^3$ **j** $4^2x^2z^2$

4 a $7\times7\times7\times7, 7^7$ **b** $5\times5\times5\times5, 5^4$

5 a $\frac{1}{y^3}$ **b** $\frac{1}{x^4}$ **c** $\frac{1}{x^2}$ **d** $\frac{1}{a^5}$

e $\frac{3}{x^2}$ **f** $\frac{5}{b^3}$ **g** $\frac{4}{x}$ **h** $\frac{2}{m^9}$

i $\frac{2x^2}{y^3}$ **j** $\frac{3x}{y^4}$ **k** $\frac{3b^4}{a^2}$ **l** $\frac{5n^2}{m^3}$

6 a b^4 **b** x^7 **c** y **d** $5m^3$ **e** $2y^2$

f $3x^4$ **g** $5a^2b^3$ **h** $\frac{4y^5}{x^2}$ **i** $\frac{10a^2}{b^4}$

7 a x^7 **b** p^7 **c** t^9 **d** d^5

e g^4 **f** f^3 **g** $2p^5$ **h** $3c^8$

i $6s^{11}$ **j** a^5b^8 **k** d^9f^5 **l** v^5z^8

m $15a^3b^6$ **n** $6x^3y^3$ **o** $18e^9r^3$ **p** $-8p^4c^3$

q $-10r^7s^8$ **r** $6d^6f^4$

8 a a^2 **b** d **c** r^2 **d** c^4

e l **f** b^3 **g** $4d^2$ **h** $\frac{f}{2}$

i $3n^3$ **j** $2p^2$ **k** $\frac{3m^4}{2}$ **l** $\frac{d^2}{3}$

m $4t^3r$ **n** $\frac{5h^4d}{3}$ **o** $2q^2$ **p** $\frac{xy^2}{2}$

q $\frac{r^2s}{3}$ **r** $\frac{2cd^5}{5}$ **s** $\frac{a^3y}{2}$ **t** $\frac{n}{2}$

9 a xy^2 **b** m **c** r^2s^4

d $2a^2b^2$ **e** $\frac{9x^8y^4}{2}$ **f** $4w^4$

10 a $\frac{b^4}{a^3}$ **b** $\frac{x^4}{y^3}$ **c** $\frac{1}{x^2y^4}$ **d** $\frac{b}{a^4}$

11 He hasn't put brackets around -2; i.e. $(-2)^4$.

12 a i 9 **ii** -9

b Part **i** is $-3\times(-3)$ and part **ii** is $-(3\times3)$.

c i -8 **ii** -8

d They are both -8 since $-2\times(-2)\times(-2)=-8$.

13 a 13 **b** 18 **c** 81 **d** 27 **e** 64 **f** 16

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Exercise 3H

1 **a** 1 **b** a^{mn} **c** $a^m \times b^m$ **d** $\frac{a^m}{b^m}$

2 **a** $(4^2)^3 = 4^2 \times 4^2 \times 4^2$
$= 4^6$

b $(2a)^3 = 2a \times 2a \times 2a$
$= 2 \times 2 \times 2 \times a \times a \times a$
$= 2^3a^3$

c $\left(\frac{4}{7}\right)^4 = \frac{4}{7} \times \frac{4}{7} \times \frac{4}{7} \times \frac{4}{7}$
$= \frac{4 \times 4 \times 4 \times 4}{7 \times 7 \times 7 \times 7}$
$= \frac{4^4}{7^4}$

3 **a** 1 **b** 1 **c** 1 **d** 1
e 3 **f** 4 **g** 2 **h** 0
i 1 **j** 3 **k** 2 **l** 9

4 **a** b^{12} **b** f^{20} **c** k^{21}
d $3x^6$ **e** $5c^{18}$ **f** $4s^{18}$

5 **a** $9x^2$ **b** $64m^3$ **c** $125y^3$ **d** $16x^{12}$
e $x^{10}y^5$ **f** $27a^9$ **g** $x^{24}y^{12}$ **h** a^6b^3
i $m^{12}n^{12}$ **j** $\frac{x^2}{25}$ **k** $\frac{y^4}{81}$ **l** $\frac{m^4}{16}$
m $\frac{x^6}{y^3}$ **n** $\frac{x^{12}}{y^8}$ **o** $\frac{x^3}{y^{15}}$ **p** $\frac{3}{2}$
q $\frac{5}{x}$ **r** $\frac{y}{x^2}$

6 **a** m **b** $\frac{y^5}{10}$ **c** $\frac{4b^4}{3}$
d $\frac{27c^4}{2}$ **e** $\frac{25r^4}{3}$ **f** $\frac{8p^5}{3}$
g $\frac{16s^8}{t^{12}}$ **h** $\frac{r^8}{625s^{12}}$ **i** $9x^4$

7 **a** $\frac{1}{x^8}$ **b** $\frac{1}{x^6}$ **c** 1
d $\frac{8}{y^6}$ **e** $\frac{a^2}{y^6}$ **f** $\frac{x^6}{16}$
g $\frac{1}{m^4} + 4$ **h** $\frac{8}{a^6} + 1$ **i** $\frac{a^4}{5}$

8 **a** $\frac{1}{4}$ **b** 36 **c** 40
d 1 **e** 1 **f** 9

9 **a** $2p^3q^7$ **b** $108a^9b^6$ **c** $48r^9y^{12}$ **d** $2m^9n^4$
e $21s^3y^2$ **f** $\frac{3d^{10}c^4}{2}$ **g** $2r^6$ **h** y

10 **a** a^7b^2 **b** $54x^5y^{11}$ **c** $\frac{2p^4}{9q^2}$
d $4a^8b^3$ **e** $\frac{324r^{11}}{s}$ **f** $\frac{2y^{14}s^2}{x^5}$

Exercise 3I

1 **a** 124 **b** 280 **c** 3020
d 0.045 **e** 0.00375 **f** 0.06

2 **a** 10^3 **b** 10^7 **c** 10^{-6} **d** 10^{-3}

3 **a** positive **b** negative **c** positive **d** negative

4 **a** 4.87 **b** 4.872 **c** 4.9

5 **a** 3120 **b** 54 293 **c** 710 500
d 8 213 000 **e** 59 500 **f** 800 200
g 10 120 **h** 9 990 000 **i** 210 500 000
j 0.0045 **k** 0.0272 **l** 0.0003085
m 0.00783 **n** 0.000092 **o** 0.265
p 0.0001002 **q** 0.000006235 **r** 0.98

6 **a** 4.3×10^4 **b** 7.12×10^5 **c** 9.012×10^5
d 1.001×10^4 **e** 2.39×10^4 **f** 7.03×10^8
g 7.8×10^{-4} **h** 1.01×10^{-3} **i** 3×10^{-5}
j 3.004×10^{-2} **k** 1.12×10^{-1} **l** 1.92×10^{-3}

7 **a** 6.24×10^3 **b** 5.73×10^5 **c** 3.02×10^4
d 4.24×10^5 **e** 1.01×10^4 **f** 3.50×10^7
g 7.25×10^4 **h** 3.56×10^5 **i** 1.10×10^8
j 2.42×10^{-3} **k** 1.88×10^{-2} **l** 1.25×10^{-4}
m 7.87×10^{-3} **n** 7.08×10^{-4} **o** 1.14×10^{-1}
p 6.40×10^{-6} **q** 7.89×10^{-5} **r** 1.30×10^{-4}

8 **a** 7.7×10^6 km^2 **b** 2.5×10^6 **c** 7.4×10^9 km
d 1×10^{-2} cm **e** 1.675×10^{-27} kg **f** 9.5×10^{-13} g

9 **a** 4.5×10^9
b 3.16×10^9 (including leap years)
c 2×10^{21}

10 The numeral part has to be between 1 and 10; i.e. 3.8×10^8.

11 **a** 2.85×10^{-3} **b** 1.55×10^{-3} **c** 4.41×10^{-8}
d 6.38×10^{-3} **e** 8.00×10^7 **f** 3.63×10^8
g 1.80×10^{-3} **h** 3.42×10^{15}

12 328 min

13 **a** **i** 9×10^{17} J **ii** 2.34×10^{21} J
iii 2.7×10^{15} J **iv** 9×10^{11} J
b **i** 1.11×10^8 kg **ii** 4.22×10^{-1} kg
iii 9.69×10^{-13} kg **iv** 1.89×10^{-19} kg
c 5.4×10^{41} J

Exercise 3J

1 **a** \$50 **b** \$1050 **c** \$52.50 **d** \$55.13

2 **a** 4.9 kg **b** $\frac{2}{100}$, 0.98 **c** 4.52 kg

3 **a** growth **b** growth **c** decay
d decay **e** growth **f** decay

4 **a** A = amount of money at any time, n = number of years of investment
$A = \$200\,000 \times 1.17^n$

b A = house value at any time, n = number of years since initial valuation
$A = \$530\,000 \times 0.95^n$

c A = car value at any time, n = number of years since purchase
$A = \$14\,200 \times 0.97^n$

d A = population at any time, n = number of years since initial census
$A = 172\,500 \times 1.15^n$

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e A = litres in tank at any time, n = number of hours elapsed
$A = 1200\text{L} \times 0.9^n$

f A = cell size at any time, n = number of minutes elapsed
$A = 0.01\text{ cm}^2 \times 2^n$

g A = size of oil spill at any time, n = number of minutes elapsed
$A = 2\text{ m}^2 \times 1.05^n$

h A = mass of substance at any time, n = number of hours elapsed
$A = 30\text{ g} \times 0.92^n$

5 a 1.1
b i \$665 500
ii \$1 296 871.23
iii \$3 363 749.98
c after 7.3 years

6 a 300 000
b i \$216 750 **ii** \$96 173.13 **iii** \$42 672.53
c 3.1 years

7 a $V = 15000 \times 0.94^n$
b i 12 459 L **ii** 9727 L
c 769.53 L **d** 55.0 hours

8 a 3000
b i 3000 **ii** 20 280 **iii** 243 220
c It will take 10 hours 11 minutes to reach 50 000 000.

9 a $D = 10 \times 0.875^t$, where t = number of 10 000 km travelled
b 90 000

10 a $T = 90°\text{C} \times 0.92^t$
b i 76.2°C **ii** 79.4°C
c 3 minutes 13 seconds

11 a i \$1610.51 **ii** \$2143.59 **iii** \$4177.25
b i \$1645.31 **ii** \$2218.18 **iii** \$4453.92

12 a \$2805.10 **b** \$2835.25 **c** \$2837.47

Puzzles and games

1 magic square sum = $3x + 2y$

$\frac{4x^2}{2x}$	$-y$	$x + 3y$
$4y$	$x + y$	$2x - 3y$
$x - 2y$	$2x + 2y$	$2y$

2 3^{3n-3}
3 1 cent and then double each day
4 5
5 2^{24}
6 200
7 $\frac{5 - 2x}{30}$
8 n^2, 225

Multiple-choice questions

1 C **2** B **3** C **4** D
5 B **6** D **7** C **8** E
9 D **10** A **11** C **12** D

Short-answer questions

1 a 4 **b** 5
c i 4 **ii** −3

2 a $y + 3$ **b** $xy - 5$ **c** $\frac{a + b}{4}$

3 a 14 **b** −30 **c** 35

4 a $7x - 5$ **b** $13a - 2b$
c $xy - 3xy^2$ **d** $12mn$
e $-14x^2y$ **f** $\frac{2b}{3}$

5 a $10x + 20$ **b** $-6x + 8y$
c $6x^2 + 15xy$ **d** $4a + 15$
e $5y + 13$ **f** $8t + 11$

6 a $8(2x - 5)$ **b** $5xy(2x + 7y)$
c $2x(2x - 5)$ **d** $-2x(y + 9)$

7 a $\frac{14x}{15}$ **b** $\frac{6 - 7a}{14}$ **c** $\frac{9x + 8}{20}$

8 a $\frac{3}{8}$ **b** $4x$
c $3x - 1$ **d** $\frac{2}{3}$

9 a $12x^7$ **b** $8x^4y^4$
c b^4 **d** $\frac{2a^2b^3}{3}$

10 a $\frac{4}{x^3}$ **b** $\frac{3r^4}{s^2}$ **c** $\frac{2y^4}{3x^3}$ **d** $4m^5$

11 a b^8 **b** $8m^6$ **c** $\frac{x^2}{49}$ **d** $\frac{64y^6}{z^{12}}$

12 a 1 **b** 4 **c** 6 **d** 1

13 a $\frac{5y^6}{4}$ **b** $\frac{25x^3y^2}{2}$ **c** $\frac{10y^3}{x^2}$ **d** $\frac{x^8}{2y^3}$

14 a 4250 **b** 37 000 000
c 0.021 **d** 0.0000725

15 a 1.24×10^5 **b** 3.95×10^7
c 9.02×10^{-6} **d** 4.60×10^{-4}

16 a $P = 20(1.1)^n$ **b** $A = 100000(0.85)^n$

Extended-response questions

1 a $2(5x + 1)$ m
b 32 m
c $5x^2 + 3x$
d \$1080

2 a $A = 2(1.09)^t$
b i 2.3762 m²
ii 3.0772 m²
c 37.4 weeks

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Chapter 4

Pre-test

1 **a** 11

b **i** $\frac{1}{11}$ **ii** $\frac{2}{11}$ **iii** $\frac{4}{11}$

iv $\frac{7}{11}$ **v** $\frac{3}{11}$ **vi** $\frac{8}{11}$

2 **a** $\frac{1}{8}$ **b** $\frac{1}{2}$ **c** $\frac{1}{2}$ **d** $\frac{1}{4}$

e $\frac{5}{8}$ **f** $\frac{7}{8}$ **g** $\frac{1}{4}$

3 0, 1 in 5, 39%, 0.4, $\frac{1}{2}$, 0.62, 71%, $\frac{3}{4}$, $\frac{9}{10}$, 1

4 **a** **i** 14 **ii** 25 **iii** 11

b **i** $\frac{18}{25}$ **ii** $\frac{7}{25}$ **iii** $\frac{7}{25}$

5 **a** $\frac{7}{16}$ **b** $\frac{9}{16}$

6 **a**

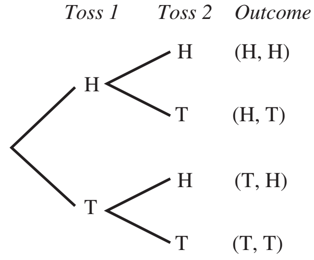
		Roll 1			
		1	**2**	**3**	**4**
Roll 2	**1**	2	3	4	5
	2	3	4	5	6
	3	4	5	6	7
	4	5	6	7	8

b 16

c **i** $\frac{1}{16}$ **ii** $\frac{3}{16}$ **iii** $\frac{3}{8}$

iv $\frac{5}{8}$ **v** $\frac{13}{16}$ **vi** $\frac{3}{16}$

7 **a**



b 4

c **i** $\frac{1}{4}$ **ii** $\frac{1}{4}$ **iii** $\frac{1}{2}$ **iv** $\frac{3}{4}$ **v** $\frac{1}{2}$ **vi** 1

Exercise 4A

1 C, A, B, D

2 **a** $\frac{1}{4}$ **b** $\frac{1}{6}$ **c** $\frac{1}{4}$

d $\frac{3}{8}$ **e** $\frac{2}{3}$ **f** 0

3 **a** 2 **b** {H, T} **c** yes

d $\frac{1}{2}$ **e** $\frac{1}{2}$ **f** 1

4 **a** 7

b **i** $\frac{1}{7}$ **ii** $\frac{2}{7}$ **iii** $\frac{5}{7}$ **iv** $\frac{3}{7}$

5 **a** $\frac{3}{10}$ **b** $\frac{2}{5}$ **c** $\frac{3}{5}$ **d** $\frac{1}{2}$

6 **a** 43 **b** 47

c **i** 0.09 **ii** 0.43 **iii** 0.47 **iv** 0.91

7 **a** 0.62 **b** 0.03 **c** 0.97 **d** 0.38

8 **a** $\frac{1}{10}$ **b** $\frac{1}{2}$ **c** $\frac{1}{2}$ **d** $\frac{1}{2}$

e $\frac{2}{5}$ **f** $\frac{1}{5}$ **g** $\frac{3}{10}$ **h** $\frac{9}{10}$

9 **a** $\frac{1}{50}$ **b** $\frac{3}{10}$ **c** $\frac{49}{50}$

10 **a** $\frac{6}{25}$ **b** $\frac{1}{50}$ **c** $\frac{21}{25}$

d $\frac{2}{5}$ **e** $\frac{2}{25}$ **f** $\frac{4}{25}$

11 **a** 59

b 4, as $\frac{41}{100}$ of 10 is closest to 4.

c 8, as $\frac{41}{100}$ of 20 is closest to 8.

12 **a** $\frac{1}{4}$ **b** $\frac{1}{13}$ **c** $\frac{1}{52}$ **d** $\frac{1}{2}$

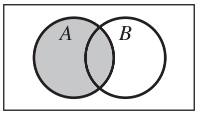
e $\frac{2}{13}$ **f** $\frac{4}{13}$ **g** $\frac{12}{13}$ **h** $\frac{9}{13}$

Exercise 4B

1 **a** D **b** C **c** E **d** A **e** B

2 **a** no **b** yes **c** no

3 **a**



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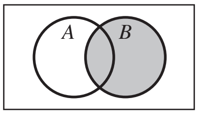

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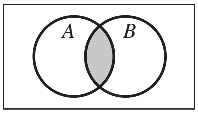

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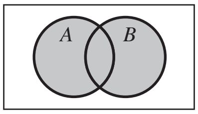

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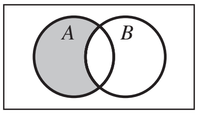
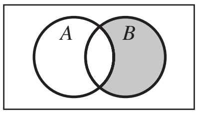
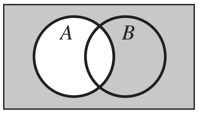


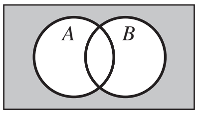
f



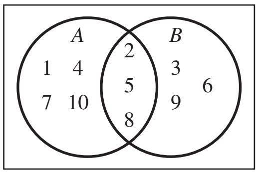
g



h



4 **a**



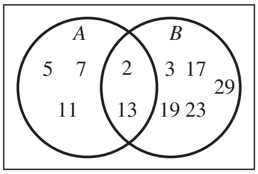
b **i** {2, 5, 8}

ii {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}

c **i** $\frac{7}{10}$ **ii** $\frac{3}{10}$ **iii** 1

d No, there is at least one number in *A* and *B*.

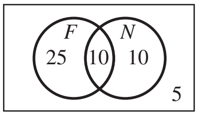
5 **a**



b **i** {2, 13} **ii** {2, 3, 5, 7, 11, 13, 17, 19, 23, 29}

c **i** $\frac{1}{2}$ **ii** $\frac{7}{10}$ **iii** $\frac{1}{5}$ **iv** 1

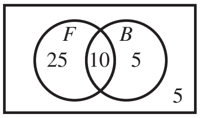
6 **a**



b **i** 25 **ii** 5

c **i** $\frac{2}{5}$ **ii** $\frac{1}{5}$ **iii** $\frac{1}{5}$

7 **a**



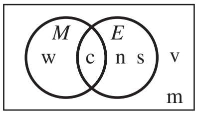
b **i** 25 **ii** 5

c **i** $\frac{7}{9}$ **ii** $\frac{2}{9}$ **iii** $\frac{8}{9}$ **iv** $\frac{2}{9}$ **v** $\frac{1}{9}$

8 3

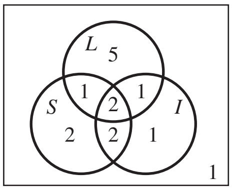
9 5

10 **a**



b **i** $\frac{1}{3}$ **ii** $\frac{2}{3}$ **iii** $\frac{1}{6}$ **iv** $\frac{2}{3}$ **v** $\frac{1}{3}$

11 **a**



b 1

c **i** $\frac{3}{5}$ **ii** $\frac{1}{3}$ **iii** $\frac{13}{15}$ **iv** $\frac{1}{15}$

Exercise 4C

1 **a** B **b** A **c** D **d** C

2 **a** **i** 4 **ii** 6 **iii** 3 **iv** 1
v 10 **vi** 7 **vii** 4 **viii** 7

b 13

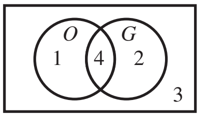
3 **a**

	A	not *A*	
B	2	6	8
not *B*	5	3	8
	7	9	16

b **i** 2 **ii** 6 **iii** 5 **iv** 3
v 7 **vi** 8 **vii** 13

c **i** $\frac{1}{8}$ **ii** $\frac{9}{16}$ **iii** $\frac{5}{16}$

4 **a**



b

	O	not *O*	
G	4	2	6
not *G*	1	3	4
	5	5	10

c **i** 2 **ii** 5 **iii** 4 **iv** 7

d **i** $\frac{3}{5}$ **ii** $\frac{2}{5}$ **iii** $\frac{1}{10}$ **iv** $\frac{2}{5}$ **v** $\frac{7}{10}$

5 **a**

	A	not *A*	
H	4	3	7
not *H*	4	1	5
	8	4	12

b **i** 3 **ii** 1

c **i** $\frac{11}{12}$ **ii** $\frac{1}{3}$

6 **a**

	A	not *A*	
B	3	3	6
not *B*	4	1	5
	7	4	11

b

	A	not *A*	
B	2	7	9
not *B*	2	1	3
	4	8	12

7 **a** $\frac{1}{8}$ **b** $\frac{5}{24}$

8 **a** 0

b

	A	not *A*	
B	0	6	6
not *B*	10	2	12
	10	8	18

9 **a** $\frac{3}{8}$ **b** $\frac{5}{32}$

10 **a** $\frac{4}{13}$ **b** $\frac{4}{13}$ **c** $\frac{7}{13}$ **d** $\frac{7}{13}$

11 **a** 18 **b** 75

Exercise 4D

1 **a** $\frac{1}{2}$ **b** $\frac{1}{3}$

2 **a** $\frac{7}{10}$ **b** $\frac{7}{12}$

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3 a $\frac{1}{3}$ **b** $\frac{1}{2}$

4 a i $\frac{9}{13}$ **ii** $\frac{3}{13}$ **iii** $\frac{3}{7}$ **iv** $\frac{1}{3}$

b i $\frac{14}{17}$ **ii** $\frac{4}{17}$ **iii** $\frac{4}{7}$ **iv** $\frac{2}{7}$

c i $\frac{3}{4}$ **ii** $\frac{5}{8}$ **iii** $\frac{5}{7}$ **iv** $\frac{5}{6}$

d i $\frac{7}{16}$ **ii** $\frac{1}{8}$ **iii** $\frac{1}{4}$ **iv** $\frac{2}{7}$

5 a i $\frac{7}{18}$ **ii** $\frac{1}{9}$ **iii** $\frac{1}{5}$ **iv** $\frac{2}{7}$

b i $\frac{4}{9}$ **ii** $\frac{1}{9}$ **iii** $\frac{1}{5}$ **iv** $\frac{1}{4}$

c i $\frac{8}{17}$ **ii** $\frac{7}{17}$ **iii** $\frac{7}{10}$ **iv** $\frac{7}{8}$

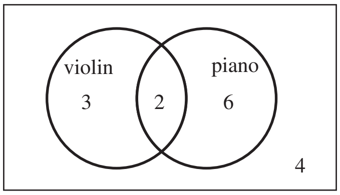
d i $\frac{3}{4}$ **ii** $\frac{1}{4}$ **iii** $\frac{2}{3}$ **iv** $\frac{1}{3}$

6 a

	A	not A	
B	9	6	15
not B	4	1	5
	13	7	20

b $\frac{1}{5}$ **c** $\frac{3}{5}$ **d** $\frac{9}{13}$

7 a



b 4 **c** $\frac{2}{5}$ **d** $\frac{1}{4}$

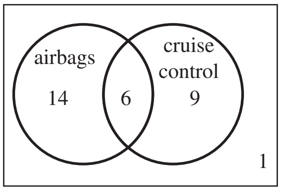
8 $\frac{1}{4}$

9 $\frac{2}{3}$

10 a $\frac{1}{13}$ **b** $\frac{1}{13}$

11 $P(A|B) = P(B|A) = 0$

12 a



	airbags	no airbags	
cruise control	6	9	15
no cruise control	14	1	15
	20	10	30

b i $\frac{3}{10}$ **ii** $\frac{7}{15}$

c $\frac{2}{5}$ **d** $\frac{3}{10}$

Exercise 4E

1 a i

		1st		
		D	O	G
2nd	D	(D, D)	(O, D)	(G, D)
	O	(D, O)	(O, O)	(G, O)
	G	(D, G)	(O, G)	(G, G)

ii

		1st		
		D	O	G
2nd	D	X	(O, D)	(G, D)
	O	(D, O)	X	(G, O)
	G	(D, G)	(O, G)	X

b i 9 **ii** 6

c i $\frac{1}{3}$ **ii** $\frac{5}{9}$ **iii** $\frac{4}{9}$ **iv** $\frac{8}{9}$ **v** $\frac{2}{9}$

d i 0 **ii** $\frac{2}{3}$ **iii** $\frac{1}{3}$ **iv** 1 **v** $\frac{1}{3}$

2 a 9 **b** 6

3 a

		1st roll			
		1	2	3	4
2nd roll	1	(1, 1)	(2, 1)	(3, 1)	(4, 1)
	2	(1, 2)	(2, 2)	(3, 2)	(4, 2)
	3	(1, 3)	(2, 3)	(3, 3)	(4, 3)
	4	(1, 4)	(2, 4)	(3, 4)	(4, 4)

b 16 **c** $\frac{1}{16}$

d i $\frac{1}{4}$ **ii** $\frac{5}{8}$ **iii** $\frac{13}{16}$

4 a

		1st toss	
		H	T
2nd toss	H	(H, H)	(T, H)
	T	(H, T)	(T, T)

b 4 **c** $\frac{1}{4}$

d i $\frac{1}{2}$ **ii** $\frac{3}{4}$

e 250

5 a

		1st		
		S	E	T
2nd	S	X	(E, S)	(T, S)
	E	(S, E)	X	(T, E)
	T	(S, T)	(E, T)	X

b i $\frac{1}{6}$ **ii** $\frac{2}{3}$ **iii** $\frac{2}{3}$ **iv** $\frac{1}{3}$ **v** 1

6 **a**

		1st				
		L	E	V	E	L
2nd	L	X	(E, L)	(V, L)	(E, L)	(L, L)
	E	(L, E)	X	(V, E)	(E, E)	(L, E)
	V	(L, V)	(E, V)	X	(E, V)	(L, V)
	E	(L, E)	(E, E)	(V, E)	X	(L, E)
	L	(L, L)	(E, L)	(V, L)	(E, L)	X

b 20

c **i** 8 **ii** 12 **iii** 12

d **i** $\frac{2}{5}$ **ii** $\frac{3}{5}$ **iii** $\frac{3}{5}$

e $\frac{1}{5}$

7 **a**

		Die 2					
		1	2	3	4	5	6
Die 1	1	2	3	4	5	6	7
	2	3	4	5	6	7	8
	3	4	5	6	7	8	9
	4	5	6	7	8	9	10
	5	6	7	8	9	10	11
	6	7	8	9	10	11	12

b 36

c **i** 2 **ii** 6 **iii** 15

d **i** $\frac{1}{6}$ **ii** $\frac{1}{6}$ **iii** $\frac{35}{36}$ **iv** $\frac{1}{12}$

e $\frac{1}{6}$. Her guess is wrong.

8 **a** **i** 100 **ii** 90

b **i** $\frac{1}{10}$ **ii** $\frac{1}{10}$ **iii** $\frac{4}{5}$

c $\frac{19}{100}$

9 **a** without **b** with

c with **d** without

10 **a**

		1st			
		2.5	5	10	20
2nd	2.5	5	7.5	12.5	22.5
	5	7.5	10	15	25
	10	12.5	15	20	30
	20	22.5	25	30	40

b 16

c **i** 1 **ii** 8 **iii** 8

d **i** $\frac{1}{16}$ **ii** $\frac{1}{8}$ **iii** $\frac{1}{4}$ **iv** $\frac{3}{16}$

e $\frac{7}{16}$

Exercise 4F

1 **a** 8 **b** $\frac{1}{8}$

c **i** 3 **ii** 4

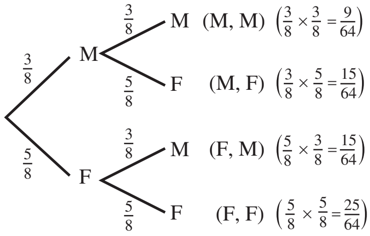
d $\frac{7}{8}$

2 **a** **i** $\frac{2}{5}$ **ii** $\frac{3}{5}$

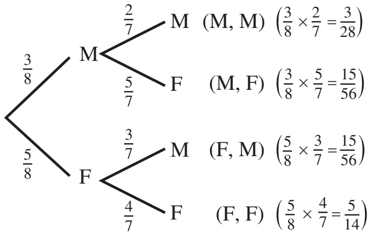
b **i** $\frac{2}{5}$ **ii** $\frac{3}{5}$

c **i** $\frac{1}{4}$ **ii** $\frac{3}{4}$

3 **a**

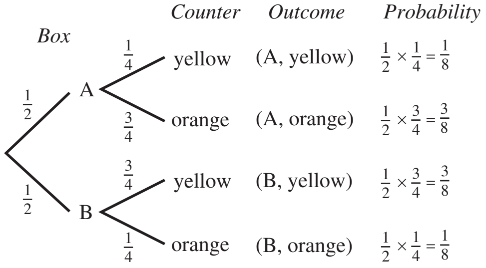


b



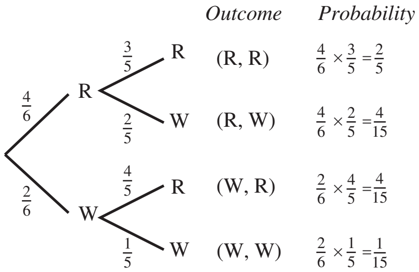
4 **a** $\frac{1}{4}$ **b** $\frac{3}{4}$

c



d $\frac{3}{8}$ **e** $\frac{1}{2}$

5 **a**



b **i** $\frac{4}{15}$ **ii** $\frac{2}{5}$ **iii** $\frac{8}{15}$

c **i** $\frac{2}{9}$ **ii** $\frac{4}{9}$ **iii** $\frac{4}{9}$

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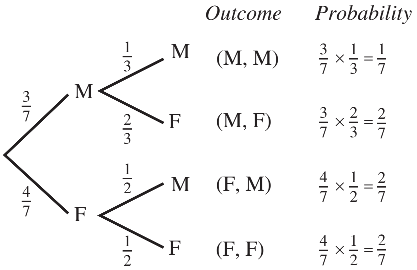
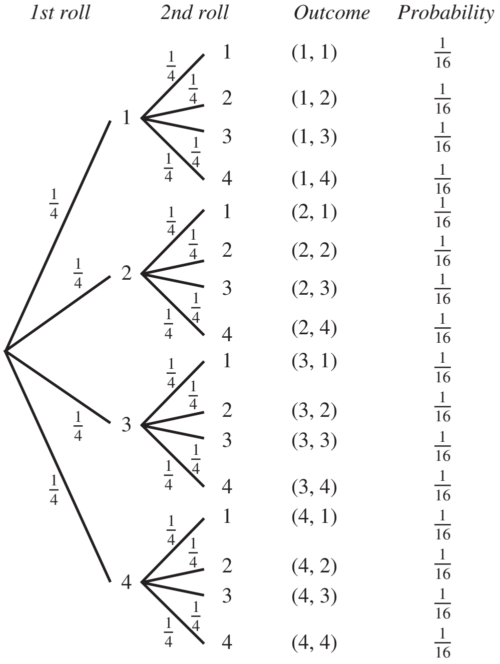
6 **a**



i $\frac{1}{7}$ **ii** $\frac{2}{7}$ **iii** $\frac{4}{7}$ **iv** $\frac{3}{7}$

b **i** $\frac{9}{49}$ **ii** $\frac{16}{49}$ **iii** $\frac{24}{49}$ **iv** $\frac{25}{49}$

7 **a**

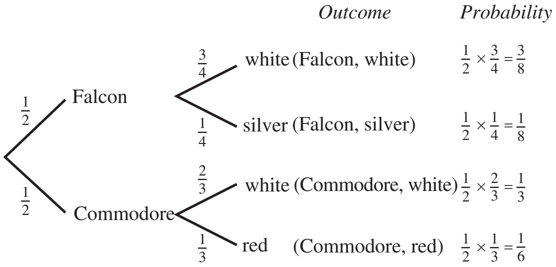


b 16

c **i** $\frac{1}{16}$ **ii** $\frac{1}{4}$

d **i** $\frac{1}{16}$ **ii** $\frac{1}{4}$ **iii** $\frac{5}{8}$

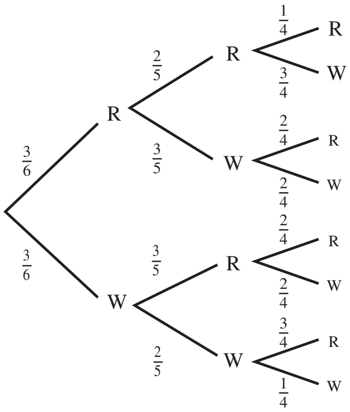
8 **a**



b **i** $\frac{3}{8}$ **ii** $\frac{1}{6}$ **iii** $\frac{17}{24}$

iv $\frac{7}{24}$ **v** $\frac{5}{6}$ **vi** $\frac{1}{3}$

9



a $\frac{3}{6}\times\frac{2}{5}\times\frac{1}{4}=\frac{1}{20}$

b $P(\text{R, R, W}) + P(\text{R, W, R}) + P(\text{W, R, R})$

$= 3 \times P(\text{R, R, W})$

$= 3 \times \frac{3}{6}\times\frac{2}{5}\times\frac{3}{4}=\frac{9}{20}$

c $1 - P(\text{not red}) = 1 - \frac{3}{6}\times\frac{2}{5}\times\frac{1}{4}=\frac{19}{20}$

10 **a** **i** 0.17 **ii** 0.11 **iii** 0.83

b **i** 0.1445 **ii** 0.0965 **iii** 0.8555

Exercise 4G

1 **a** yes **b** no **c** no

d yes **e** yes

2 **a** with **b** without

3 yes

4 **a** $\frac{1}{2}$ **b** $\frac{1}{2}$

5 **a** $P(A) = \frac{3}{5}$, $P(A|B) = \frac{2}{5}$, not independent

b $P(A) = \frac{1}{3}$, $P(A|B) = \frac{1}{3}$, independent

c $P(A) = \frac{1}{2}$, $P(A|B) = \frac{1}{2}$, independent

6 **a** $\frac{1}{8}$ **b** $\frac{1}{64}$ **c** $\frac{1}{216}$

7 If we assume that the ‘1 in 6’ claim is true and they are chosen from a very large pool, then:

a Tilly is incorrect because she might be unlucky.

b Cody is incorrect since the probability is still $\frac{1}{6}$.

c It is possible to win six times in a row, although it is unlikely in this case.

8 **a** $\frac{1}{32}$ **b** $\frac{31}{32}$ **c** $\frac{31}{32}$

9 **a** $\frac{1}{6}$ **b** $\frac{5}{36}$ **c** $\frac{671}{1296} = 0.52$

Puzzles and games

1 MUTUALLY EXCLUSIVE

2 $\frac{1}{6}$

3 Results may vary.

4 a $\frac{1}{12}$ **b** $\frac{1}{2}$ **c** $\frac{3}{4}$ **d** $\frac{2}{3}$

5 $\frac{3}{5}$

6 $\frac{1}{12}$

Multiple-choice questions

1 C	**2** C	**3** A	**4** D	**5** C
6 B	**7** B	**8** E	**9** A	

Short-answer questions

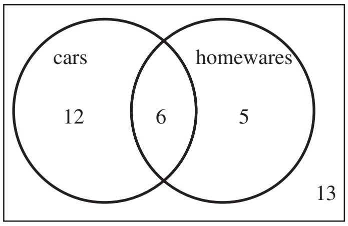
1 a $\frac{1}{6}$ **b** $\frac{1}{2}$ **c** $\frac{2}{3}$

2 a $\frac{1}{8}$ **b** $\frac{1}{4}$ **c** $\frac{3}{8}$ **d** $\frac{5}{8}$ **e** $\frac{1}{2}$

3 a i $\frac{2}{5}$ **ii** $\frac{1}{4}$ **iii** $\frac{1}{5}$ **iv** $\frac{1}{10}$ **v** $\frac{1}{20}$

b i $\frac{3}{5}$ **ii** $\frac{17}{20}$

4 a



b

	C	not C	
H	6	5	11
not H	12	13	25
	18	18	36

c 13

d i $\frac{1}{6}$ **ii** $\frac{5}{36}$ **iii** $\frac{1}{2}$

5 a 8 **b** $\frac{6}{13}$

6 a $\frac{2}{5}$ **b** $\frac{1}{5}$

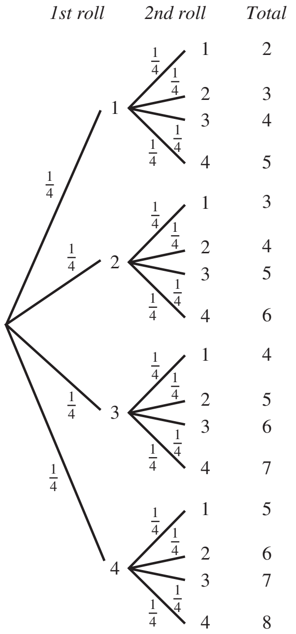
7 a

		1st				
		H	A	P	P	Y
2nd	H	(H, H)	(A, H)	(P, H)	(P, H)	(Y, H)
	E	(H, E)	(A, E)	(P, E)	(P, E)	(Y, E)
	Y	(H, Y)	(A, Y)	(P, Y)	(P, Y)	(Y, Y)

b 15

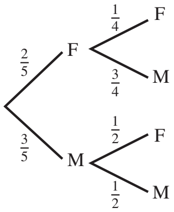
c i $\frac{1}{15}$ **ii** $\frac{2}{15}$ **iii** $\frac{13}{15}$

8 a



b i $\frac{1}{16}$ **ii** $\frac{1}{4}$ **iii** 0 **iv** 1

9



a $\frac{2}{5}$ **b** $\frac{3}{4}$ **c** $\frac{3}{10}$ **d** $\frac{3}{5}$ **e** $\frac{7}{10}$

10 a $\frac{7}{11}, \frac{2}{5}$, no **b** $\frac{1}{2}, \frac{1}{2}$, yes

Extended-response questions

1 a 8 **b i** $\frac{7}{15}$ **ii** $\frac{1}{15}$

c

	R	not R	
S	3	1	4
not S	3	8	11
	6	9	15

d i $\frac{1}{2}$ **ii** $\frac{3}{4}$

2 a

		1st		
		R	S	W
2nd	R	(R, R)	(S, R)	(W, R)
	S	(R, S)	(S, S)	(W, S)
	W	(R, W)	(S, W)	(W, W)

b i $\frac{1}{9}$ **ii** $\frac{1}{3}$ **iii** $\frac{5}{9}$ **iv** $\frac{4}{9}$

c 4 **d** $\frac{5}{9}$

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Chapter 5

Pre-test

1 a J b G c R d K
e L f I g A h H
i F j B k C l M
m O n D o E p P
q Q r N
2 a 8 b 40 c 82 d 13
3 a 6
b i 19 ii 23
c 30 d 10%
4 a 8 b 8.5 c 5 d 8
5 a i mean = 45 ii mode = 41
iii median = 41 iv range = 20
b i mean = 6 ii mode = 2
iii median = 6 iv range = 10
6 a 15 g
b 111 g, 139 g are most frequent.
c min = 98 g, max = 145 g
d 47 g

Exercise 5A

1 Check with your teacher.
2 a E b F c A d B
e H f D g G h C
3 a B b E c C
d D e F f A
4 C
5 D
6 a numerical and discrete
b numerical and discrete
c categorical and nominal
d numerical and continuous
e categorical and ordinal
7 D
8 C
9 D
10 a Carrying out survey at a train station will create a very high proportion of train users in survey's results.
b Survey will reach only those people who use computers.
c Survey will access only people over 18 years of age.
11 Check with your teacher.
12 Check with your teacher.

Exercise 5B

1 a numerical
b categorical (nominal)
c categorical (ordinal)
d numerical

2 a

Car colour	Tally	Frequency
Red	𝍷𝍷𝍷	3
White	𝍸	5
Green	𝍷𝍷	2
Silver	𝍷𝍷	2
Total	**12**	**12**

b

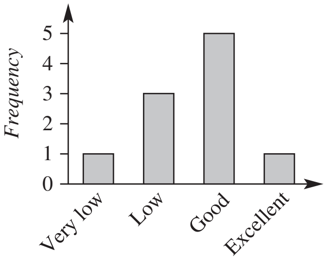
Class interval	Frequency	Percentage frequency
80–84	8	16%
85–89	23	46%
90–94	13	26%
95–100	6	12%
Total	**50**	**100%**

3 a i

Application	Tally	Frequency
Very low	𝍷	1
Low	𝍷𝍷𝍷	3
Good	𝍸	5
Excellent	𝍷	1
Total	**10**	**10**

ii

Student level of application

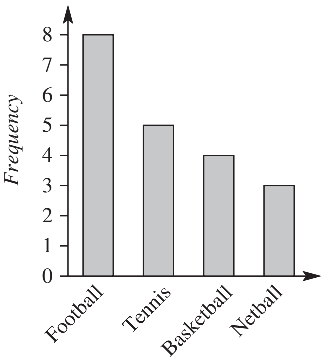


b i

Favourite sport	Tally	Frequency
Football	𝍸 𝍷𝍷𝍷	8
Tennis	𝍸	5
Basketball	𝍷𝍷𝍷𝍷	4
Netball	𝍷𝍷𝍷	3
Total	**20**	**20**

ii

Class favourite sport



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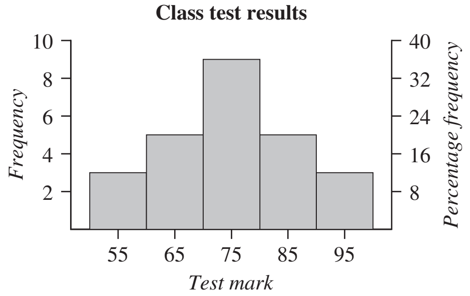
4 a

Class interval	Tally	Frequency	Percentage frequency
50–59	|||	3	12%
60–69	卌	5	20%
70–79	卌 ||||	9	36%
80–89	卌	5	20%
90–99	|||	3	12%
Total	**25**	**25**	**100%**

b

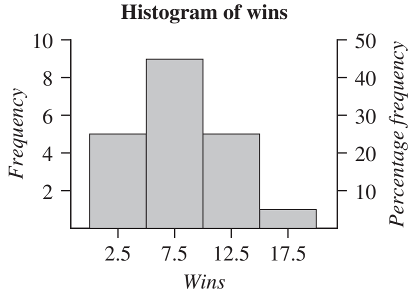


c the 70–79 interval **d** 32%

5 a

Class interval	Tally	Frequency	Percentage frequency
0–4	卌	5	25%
5–9	卌||||	9	45%
10–14	||||	5	25%
15–19			1	5%
Total		**20**	**100%**

b



c the 5–9 interval **d** 75%

6 a

Type of transport	Frequency	Percentage frequency
Car	16	40%
Train	6	15%
Ferry	8	20%
Walking	5	12.5%
Bicycle	2	5%
Bus	3	7.5%
Total	**40**	**100%**

b **i** 6 **ii** car **iii** 40%
iv 17.5% **v** 42.5%

7 a skewed **b** symmetrical

8 a

Mass	Frequency	Percentage frequency
10–14	3	6%
15–19	6	12%
20–24	16	32%
25–29	21	42%
30–34	4	8%
Total	**50**	**100%**

b 50 **c** 32%

d At least 25 g but less than 30 g.

e 42% **f** 94%

9 a

Section	Frequency	Percentage frequency
Strings	16	45.7%
Woodwind	8	22.9%
Brass	7	20%
Percussion	4	11.4%
Total	**35**	**100%**

b 40 **c** 52.5% **d** 47.5% **e** 9.3%

10 Frequencies of individual scores are lost if the histogram displays only categories of scores.

11 a Russia; ~ 14 years **b** Pakistan

c In nearly all countries, the female life expectancy is more than that for males.

d Living conditions in some areas; a high prevalence of HIV/AIDS.

12 a Saturday and Sunday; vendor would expect greater sales at the weekend

b May have been a particularly warm day or a public holiday

c **i** Wednesday; $250 **ii** Thursday

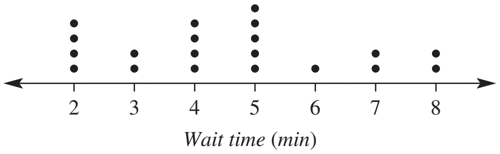
d The graph does not help us to visualise the profit and loss.

Exercise 5C

1 a histogram **b** dot plot

c column graph **d** stem-and-leaf

2



3 a 32, 35, 41, 43, 47, 54, 54, 56, 60, 62, 71, 71

b 2, 3, 7, 14, 14, 18, 19, 23, 26, 26, 30, 35

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4

Stem	Leaf
10	1 1 4 8
11	0 3 3 6
12	2 3 7
13	0 2 9

5 a 11 **b** 1 **c** 16

d One family had 3 children but the data were generally symmetrical.

6 a 9 **b** 39

c He had one bad hole with 7 strokes, but generally the data were consistent, between 3 and 5 strokes.

7 a i

Stem	Leaf
1	5 5
2	0 1 2 4 5 6 6
3	1 7 7 8
4	6
5	2

1|5 means 15

ii skewed

b i

Stem	Leaf
1	2 6
2	1 3 5 7
3	1 2 5 5 6 6 8
4	0 0 2 4 8
5	1 3 5

3|2 means 32

ii symmetrical

c i

Stem	Leaf
11	6 7 8 9
12	1 4 5 7
13	3 5 7
14	5 7 9
15	3 8
16	0 2

13|5 means 135

ii skewed

d i

Stem	Leaf
2	0
3	3 7 8
4	3 4 5 7 8 9
5	2 4 5 8
6	1 3 5
7	0

3|7 means 3.7

ii symmetrical

8 a i

Set 1 leaf	Stem	Set 2 leaf
9 8	3	2 5
8 6 3 2 2 0	4	1 7 7
9 7 3 3	5	2 2 5 6
4 1	6	0 1 3 4 7

5|2 means 52

ii Set 1 is symmetrical, whereas set 2 is skewed with more data at the higher end.

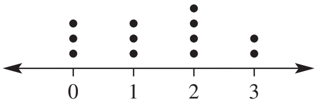
b i

Set 1 leaf	Stem	Set 2 leaf
8 6 4	16	0 3 3 5 7
6 5 2 1	17	0 1 1 4 8
8 7 7 5 1 0	18	2 2 6 7
9 5 2	19	0 4
8 1	20	

19|5 means 195

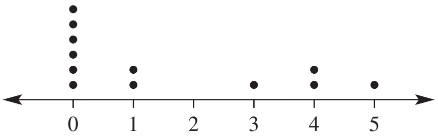
ii Set 1 is symmetrical, whereas set 2 is skewed with most of the data at the lower numbers.

9 a



Nick's goal scoring

b



Jack's goal scoring

c well-spread performance

d irregular performance, skewed

10 a 4.1 min

b ~22.5 min

c This would increase the average time.

11 a

Inner city leaf	Stem	Outer suburb leaf
9 6 4 3 1 1	0	3 4 9
9 4 2 0	1	2 8 8 9
4 1	2	1 3 4
	3	4
	4	1

2|1 means 21 km

b For the inner city, the data are closer together and bunched around the lower distances. The outer-suburb data are more spread out.

c In the outer suburbs, students will be travelling greater distances to their school, whereas at inner-city schools they are more likely to live close to the school.

12 a $a = 3$, $b = 9$, $c = 7$ or 8
  b $a = 0$ or 1, $b = 0$, 1, 2, 3, 4 or 5

13 a The stem 1 is allocated the leaves 0–4 (included) and 1* is allocated 5–9 (included).
  b i 1
    ii 0*
  c For city B, for example, most temperatures are in the 20s; splitting into 20–24 and 25–29 allows better analysis of the data and still means that a stem-and-leaf plot is an appropriate choice of graph.
  d City A experienced cooler weather, with temperatures between 8°C and 18°C. City B had warmer weather and a wider range of temperatures, between 17°C and 31°C.
  e The cities may have been experiencing different seasons; maybe winter and summer.

Exercise 5D

1 a mode **b** mean **c** median
  d bimodal **e** range

2 a 4 **b** 4.5 **c** 3.2

3 a 7 **b** 10 and 14

4 a 28 **b** 7 **c** 4

5 a i 5.4 **ii** 8 **iii** 6
  b i 16.25 **ii** 10 **iii** 45
  c i 70 **ii** 50, 90 **iii** 40
  d i 25 **ii** no mode **iii** 18
  e i 2.325 **ii** 1.9 **iii** 1
  f i 1.6 **ii** no mode **iii** 1.2

6 a 7 **b** 4 **c** 11 **d** 75
  e 7 **f** 5 **g** 33.5 **h** 3.15

7 a 7 **b** 6 **c** 7 **d** 6

8 a \$42 **b** \$17.50 **c** \$20.75
  d Due to the \$50 value, which is much larger than the other amounts.

9 a i 25 **ii** 39 **iii** 34.3 **iv** 38
  b i 28 **ii** 4 **iii** 17.2 **iv** 17
  c i 24 **ii** no mode
    iii 110 **iv** 108
  d i 3.2 **ii** 3.0, 5.3 **iii** 4.6 **iv** 4.9

10 a Mark: **i** 83.6 **ii** 85 **iii** 31
  Hugh: **i** 76.4 **ii** 79 **iii** 20
  b Mark's scores varied more greatly, with a higher range, whereas Hugh's results were more consistent. Mark had the higher mean and median, though, as he had several high scores.

11 The median, since the mean is affected by the one large value (\$1 700 000).

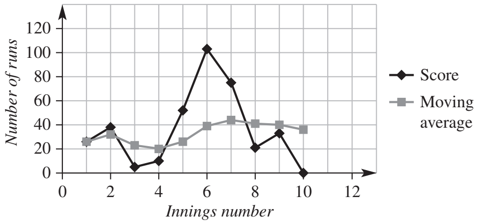
12 a 4
  b 3.7
  c i the median is unchanged in this case
    ii the mean is decreased

13 a 70 **b** 85

14 a

Innings	1	2	3	4	5	6	7	8	9	10
Score	26	38	5	10	52	103	75	21	33	0
Moving average	26	32	23	20	26	39	44	41	40	36

  b



  c i The score fluctuates wildly.
    ii The graph is fairly constant with small increases and decreases.
  d The moving average graph follows the trend of the score graph but the fluctuations are much less significant.

Exercise 5E

1 a min, lower quartile (Q_1), median (Q_2), upper quartile (Q_3), max
  b Range is max − min; IQR is $Q_3 - Q_1$. Range is the spread of all the data, IQR is the spread of the middle 50% of data.
  c An outlier is a data point (element) outside the vicinity of the rest of the data.

2 a $Q_1 - 1.5 \times \text{IQR}$
  b $Q_3 + 1.5 \times \text{IQR}$

3 a 1.5
  b i 1 **ii** 2

4 a 5 **b** −4.5 and 15.5 **c** an outlier

5 a i $Q_1 = 4, Q_3 = 8$ **ii** 4
  b i $Q_1 = 11, Q_3 = 18$ **ii** 7
  c i $Q_1 = 51, Q_3 = 62$ **ii** 11
  d i $Q_1 = 1.8, Q_3 = 2.7$ **ii** 0.9

6 a i $Q_1 = 2, Q_3 = 11$ **ii** 9
  b i $Q_1 = 2, Q_3 = 10$ **ii** 8
  c i $Q_1 = 1.0, Q_3 = 1.6$ **ii** 0.6
  d i $Q_1 = 10.5, Q_3 = 22.5$ **ii** 12

7 a i min = 0, max = 17
    ii median = 13
    iii $Q_1 = 10, Q_3 = 15$
    iv IQR = 5
  b 0 is an outlier
  c Road may have been closed that day.

8 a i min = 4, max = 14 **ii** 7.5
    iii $Q_1 = 5, Q_3 = 9$ **iv** IQR = 4
    v no outliers
  b i min = 16, max = 31 **ii** 25
    iii $Q_1 = 21, Q_3 = 27$ **iv** IQR = 6
    v no outliers

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c **i** min = 2, max = 24 **ii** 12
iii $Q_1 = 10, Q_3 = 13$ **iv** IQR = 3
v 24 and 2

d **i** min = 1, max = 17 **ii** 7
iii $Q_1 = 4, Q_3 = 10$ **iv** IQR = 6
v no outliers

9 **a** **i** min = 25, max = 128 **ii** 47
iii $Q_1 = 38, Q_3 = 52.5$ **iv** IQR = 14.5
v yes, 128 **vi** 51.25

b Median, as it is not affected dramatically by the outlier.

c A more advanced calculator was used.

10 2 bags; 30 and 31 will be checked

11 2 fridges; 350 and 1700 are outliers

12 **a** IQR = 10

b Yes, 1 is an outlier.

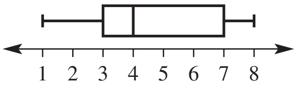
c no

Exercise 5F

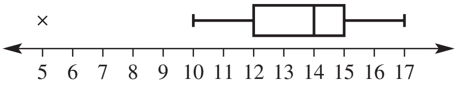
1 **a** minimum **b** Q_1
c Q_2 (median) **d** Q_3
e maximum **f** whisker
g box

2 **a** 15 **b** 5 **c** 25 **d** 20
e 10 **f** 20 **g** 10

3 **a**



b



4 **a** Q_3

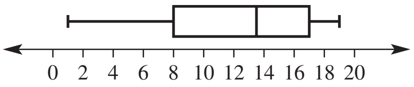
b Q_1, Q_3

c minimum, Q_1

d Q_3, maximum

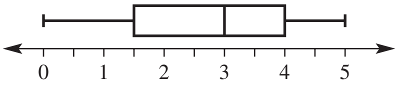
5 **a** **i** min = 1, $Q_1 = 8$, $Q_2 = 13.5$, $Q_3 = 17$, max = 19

ii



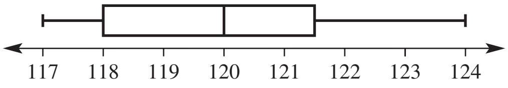
b **i** min = 0, $Q_1 = 1.5$, $Q_2 = 3$, $Q_3 = 4$, max = 5

ii



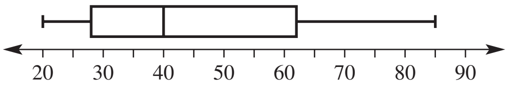
c **i** min = 117, Q_1 = 118, Q_2 = 120, Q_3 = 121.5, max = 124

ii



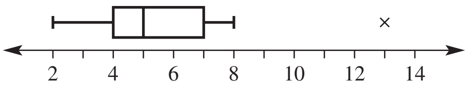
d **i** min = 20, $Q_1 = 28$, $Q_2 = 40$, $Q_3 = 62$, max = 85

ii



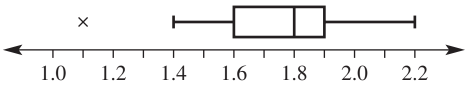
6 **a** **i** $Q_1 = 4, Q_2 = 5, Q_3 = 7$ **ii** outlier is 13

iii



b **i** $Q_1 = 1.6, Q_2 = 1.8, Q_3 = 1.9$ **ii** outlier is 1.1

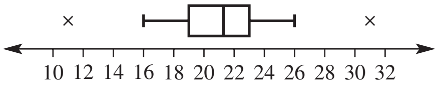
iii



c **i** $Q_1 = 19, Q_2 = 21.5, Q_3 = 23$

ii Outliers are 11 and 31.

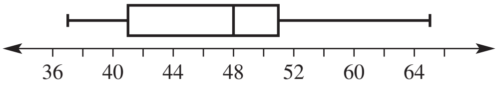
iii



d **i** $Q_1 = 41, Q_2 = 48, Q_3 = 51$

ii no outliers

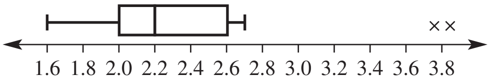
iii



7 **a** **i** minimum = 1.6 **ii** $Q_1 = 2.0$ **iii** $Q_2 = 2.2$
iv $Q_3 = 2.6$ **v** maximum = 3.9 **vi** IQR = 0.6

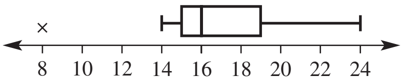
b 3.8 and 3.9 are outliers.

c



8 **a** **i** 8 **ii** 15 **iii** 16 **iv** 19
v 24 **vi** 4 **b** yes, 8

c



9 **a** Same minimum of 1.

b B **c** **i** 5 **ii** 10

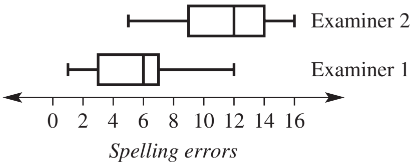
d Data points for set B are more evenly spread than those for set A.

10 **a** They have the same median and upper quartile.

b B **c** **i** 4 **ii** 5

d Data set B is more spread out.

11 **a**



b Yes, examiner 2 found more errors.

Exercise 5G

1 **a** linear **b** no trend
c non-linear **d** linear

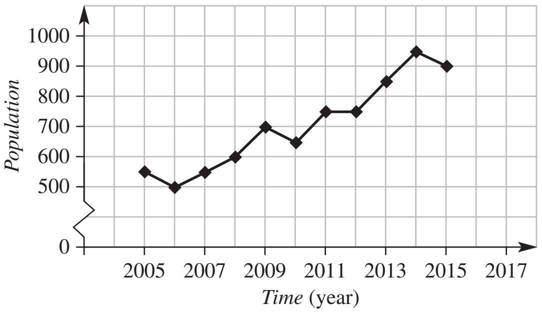
2 **a** **i** 20°C **ii** 30°C **iii** 30°C **iv** 34°C

b 36°C

c **i** 12 noon to 1 p.m. **ii** 3 to 4 p.m.

d Temperature is increasing from 8 a.m. to 3 p.m. in a generally linear way. At 3 p.m. the temperature starts to drop.

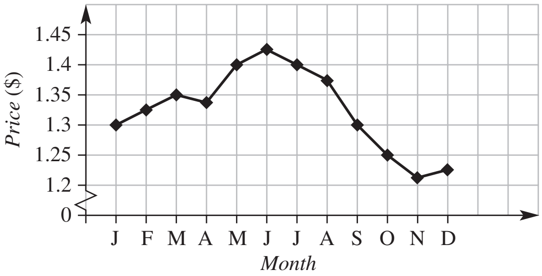
3 a Population of town



b Generally linear in a positive direction.

c **i** 500 **ii** 950

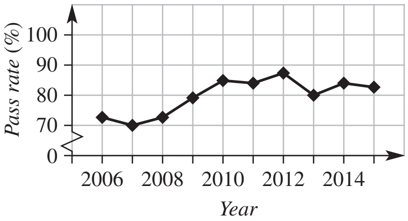
4 a Share price over the year



b The share price generally increased until it peaked in June and then continually decreased to a yearly low in November before trending upwards again in the final month.

c $0.21

5 a Exam pass rate



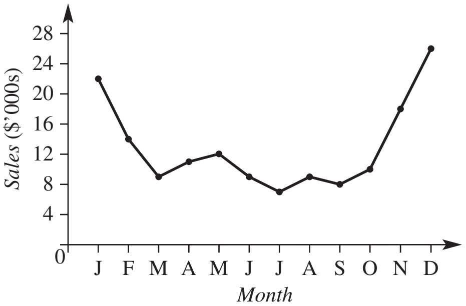
b The pass rate for the examination has increased marginally over the 10 years, with a peak in 2012.

c 2012 **d** 11%

6 a linear

b **i** $650 000 **ii** $750 000

7 a Strawberry sales



b The sales start high and decrease during the middle of the year, before increasing again towards the end of the year.

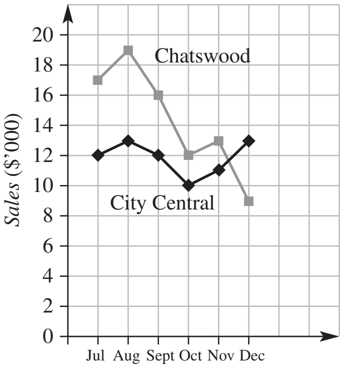
c Strawberries are in season in the warmer months, but not in the cooler winter months.

8 a **i** $6000

ii $4000

b 1

c



d **i** The sales trend for City Central for the 6 months is fairly constant.

ii Sales for Chatswood peaked in August before taking a downturn.

e about $5000

9 a **i** 5.8 km

ii 1.7 km

b **i** Blue Crest slowly gets closer to the machine.

ii Green Tail starts near the machine and gets farther from it.

c 8:30 p.m.

10 a **i** Intended to give impression that employment has been increasing in the 10-year period.

ii Intended to give impression that employment has fluctuated over the 10-year period, with some dramatic drops. In particular, that there has been an overall drop during the 10 years in government.

b The two graphs use a different reference point. To give a good impression, graph **i** bases the percentage increase by comparing with the first year in government, to reflect the increasing number of people in employment. To suggest a decline in employment, graph **ii** bases the percentage increase (or decrease) by comparing with the previous year. So, if employment doesn't increase by as much in a year as in the previous year, there will be a drop in the graph.

c Graph **i** because it does represent an increase in the number of people employed; it does also reflect when there is a drop in the number of people employed.

Exercise 5H

1 a likely **b** likely **c** unlikely

d unlikely **e** likely

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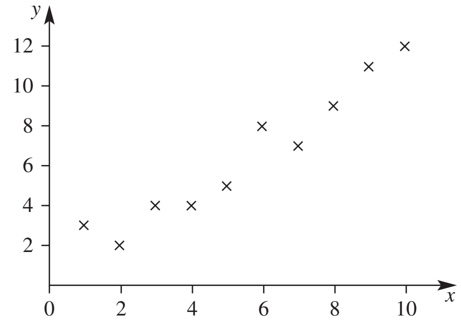
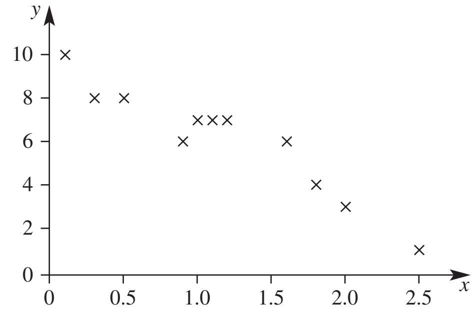
2 **a** **i**



ii *y* generally increases as *x* increases.

b **i**



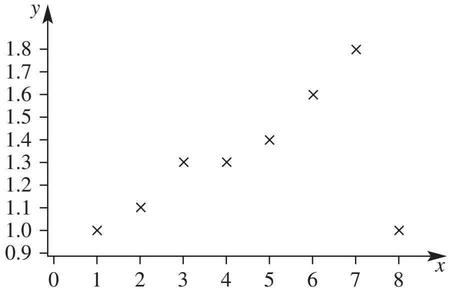
ii *y* generally decreases as *x* increases.

3 **a** weak negative

b strong positive

c strong negative

4 **a**

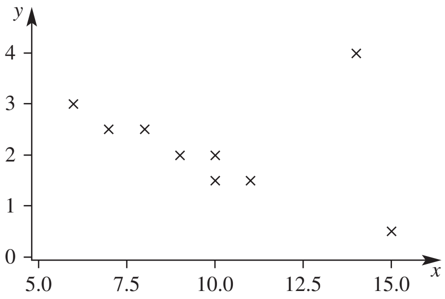


b positive

c strong

d (8, 1.0)

5 **a**

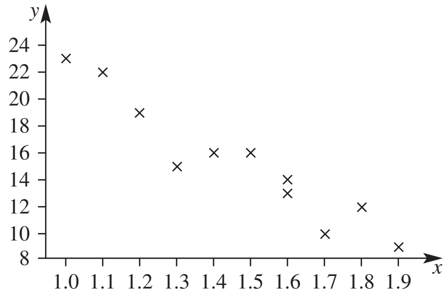


b negative

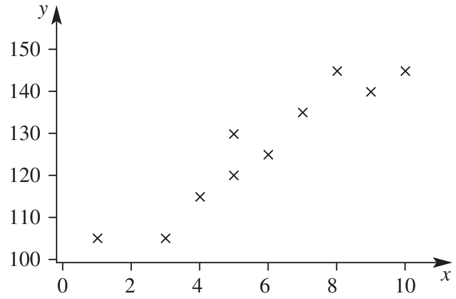
c strong

d (14, 4)

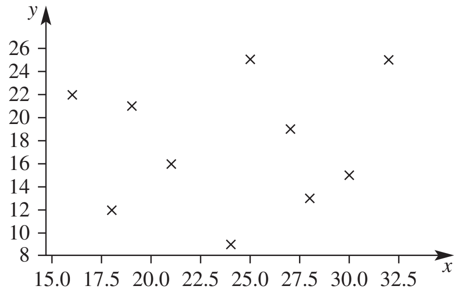
6 **a** negative



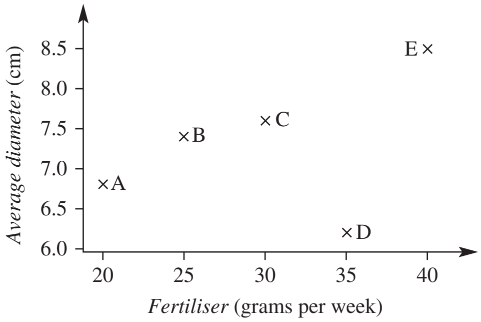
b positive



c none



7 **a**



b D

c Yes, although small sample size does lead to doubt.

8 **a** yes

b decrease

c **i** yes

ii car H

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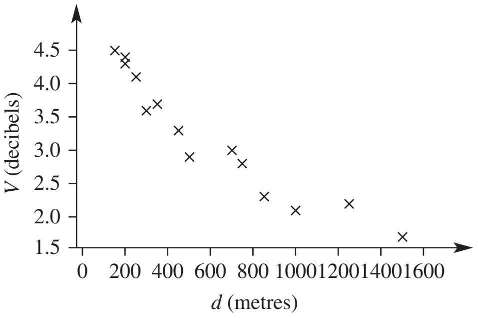
9 **a**

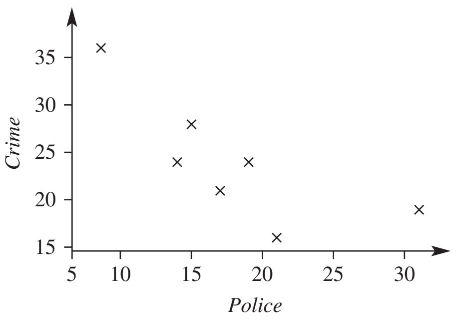


b negative

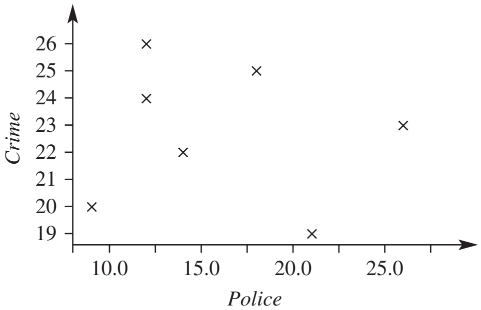
c As d increases, V decreases.

10 Each axis needs a better scale. All data are between 6 and 8 hours sleep and shows only a minimum change in exam marks. Also, there are only 4 observations presented on the plot, which is not enough to form strong conclusions.

11 **a** **i** weak negative correlation



ii no correlation



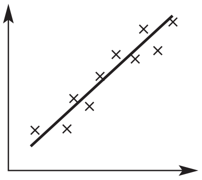
b Survey 1, as this shows an increase in the number of police has seen a decrease in the incidence of crime.

Exercise 5I

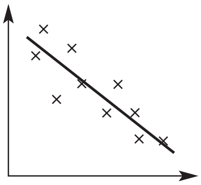
1 **a** When the data appear to fit on or near a straight line, they show a definite linear trend.

b Balance the number of points evenly either side of the line; ignore outliers when taking distance from the line into account.

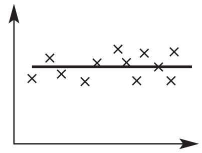
2 **a**



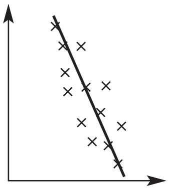
b



c



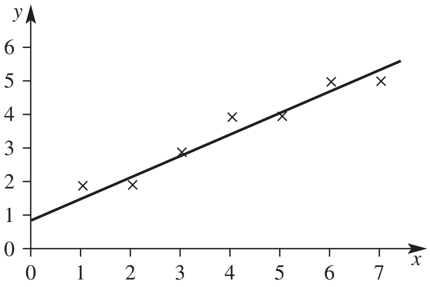
d



3 **a** ≈ 5.3 **b** ≈ 7

4 **a** $x \approx 1.5$ **b** $x \approx 11.7$

5 **a**

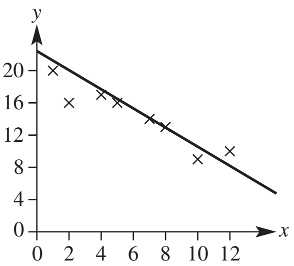


b positive correlation **c** as above

d All answers are approximate.

i 3.2 **ii** 0.9 **iii** 1.8 **iv** 7.4

6 **a**



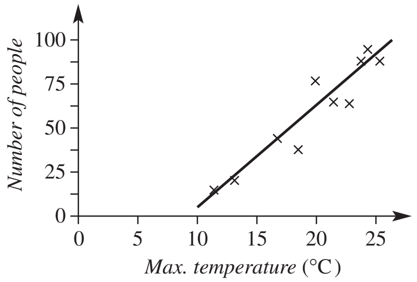
b negative **c** as above

d **i** 13.5 **ii** 23 **iii** 9 **iv** 7

7 **a** ≈ 4.5 **b** ≈ 6 **c** ≈ 0.5 **d** ≈ 50

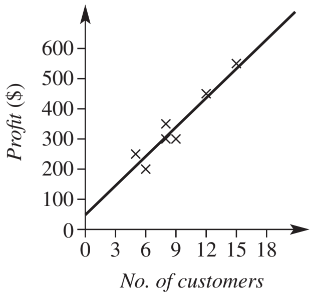
8 **a** increases

b



c **i** 65 **ii** approx. 13°C

9 **a, b**



c $600 **d** 2

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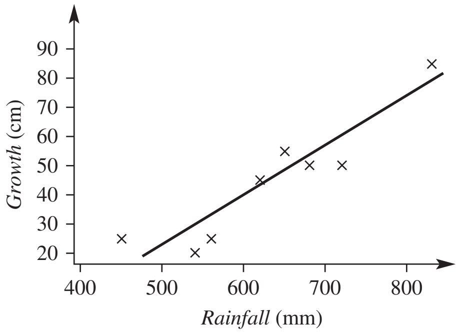
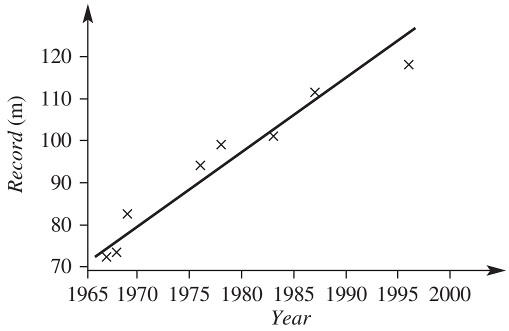
10 a, b



c **i** ≈ 25 cm **ii** ≈ 85 cm

d **i** ≈ 520 mm **ii** ≈ 720 mm

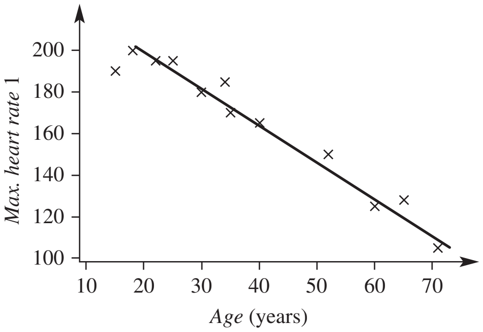
11 a, b



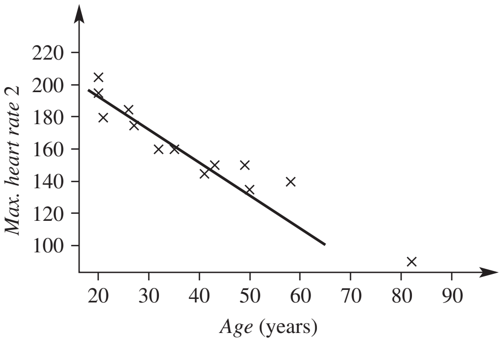
c **i** 130 m **ii** 170 m

d No, records are not likely to continue to increase at this rate.

12 a **Experiment 1**



Experiment 2



b **i** ≈ 140 **ii** ≈ 125

c **i** ≈ 25 **ii** ≈ 22

d experiment 2 **e** Student's own research.

Puzzles and games

1 66 kg

2 88%

3 8

4 **a** larger by 3 **b** larger by 3 **c** no change

5 1.1

6 3, 3, 9, 11

7 19

8 mean is × by 10, median is × by 10, mode is × by 10

Multiple-choice questions

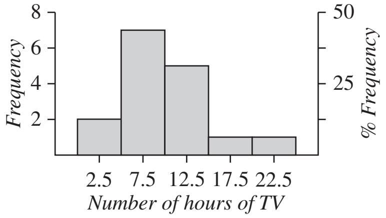
1 D	**2** C	**3** B	**4** A	**5** C
6 A	**7** E	**8** C	**9** D	**10** B

Short-answer questions

1 **a**

Class interval	Tally	Frequency	Percentage frequency
0–4	||	2	12.5%
5–9	卌||	7	43.75%
10–14	卌	5	31.25%
15–19	|	1	6.25%
20–24	|	1	6.25%
Total		**16**	**100%**

b



c It is skewed.

2 **a**

Stem	Leaf
1	5 9
2	0 4 8 9
3	2 4 7 8 8
4	2 9
5	0

3|2 means 32

b The data are symmetrical about scores in the 30s.

3 **a** **i** 5 **ii** 6 **iii** 5

b **i** 30.5 **ii** 57 **iii** 20

c **i** 1.6 **ii** 1.2 **iii** 1.5

4 **a** 43.2 years **b** 38 years

c The mean is affected by the high ages 76 and 87.

5 **a** $Q_1 = 8, Q_2 = 11, Q_3 = 15$

b $Q_1 = 8, Q_2 = 13, Q_3 = 15.5$

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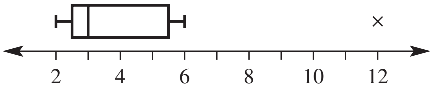
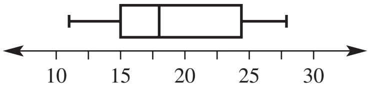
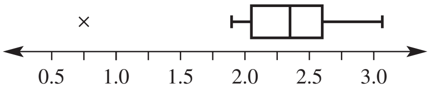
6 **a** **i** $Q_1 = 2.5, Q_3 = 5.5$
ii 3 **iii** 12
iv



b **i** $Q_1 = 15, Q_3 = 24$
ii 9 **iii** none
iv



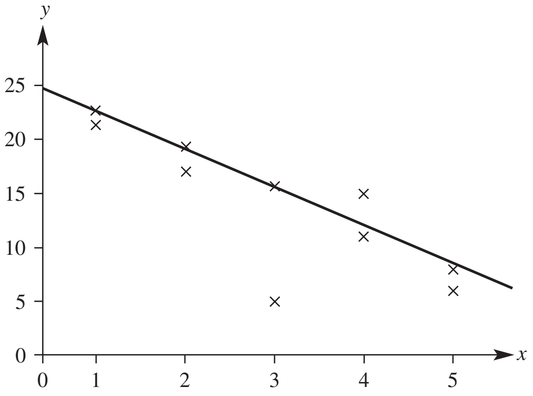
c **i** $Q_1 = 2.1, Q_3 = 2.6$
ii 0.5 **iii** 0.7
iv



7 **a** false **b** true **c** true **d** true

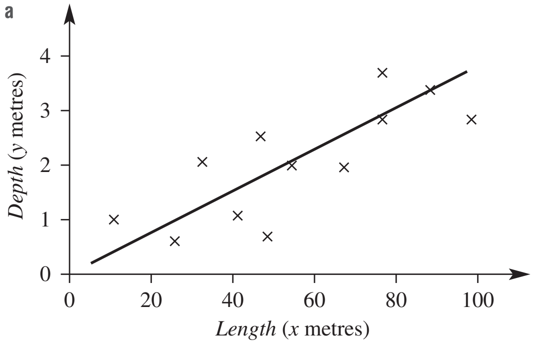
8 **a** negative **b** none **c** positive

9 **a, e**



b negative **c** strong **d** (3, 5)

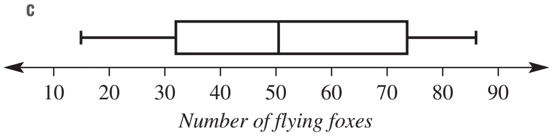
10 **a**



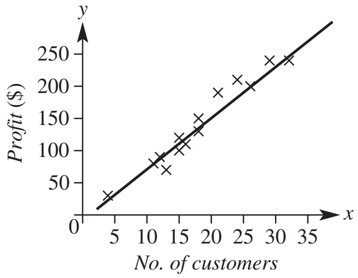
b 1.8 m

Extended-response questions

1 **a** 41 **b** no outliers
c



2 **a**



b **i** \$80 **ii** \$150 **iii** \$240
c **i** 7 **ii** 16 **iii** 27

Semester review 1

Financial mathematics

Multiple-choice questions

1 C **2** A **3** C **4** D **5** A

Short-answer questions

1 **a** \$38.64 **b** \$51.52
c \$978.88 **d** \$1094.80
2 \$889
3 \$351.20
4 \$5392
5 \$597
6 **a** \$102 **b** \$932
7 **a** \$37 180 **b** \$12 833.60
c \$22 829.56 **d** \$439.03
8 \$8837.34

Extended-response question

1 **a** \$711.55
b \$59.92
c **i** \$149.80 **ii** \$832
iii \$83 **iv** 11.08%

Measurement

Multiple-choice questions

1 C **2** E **3** B **4** A **5** D

Short-answer questions

1 **a** 43 cm **b** 320 cm^2 **c** 30 000 cm^3
d 23 000 mm **e** 8000 ms **f** 7.8×10^9 ns
g 0.008 Mt **h** 2.3×10^6 TB
2 **a** 8 cm **b** 44 m **c** 9 m
3 **a** **i** 37.70 cm **ii** 113.10 cm^2
b **i** 14.28 cm **ii** 12.28 cm^2
c **i** 11.14 m **ii** 7.14 m^2

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4 **a** 10.5 m^2 **b** 112 cm^2 **c** 8 m^2

5 **a** **i** 45 cm^3 **ii** 78 m^2
b **i** 30 m^3 **ii** 72 m^2
c **i** 942.48 mm^3 **ii** 534.07 mm^2

6 $A = 169.70$ cm^2, $V = 88.27$ cm^3

7 **a** 6.5 mL to 7.5 mL **b** 8.985 g to 8.995 g
c 699.5 km to 700.5 km **d** 695 km to 705 km

8 **a** 4.25 m and 4.35 m
b 6.75 m to 6.85 m
c perimeter: 22 m to 22.4 m
area: 28.6875 m^2 to 29.7975 m^2

Extended-response question

1 **a** 7.85 m^3 **b** 31.42 m^2 **c** \$1130

Algebraic expressions and indices

Multiple-choice questions

1 C **2** D **3** A **4** D **5** B

Short-answer questions

1 **a** $7xy + 4x$ **b** $-21ab$ **c** $\frac{a}{2}$

2 **a** **i** $-4x + 12$ **ii** $15x^2 + 6x$ **iii** $13x - 6$
b **i** $6(3 - b)$ **ii** $3x(x + 2)$ **iii** $-4y(2x + 3)$

3 **a** $x + 3$ **b** $\frac{3}{4}$ **c** $\frac{9x}{10}$ **d** $\frac{2x - 3}{8}$

4 **a** $10x^6$ **b** $\frac{4x^2}{y^3}$ **c** $8\,m^{12}$ **d** 4
e $\frac{9a^2}{b^8}$ **f** $\frac{3b^2}{a^5}$ **g** $4t^5$ **h** $\frac{2y^2}{x^4}$

5 **a** **i** 473 000 **ii** 0.00521
b **i** 2.76×10^{-5} **ii** 8.71×10^6

Extended-response question

1 **a** $A = 3000(1.06)^n$
b **i** \$3370.80 **ii** \$4255.56
c 11.9 years

Probability

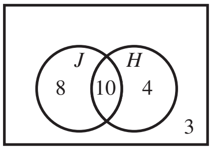
Multiple-choice questions

1 C **2** E **3** A **4** B **5** D

Short-answer questions

1 **a** $\frac{2}{5}$ **b** $\frac{11}{20}$ **c** $\frac{17}{20}$ **d** $\frac{9}{10}$

2 **a**



b

	H	not *H*	Total
J	10	8	18
not *J*	4	3	7
Total	14	11	25

c 3

d **i** $\frac{4}{25}$ **ii** $\frac{22}{25}$ **iii** $\frac{2}{5}$ **iv** $\frac{5}{9}$

3 **a** 36
b **i** $\frac{1}{9}$ **ii** $\frac{1}{6}$ **iii** $\frac{7}{12}$ **iv** $\frac{1}{6}$

4 **a** $\frac{1}{15}$ **b** $\frac{8}{15}$ **c** $\frac{14}{15}$

5 **a** $P(A) = P(A|B) = \frac{1}{3}$, independent
b $P(A) = \frac{5}{8} \neq P(A|B) = \frac{3}{5}$, not independent

Extended-response question

1 **a**

	T	A
T	(T, T)	(A, T)
A	(T, A)	(A, A)

b **i** $\frac{1}{4}$ **ii** $\frac{3}{4}$ **c** $\frac{1}{4}$

Single variable and bivariate statistics

Multiple-choice questions

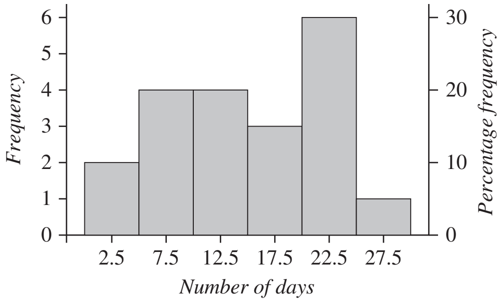
1 A **2** C **3** E **4** B **5** C

Short-answer questions

1 **a**

Class interval	Frequency	Percentage frequency
0–4	2	10%
5–9	4	20%
10–14	4	20%
15–19	3	15%
20–24	6	30%
25–29	1	5%
Total	**20**	**100%**

b



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c **i** 14
ii 50%
iii 20–24 days, those that maybe catch public transport to work or school each week day

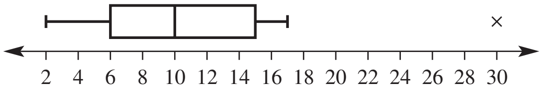
2 **a**

Stem	Leaf
0	4 7 8 9
1	2 5 5 7 8
2	4 4 6
3	2 6
4	1

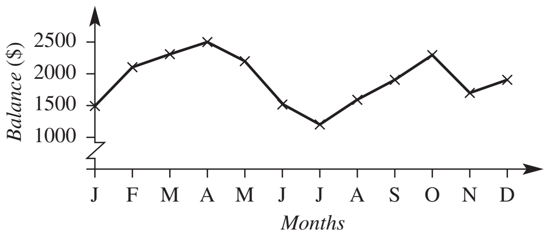
3|6 means 36

b skewed

3 **a** 2 4 6 7 8 10 12 12 15 17 30
b **i** min = 2, max = 30 **ii** 10
iii $Q_1 = 6, Q_3 = 15$ **iv** 9
v yes, 30
c



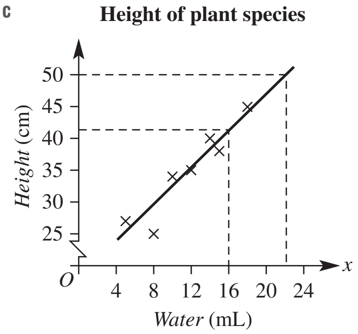
4 **a**



b Balance fluctuated throughout the year but ended up with more money after 12 months.
c May and June
d increase of $500

Extended-response question

1 **a, c**



b positive
d **i** 41 cm
ii 22 mL

Chapter 6

Pre-test

1 **a** (3, 5) **b** (4, −2) **c** (−4, −4)
d (−3, 1) **e** (2, −2) **f** (2, 0)
2 **a** *G* **b** *D* **c** *B*
d *S* **e** *N* **f** *Q*
3 **a** square
b isosceles triangle
c hexagon
4 **a** 11 **b** 19 **c** 10 **d** 3.5
e 0 **f** −1 **g** 3.5 **h** −9
5 **a** 120 min **b** 200 km **c** 100 km/h
6 **a** 5 **b** 13 **c** 10
d 41 **e** 3.61 **f** 8.54
7 **a** 3, 4, 5, 6 **b** −2, −1, 0, 1
c 0, 2, 4 **d** 6, 5, 4
8 **a** 6 **b** 9 **c** 3 **d** 9
e 5 **f** 9 **g** 7 **h** 8
i 2 **j** 4 **k** 2 **l** 10

Exercise 6A

1 **a** 240 km **b** 3 hours **c** 360 km
2 **a** 360 km **b** 4 hours **c** 540 km
3 **a** 300 deer **b** 100 deer **c** 200 deer
4 **a** 1800 people **b** 450 people **c** 1350 people
5 **a** **i** $10 000 **ii** $40 000
b increased **c** $30 000
6 **a** **i** 50 cm **ii** 45 kg
b **i** 10 **ii** 3
7 **a** 80 cm **b** 40 cm
c approx. $2\frac{1}{4}$ months
8 **a** 400 m **b** approx. 250 m
c approx. $3\frac{1}{2}$ days
9 **a** $10 000 **b** $0 **c** 12 years
10 **a** 200 g **b** 200 g
c $2\frac{1}{4}$ h (2 h 15 min)
11 **a** $\frac{1}{2}$ h (30 min)
b **i** 1 p.m. **ii** 1:15 p.m.
iii approx. 1:08 p.m. **iv** 1:30 p.m.
c **i** −120 m **ii** approx. −80 m
d **i** 0 m **ii** −160 m **iii** −280 m
e **i** 12:45 p.m. **ii** 2 p.m. **iii** 2:45 p.m.

Exercise 6B

1 **a** S **b** P **c** Q **d** R
e T **f** S **g** Q

2 **a** 20 km **b** 2 h
c approx. 17 km

3 **a** **i** 40 kg **ii** 50 kg **iii** 80 kg
b $\frac{1}{2}$ h **c** 1st hour

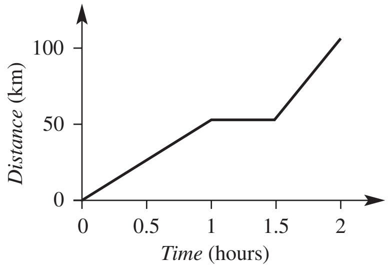
4 **a** 200 m **b** 80 s
c **i** approx. 38 m **ii** 1 m
iii approx. 150 m

5 **a** **i** 3 m **ii** 2 m **iii** 62 m
b the lawn
c **i** 1.5 m **ii** 4 m **iii** 6.5 m

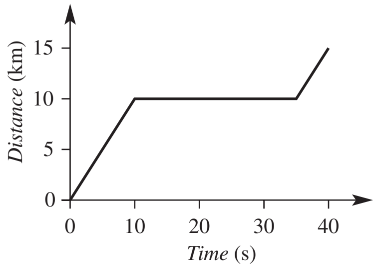
6 **a** **i** 10 s **ii** 17 s **iii** 20 s
b phase 3
c **i** approx. 40 m
ii approx. 85 m
iii approx. 165 m

7 **a** 10 km **b** 20 km
c 27 min **d** 9 min

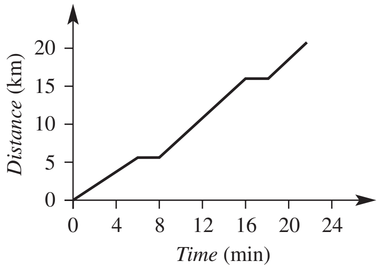
8



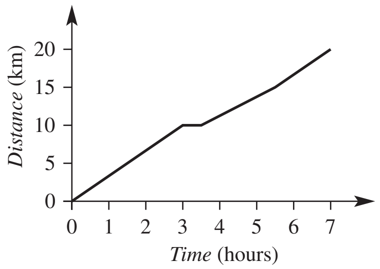
9



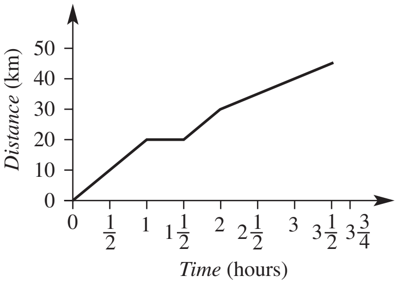
10 **a** 20 km **b** 22 min
c



11

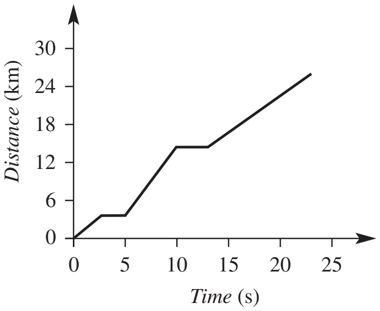


12 **a** **i**



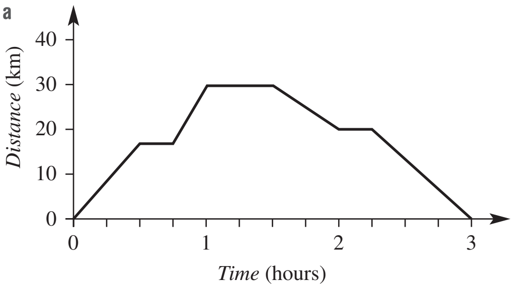
ii 3 h

b **i**



ii 18 s

13 **a**



b 48 km/h
c 30 km/h

Exercise 6C

1 **a** $A(2, 1)$ $B(-3, 3)$ $C(2, -3)$ $D(-4, 0)$ $E(4, 4)$ $F(0, -2)$ $G(3, 0)$ $H(-3, -2)$ $I(1, 4)$ $J(-2, -4)$ $K(-4, 5)$
b D, O, G
c O, F
d (0, 0)

2 **a** $6 + 4 = 10; (-3, 10)$
b $4 + 4 = 8; (-2, 8)$
c $2 + 4 = 6; (-1, 6)$
d $0 + 4 = 4; (0, 4)$
e $-2 + 4 = 2; (1, 2)$
f $-4 + 4 = 0; (2, 0)$
g $-6 + 4 = -2; (3, -2)$

3 $(-2, 1)$ $(-1, -1)$ $(0, -3)$ $(1, -5)$ $(2, -7)$

4 **a** (0, 1) and (2, −3) are not in line with the other points.
b (0, 0) and (2, −2)

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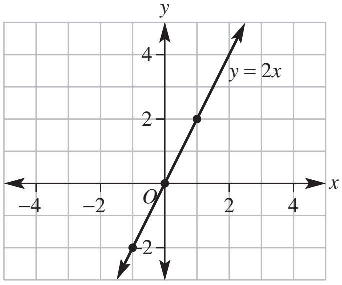
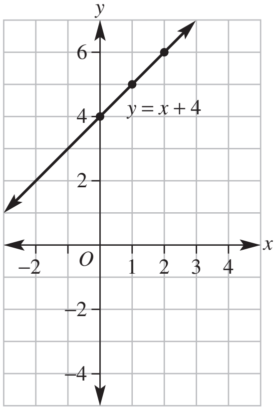
5 **a** $y = 2x$

x	-1	0	1
y	-2	0	2



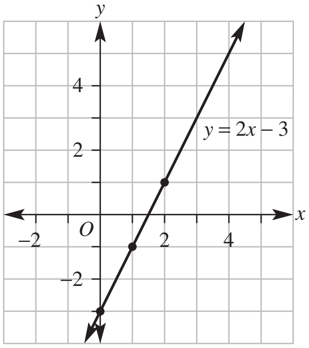
b $y = x + 4$

x	0	1	2
y	4	5	6



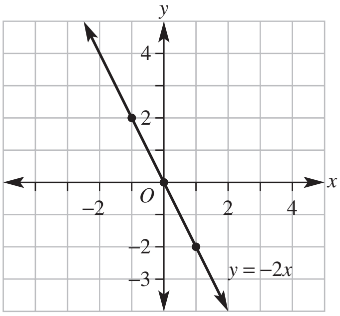
c $y = 2x - 3$

x	0	1	2
y	-3	-1	1



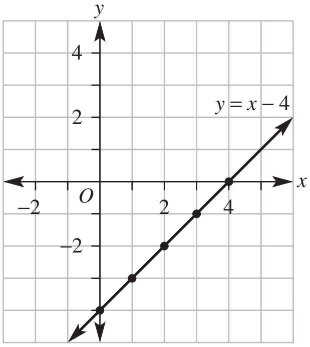
d $y = -2x$

x	0	1	2
y	-3	-1	1



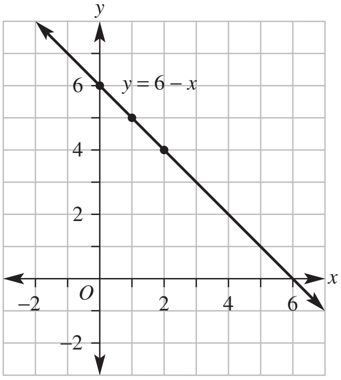
e $y = x - 4$

x	1	2	3
y	-3	-2	-1



f $y = 6 - x$

x	0	1	2
y	6	5	4



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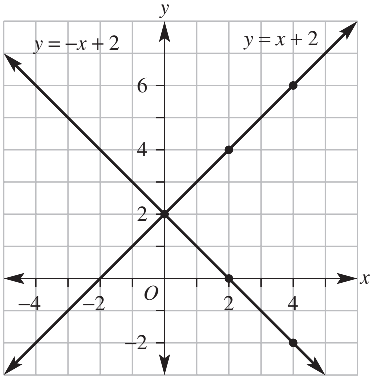
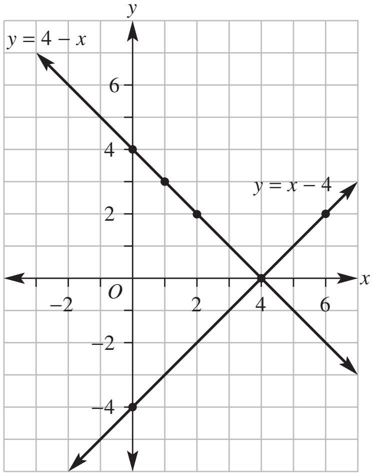
6 a



b



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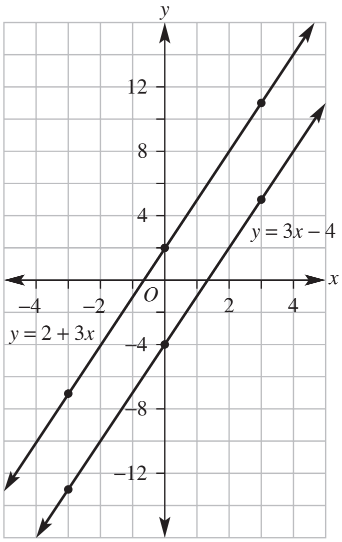
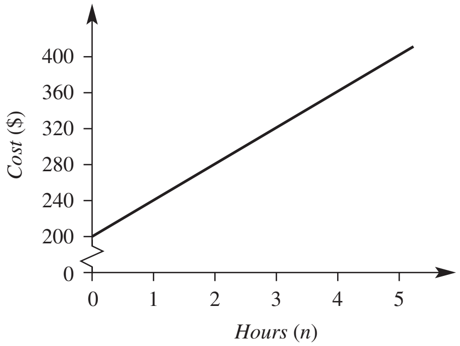


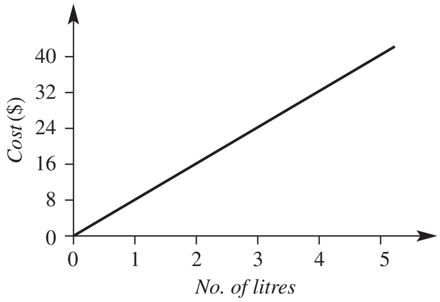
7 a (0, 0) **b** (1, 4) **c** (−1, 3)
d (0, 2) **e** (−1, −5)

8 a



b i \$300 **ii** 4.5 h

9 a

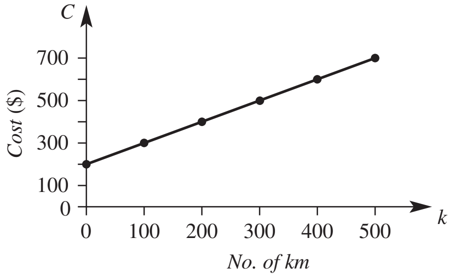


b i \$28 **ii** 2.5 litres

10 a

No. of km (k)	0	100	200	300	400	500
Cost (C)	200	300	400	500	600	700

b

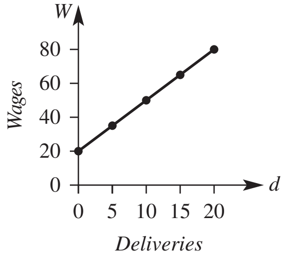


c i \$450 **ii** 450 km

11 a

No. of deliveries (d)	0	5	10	15	20
Wages (W)	20	35	50	65	80

b



c i \$56 **ii** 18

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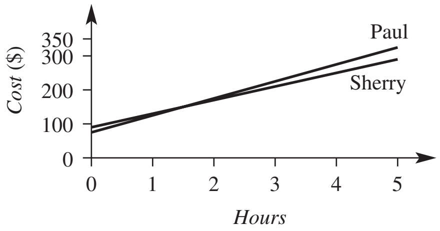
12 a Paul

No. of hours work	0	1	2	3	4	5
Cost (C)	75	125	175	225	275	325

Sherry

No. of hours work	0	1	2	3	4	5
Cost (C)	90	130	170	210	250	290

b



c **i** \$250 **ii** \$150 **iii** 0.5 hours
iv 4.25 hours **v** 1.5 hours

d Paul is cheaper only for 1.5 hours or less.

Exercise 6D

1 a Pythagoras' theorem: $c^2 = a^2 + b^2$
b 13 m **c** 6 m
d 2.5 m **e** middle, middle
2 a $\sqrt{20}$ **b** $\sqrt{18}$
3 a (3.5, 5) **b** (3, 4) **c** (0, −1) **d** $\left(\frac{1}{2}, \frac{1}{2}\right)$
4 a 5 **b** $\sqrt{41}$ **c** 5 **d** $\sqrt{74}$
5 a $\sqrt{13}$ **b** $\sqrt{18}$ **c** $\sqrt{29}$
d $\sqrt{29}$ **e** $\sqrt{13}$ **f** $\sqrt{25} = 5$
6 a 5 **b** 10 **c** 11.2 **d** 5.7 **e** 5 **f** 3.6
7 a $\sqrt{2}$ **b** $\sqrt{13}$ **c** $\sqrt{34}$ **d** $\sqrt{89}$ **e** $\sqrt{26}$ **f** $\sqrt{10}$
8 a (2, 5) **b** (4, 8) **c** (3, 5)
d (2.5, 4.5) **e** (6, 2.5) **f** (2.5, 4)
g (−1, −2) **h** (−3, −4) **i** (−4, −3)
j (1, 1) **k** (−3, −4) **l** (0, 0)
9 (−2, −5)
10 a $A(1, 4)$, $B(6, 4)$, $C(6, 1)$, $D(1, 1)$
b (3.5, 2.5) **c** (3.5, 2.5)
d The diagonals of a rectangle bisect (i.e. cut in half) each other.
11 b i 5 **ii** 5
c isosceles
d $P = 16$ units, $A = 12\,\text{units}^2$
e (4, 0)
12 a (3, 4) **b** $\sqrt{13}$
c $\sqrt{13}$; length of radius
d 22.7 units **e** $40.8\,\text{units}^2$

Exercise 6E

1 a zero **b** negative
c positive **d** undefined
2 a + **b** − **c** + **d** − **e** −
f + **g** + **h** − **i** −
3 a 1 **b** $\frac{1}{4}$ **c** $-\frac{3}{5}$
4 a $-\frac{3}{8}$ **b** $\frac{1}{15}$ **c** −3
5 a 2 **b** 5 **c** −3
d −2 **e** $\frac{4}{3}$ **f** 0
g 0 **h** undefined **i** undefined
6 $EF\,\frac{2}{3}$, $GH\,\frac{2}{3}$, $DC\,1$, $AB\,\frac{3}{2}$
7 a 3 **b** 2 **c** $-\frac{1}{2}$
d −1 **e** 0 **f** undefined
8 a

Line segment	Rise	Run	Gradient
AB	1	2	$\frac{1}{2}$
AC	2	4	$\frac{1}{2}$
AD	3	6	$\frac{1}{2}$
BC	1	2	$\frac{1}{2}$
BD	2	4	$\frac{1}{2}$
CD	1	2	$\frac{1}{2}$

b They have the same gradient.
9 a 2 **b** $\frac{1}{2}$ **c** −1
d −2 **e** 1 **f** $-\frac{2}{5}$
10 a 1 **b** 1 **c** $-\frac{3}{5}$
d 0 **e** 11 **f** $\frac{1}{3}$
11 gradient = 0.344
12 a A, D **b** C, E, G **c** D **d** B, F, H
e G **f** Answers will vary.

Exercise 6F

1 a gradient **b** two **c** units
d km/h **e** L/min
2 a 90 km/h **b** 15 L/min
3 a i 60 km **ii** 60 km/h
b i 0 km/h **ii** 90 km/h
4 a i 15 km **ii** 15 km/h
b i 0 km/h **ii** 30 km/h
5 a i 2 L **ii** 0.5 L
b i 0.2 L/s **ii** 0.05 L/s **iii** 0.05 L/s
6 a i 1.5 L **ii** 0.5 L
b i 0.15 L/s **ii** 0.05 L/s **iii** 0.15 L/s
7 a 3 km **b** 4 min
c i 0.5 km/ min **ii** 0.75 km/ min
iii 0.5 km/ min **iv** 0.25 km/ min

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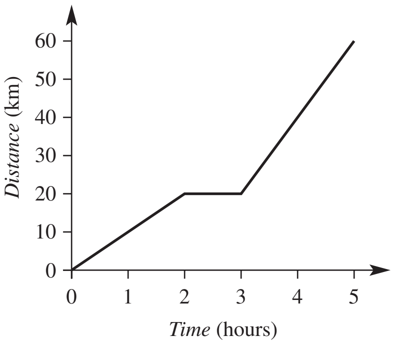
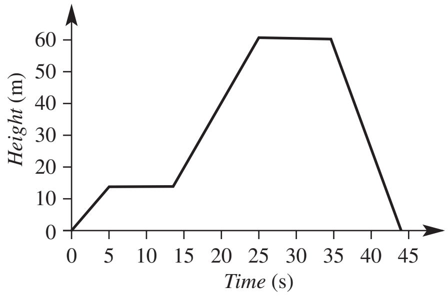
8 **a** C **b** A **c** B; steepest

9 **a**



b 60 km

10



Time is 44 seconds.

11 **a** 3

b **i** 6 km **ii** 14 km

c B, D, G **d** E, H

e **i** 6 km/h **ii** 14 km/h **iii** 16 km/h

iv 6.4 km/h **v** 16 km/h

f E and H, same gradient

g $5\frac{1}{4}$ hours **h** 40 km **i** 10 km/h

Exercise 6G

1 **a** gradient–intercept

b gradient

c coefficient

d *y*-intercept

2 **a** **i** 2 **ii** 4

b **i** 6 **ii** −7

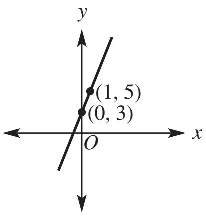
c **i** $-\frac{2}{3}$ **ii** 7

d **i** −7 **ii** −3

e **i** $\frac{3}{5}$ **ii** −8

f **i** 9 **ii** −5

3 **a**



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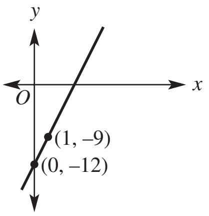

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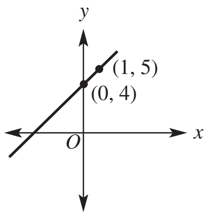

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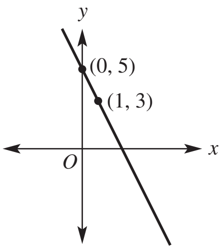

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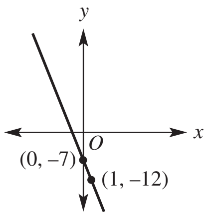

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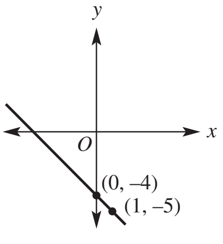
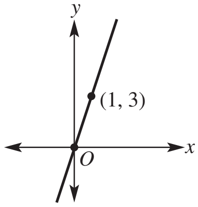


4 **a**



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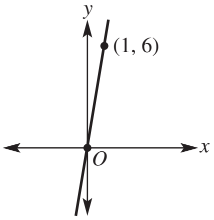

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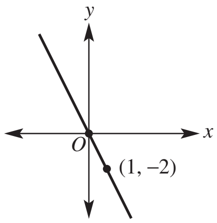

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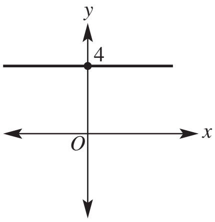

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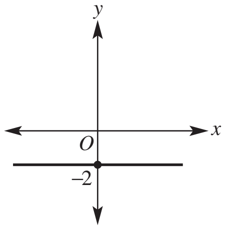

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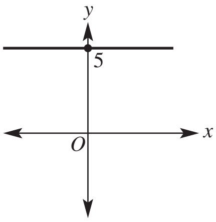

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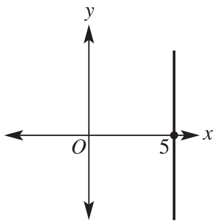

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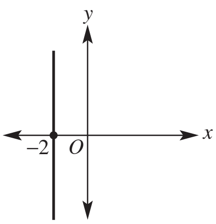
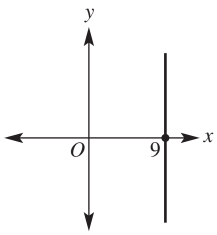


i



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5 a $y = 4x + 2$ **b** $y = 3x - 2$ **c** $y = 5x$
d $y = -3x + 5$ **e** $y = -4x - 3$ **f** $y = -2x$

6 a 1, 0 **b** $-\frac{3}{2}$, 3 **c** $\frac{1}{2}$, 4.5
d 0, 4 **e** 0, 7
f undefined, none

7 a D **b** B **c** E **d** A **e** F
f G **g** C **h** H **i** I

8 a $b = 5$ in each equation; e.g. $y = 2x + 5$, $y = -3x + 5$ etc.
b $b = -2$ in each equation; e.g. $y = 7x - 2$, $y = x - 2$ etc.
c $b = 0$ in each equation; e.g. $y = 2x$, $y = -5x$ etc.

9 a $m = 3$ in each equation; e.g. $y = 3x - 1$, $y = 3x$, $y = 3x + 4$ etc.
b $m = -1$ in each equation; e.g. $y = -x$, $y = -x + 7$, $y = -x - 3$ etc.
c $m = 0$ in each equation; e.g. $y = 4$, $y = -2$ etc.
d m is undefined in each equation; e.g. $x = -7$ etc.

10 a ii and iii **b** i and iv

11 a no **b** yes **c** no **d** yes **e** yes

12 a $y = x + 4$ **b** $y = x - 1$
c $y = \frac{x}{2}$ **d** $y = 2x + 1$

14 a They all have the same gradient.
b They all have a y-intercept at -1.

Exercise 6H

1 a C, D **b** B, E **c** yes **d** yes **e** yes

2 a 4 **b** –7 **c** $-\frac{3}{4}$ **d** $\frac{8}{7}$

3 a $-\frac{1}{3}$ **b** $\frac{1}{2}$ **c** $-\frac{8}{7}$ **d** $\frac{9}{4}$

4 a parallel **b** perpendicular **c** neither
d neither **e** parallel **f** parallel
g neither **h** neither **i** perpendicular
j perpendicular

5 a $y = 4x + 2$ **b** $y = 2x + 4$ **c** $y = -x - 3$
d $y = -\frac{1}{2}x + 3$ **e** $y = -\frac{1}{3}x - 5$ **f** $y = -2x - 10$
g $y = -6x + 6$ **h** $y = 4x - 7$

6 a $y = x + 4$ **b** $y = -x - 6$ **c** $y = -4x - 1$
d $y = \frac{2}{3}x - 6$ **e** $y = -\frac{4}{5}x + 7$ **f** $y = -\frac{1}{2}x + 6$
g $y = \frac{1}{4}x - 2$ **h** $y = -\frac{3}{2}x + 5$ **i** $y = -\frac{3}{4}x - 5$
j $y = \frac{7}{2}x + 31$

7 a i 1 **ii** -1
b i $y = x$ **ii** $y = x - 2$
iii $y = x + 3$ **iv** $y = -x + 2$
v $y = -x$ **vi** $y = -x - 4$

8 a $y = 2x + 2$ **b** $y = 2x - 4$
c $y = -\frac{1}{2}x - 4$ **d** $x = -8$

9 a $y = -\frac{3}{2}x + 7$ **b** $y = -\frac{2}{3}x - 2$
c $y = \frac{5}{4}x + 2$ **d** $y = \frac{3}{2}x - \frac{7}{2}$

10 a parallel **b** parallel
c perpendicular **d** perpendicular

11 a i 1 **ii** 1 **iii** -1 **iv** -1
b Opposite sides are parallel; adjacent sides are perpendicular.
c rectangle

12 a i $\frac{4}{3}$ **ii** $-\frac{3}{4}$ **iii** 0
b Right-angled triangle (AB is perpendicular to BC).

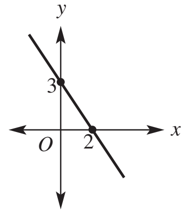
Exercise 6I

1 a The x-intercept is where $y = 0$.
b The y-intercept is where $x = 0$.

2 a 3 **b** -3

3 a 4 **b** $-3\frac{1}{3}$ **c** -6
d 18 **e** 12 **f** -6

4 a



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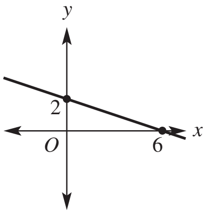

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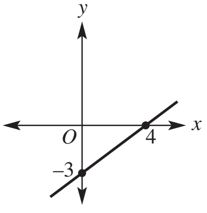

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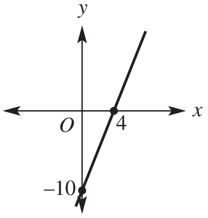

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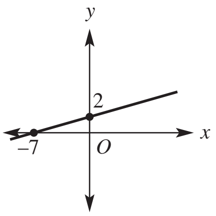

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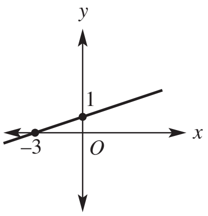

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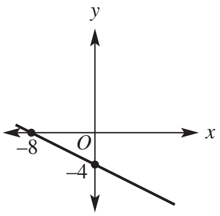

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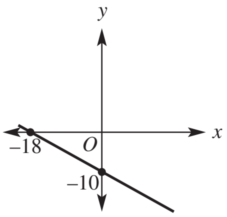

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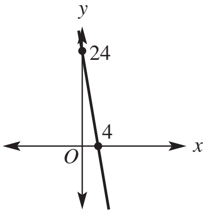
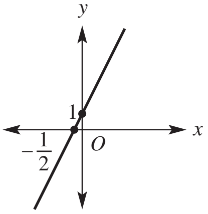
i

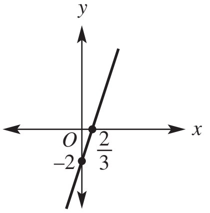


5 **a** B **b** C **c** A **d** D

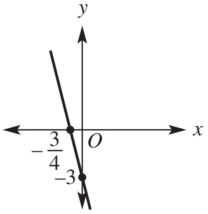
6 **a**



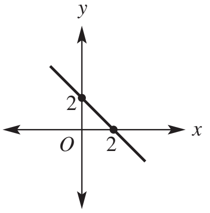
b



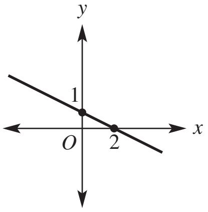
c



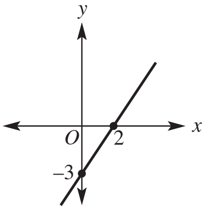
d



e



f



7 **a** C **b** B **c** A

8 **a** F **b** B **c** A

d E **e** D **f** C

9 **a** -2 **b** $\frac{1}{5}$ **c** 2 **d** $\frac{1}{2}$

10 **a** **i** x-int $= 2$, y-int $= -4$

ii $A = 4\,\text{units}^2$

b **i** x-int $= -2$, y-int $= 2$

ii $A = 2\,\text{units}^2$

c **i** x-int $= -1.5$, y-int $= -3$

ii $A = 2.25\ \text{units}^2$

d **i** x-int $= -4$, y-int $= 2$

ii $A = 4\ \text{units}^2$

11 **a** 90 m **b** $7\frac{1}{2}$ seconds

12 Many answers; e.g. $2x + y = 4$, $a = 2$, $b = 1$, $d = 4$

13 **a** x-int $= 2$, y-int $= -4$

b x-int $= -5$, y-int $= -10$

c x-int $= 1$, y-int $= 1$

d x-int $= 2$, y-int $= 4$

e x-int $= -4$, y-int $= 6$

f x-int $= -1$, y-int $= \frac{2}{3}$

Exercise 6J

1 D

2 C

3 **a** **i** $m = 2$ **ii** 1 **iii** $y = 2x + 1$

b **i** $m = -3$ **ii** 2 **iii** $y = -3x + 2$

c **i** $m = 4$ **ii** -3 **iii** $y = 4x - 3$

d **i** $m = -4$ **ii** 0 **iii** $y = -4x$

e **i** $m = -1$ **ii** 2 **iii** $y = -x + 2$

f **i** $m = 2$ **ii** 0 **iii** $y = 2x$

4 **a** **i** 3 **ii** 1 **iii** $y = 3x + 1$

b **i** -1 **ii** 6 **iii** $y = -x + 6$

c **i** 5 **ii** 21 **iii** $y = 5x + 21$

d **i** 3 **ii** -16 **iii** $y = 3x - 16$

e **i** -3 **ii** 2 **iii** $y = -3x + 2$

f **i** $\frac{1}{2}$ **ii** $\frac{3}{2}$ **iii** $y = \frac{1}{2}x + \frac{3}{2}$

5 **a** $y = 4$ **b** $y = -1$ **c** $x = 3$

d $x = -2$ **e** $y = 2$ **f** $x = 7$

6 **a** $y = 2x$ **b** $y = 3x$ **c** $y = \frac{2}{3}x$

d $y = -3x$ **e** $y = -x$ **f** $y = -\frac{2}{5}x$

7 **a** **i** 7 **ii** $y = 7x$

b **i** $-\frac{3}{2}$ **ii** $y = -\frac{3}{2}x$

c **i** 1 **ii** $y = x + 2$

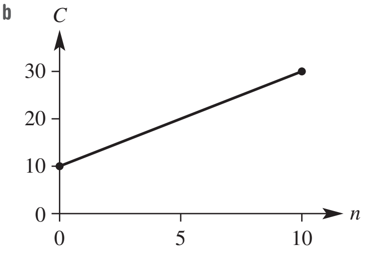
d **i** $-\frac{3}{2}$ **ii** $y = -\frac{3}{2}x$

e **i** 0 **ii** $y = 2$

f **i** undefined **ii** $x = 3$

8 **a** $P = 2n + 10$

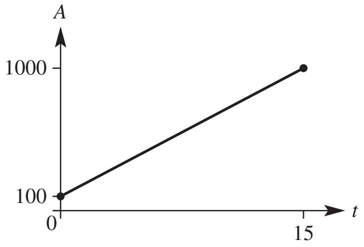
b



c **i** $28 **ii** 23.5 kg

9 **a** $A = 60t + 100$

b



c **i** $820 **ii** 10 hours

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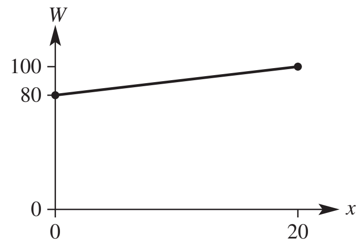
10 a $W = x + 80$

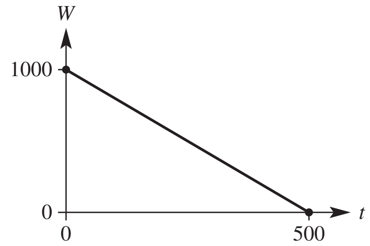
b



c i 87 kg **ii** 29 litres

11 a −2, (0, 1000)

b



c 1000 litres

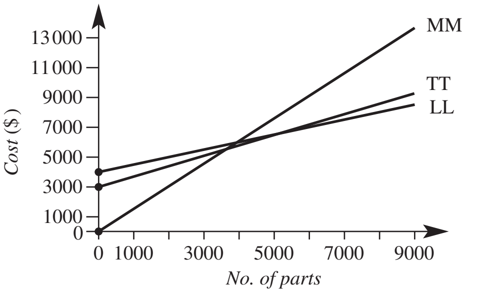
d i 360 litres **ii** 952 litres **iii** 664 litres

e i 350 hours **ii** 407.5 hours

12 a

p	0	1000	2000	3000	4000	5000	6000	7000	8000	9000
Cost, MM	0	1400	2800	4200	5600	7000	8400	9800	11 200	12 600
Cost, TT	3000	3700	4400	5100	5800	6500	7200	7900	8 600	9 300
Cost, LL	4000	4500	5000	5500	6000	6500	7000	7500	8 000	8 500

b



c i \$2100 **ii** \$1400 **iii** \$7250 **iv** \$8750

d Mandy's is best for parts fewer than or equal to 4285. Terry's is best for between 4286 and 5000 parts and equal to Lenny's at 5000. Lenny's is best for parts >5000.

Exercise 6K

1 a direct proportion **b** indirect proportion

c direct proportion **d** direct proportion

e indirect proportion

2 a decreases **b** direct

c increases **d** indirect or inverse

3 a ii and v

b i $k = 5$ **ii** $k = 12$ **iii** $k = 40$

iv $k = 22$ **v** $k = 7.5$

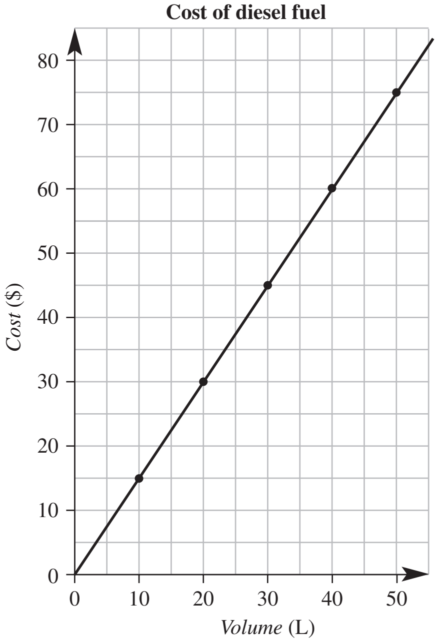
4 a $k = 4$, $y = 4x$ **b** $k = 1.2$, $y = 1.2x$

c $k = 0.5$, $y = 0.5x$

5 a

Volume (V) of diesel, in litres	0	10	20	30	40	50
Cost (C), in dollars	0	15	30	45	60	75

b



c $m = 1.5$ **d** rate = \$1.5/L **e** $k = \$1.5/\text{L}$

6 a 48 cm **b** 10 inches **c** 30 cm

d 10 cm **e** 76 cm **f** 22 inches

g 63 cm (or 64 cm) **h** 100 cm

7 a 94 cm = 37 inches, $m = \dfrac{94}{37} = 2.54$

b 2.54 cm/inch

c $k = 2.54$ cm/inch

d $y = 2.54x$

e 127 cm

8 a i 100 NZD **ii** 64 EUR **iii** 51 GBP

iv 40 AUD **v** 40 AUD **vi** 40 AUD

b i 40 EUR = 50 AUD, $m = \dfrac{40}{50} = 0.8$

ii 0.8 EUR/AUD **iii** $k = 0.8$ EUR/AUD

iv $y = 0.8x$ **v** \$500

9 a 15 cents/min **b** 40 cents/min

c 3mL/s **d** 5mL/s

e 20 m/s **f** 5 m/s

g 1.5 cents/g **h** 3.2 cents/g

i 4.8 kg/year **j** 1.54 kg/week

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10 a Not in direct proportion as it is not a straight line.

b Not in direct proportion as the line doesn't pass through the origin.

c Yes, in direct proportion as it is a straight line through the origin.

d Yes, in inverse proportion because as x increases, y decreases.

11 a Number of hours worked and wages earned are in direct proportion. If the number of hours worked doubles, then the wages earned also doubles.

b The cost of buying tomatoes and the number of kg are in direct proportion. If the number of kg doubles, then the cost also doubles.

c The speed and time taken are in inverse proportion. If the speed increases, then the time taken decreases. Alternatively, if the speed decreases, then the time taken increases.

d The size of the movie file and the time taken to download it are in direct proportion. If the size of the movie file is doubled, then the time to download will also double.

e The cost of a taxi ride and the distance travelled are not in direct proportion because the graph does not start at (0, 0). The y-intercept is the flag fall cost.

12 a i $C = 1.38n$ **ii** \$66.24

b i $W = 11.5t$ **ii** \$431.25

c i $V = 6t$ **ii** 1440 L

iii $k = 8640$, $V = 8640t$ **iv** 60 480 L

d i $d = 90t$ **ii** 315 km

iii $k = 25$m/s, $d = 25t$ **iv** 100 m

13 a i $k = \$12.50$/h **ii** $W = 12.5n$

iii \$75 **iv** 19 hours

b i $k = \$244$/tonne **ii** $P = 244n$

iii \$33 184 **iv** 1175 tonnes

c i $k = 774$ km/h **ii** $d = 774t$

iii 4.26 hours **iv** $d = 12.9t$

v 619.2 km **vi** 15.5 min

14 a Singapore dollar (SGD)

i SGD = 1.2 × AUD **ii** SGD \$288

iii AUD \$200

b Chinese yuan (CNY)

i CNY = 6.47 × AUD **ii** CNY 485.25

iii AUD \$11.59

c Korean won (KRW)

i KRW = 1160 × AUD **ii** KRW 1 160 000

iii AUD 86 cents

d South African rand (ZAR)

i ZAR = 9.5 × AUD **ii** ZAR 475

iii AUD \$5.26

Puzzles and games

1 PLOTTING LINES!

3 both 13 km apart

4 a 160 ice-creams for zero profit

b 493 ice-creams sold

Multiple-choice questions

1 A	**2** E	**3** D	**4** A	**5** B
6 E	**7** C	**8** A	**9** B	**10** D
11 D	**12** E	**13** C	**14** D	

Short-answer questions

1 a 40 km **b** 2 hours **c** 60 km

2 a i \$6000 **ii** \$8000 **iii** \$9000

b i \$2000 **ii** \$4000 **iii** \$5000

c 10 years

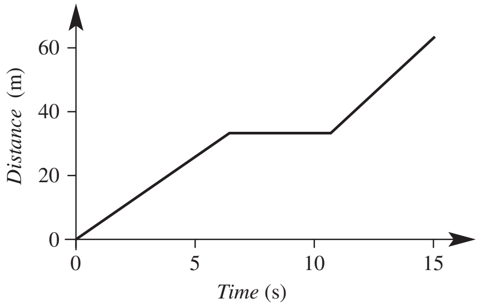
3 a 15 km

b 3 hours

c i 6 km **ii** 6 km **iii** 9 km **iv** 15 km

d $3\frac{1}{2}$ hours

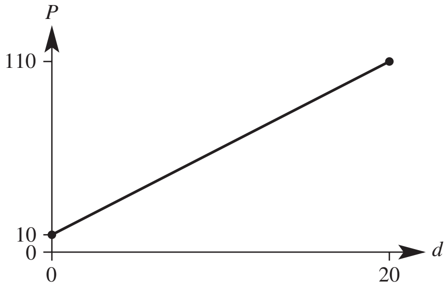
4



5 a

d	0	5	10	15	20
P	10	35	60	85	110

b



c i \$70 **ii** 17

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6 a 1 **b** -1

c -2 **d** $\frac{1}{3}$

7 a (4, 2)

b (2, 2.5)

c (1.5, -1)

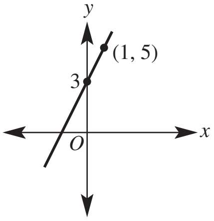
8 a $AB = 5$

b $PQ = \sqrt{50}$

9 a gradient = 3, y-intercept = 4

b gradient = -2, y-intercept = 0

10 a



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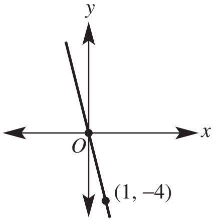
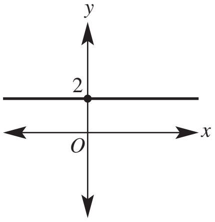
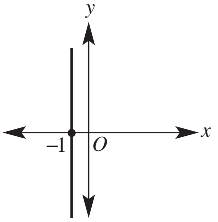


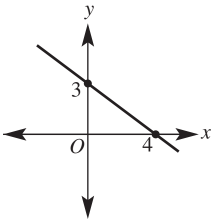
c



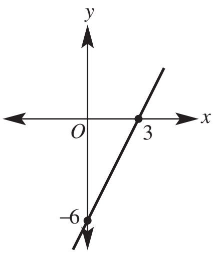
d



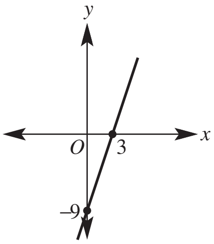
11 a



b



c



12 a i 2 **ii** 0 **iii** $y = 2x$

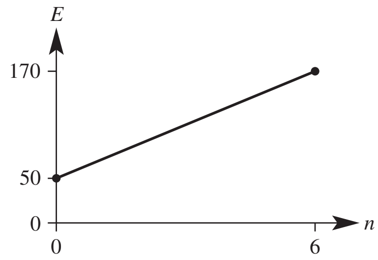
b i -4 **ii** 16 **iii** $y = -4x + 16$

13 a A **b** C **c** F

d B **e** D **f** E

14 a $E = 20n + 50$

b



c i \$130 **ii** 5.5 bins

15 A $y = 2x$ **B** $y = 2x - 4$

C $y = -\frac{1}{2}x - 4$ **D** $y = -\frac{1}{2}x + 1$

16 a $y = 2x + 3$ **b** $y = \frac{1}{2}x - 1$ **c** $y = -x + 2$

d $y = -\frac{4}{3}x - 7$ **e** $y = -4x + 6$ **f** $y = -\frac{1}{2}x + 4$

17 a 8 km **b** 22 miles

c $m = \frac{15}{24.14} = 0.621$ **d** 0.621 miles/km

e $k = 0.621$ miles/km **f** $y = 0.621x$

g 62.1 miles **h** 161 km

18 a Direct proportion. If the number of cricket balls increases, then the cost will also increase.

b Indirect proportion. If the number of people increases, then the cost per person decreases.

19 a 30 cents/min **b** 18 km/h

c 200 m/s **d** 10 mL/s

Extended-response questions

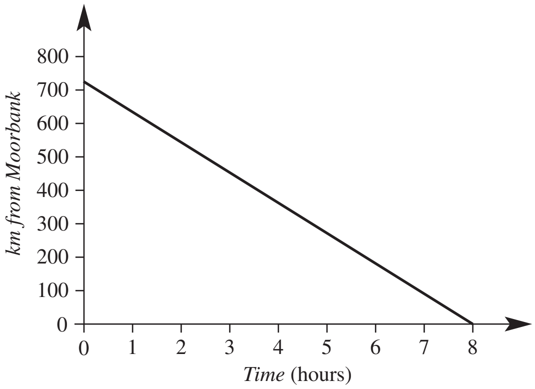
1 a i 30 km **ii** 15 km/h

b i 20 km/h **ii** 0 km/h **iii** 20 km/h

2 a

Time in hours (t)	0	2	4	6	8
Km from Moorbank	720	540	360	180	0

b



c 9 a.m. **d** 7 hours

e 8 hours **f** 4 p.m.

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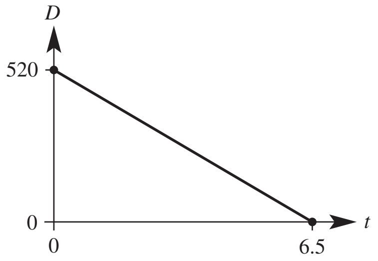
3 **a** **i** 440 km **ii** 280 km
b **i** $D = -80t + 520$ or $D = 520 - 80t$
ii



c **i** 160 km **ii** 2.25 hours

Chapter 7

Pre-test

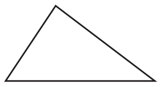
1 **a** acute **b** 90° **c** 180°
d straight **e** reflex **f** 360°
g 90° **h** supplementary
2 **a** scalene **b** isosceles **c** right-angled
d obtuse-angled **e** equilateral **f** acute-angled
3 **a** $a = 110$ **b** $b = 140$ **c** $c = 210$
d $d = 35$ **e** $e = 60$ **f** $f = 40$
4 **a** $a = 110, b = 70$
b $a = 105, b = 75$
c $a = 40, b = 140$
5 **a** square
b parallelogram, incl. square, rectangle and rhombus
c square, rectangle
d square, rhombus
e trapezium
f kite
6 **a** $S = 360°, a = 130$
b $S = 540°, b = 120$
c $S = 720°, c = 120$
7 **a** no **b** no **c** no
d no **e** yes **f** yes

Exercise 7A

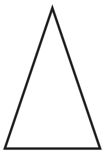
1 **a** 180° **b** equal
c **i** equal **ii** equal **iii** supplementary
2 **a** alternate **b** vertically opposite
c cointerior **d** corresponding
3 $a = 20$ supplementary, $b = 20$ alternate,
$c = 160$ corresponding, $d = 160$ vertically opposite
4 $a = 100$ supplementary, $b = 100$ alternate,
$c = 80$ corresponding, $d = 80$ vertically opposite
5 **a** $x = 110, y = 110$
b $x = 40, y = 140$
c $x = 75, y = 105$
d $x = 120, y = 120$
e $x = 110, y = 70$
f $x = 105, y = 75$
6 **a** Yes, corresponding angles are equal.
b No, alternate angles are not equal.
c No, co-interior angles are not supplementary.
d Yes, co-interior angles are supplementary.
e No, corresponding angles are not equal.
f Yes, alternate angles are equal.
7 **a** 60 **b** 20 **c** 100
d 115 **e** 50 **f** 330
8 **a** $a = 90, b = 90, c = 90$
b $a = 90, b = 90, c = 90$
c $a = 135, b = 45, c = 135$
d $a = 50, b = 130, c = 50$
e $a = 90, b = 130$
f $a = 110, b = 120$
9 **a** $(a, e), (d, f), (b, h), (c, g)$
b $(d, h), (c, e)$
c $(c, h), (d, e)$
d $(a, c), (b, d), (e, g), (f, h)$
10 **a** 90 **b** 75 **c** 10
d 30 **e** 36 **f** 30
11 **a** 12 **b** 14 **c** 10

Exercise 7B

1 **a** 30 **b** 16 **c** 33
d 60 **e** 77 **f** 98
2 **a** $c = 120$ **b** $x = 60$ **c** $x = 25 + 35$
3 C
4 **a** 70 **b** 10 **c** 25
d 58 **e** 50 **f** 29
5 **a** 65 **b** 80 **c** 40
d 20 **e** 112 **f** 32
6 **a** 145 **b** 144 **c** 45
d 60 **e** 60 **f** 47
7 **a**

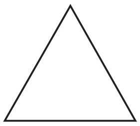


b

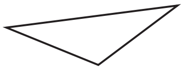


c no

d



e



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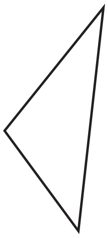
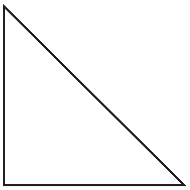
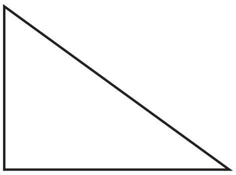


g no

h



i



8 a 65° **b** 115°

9 a $a = 60$ **b** $a = 120$

c $a = 70, b = 70$ **d** $a = 35, b = 105$

e $a = 115, b = 115, c = 45, d = 20$

f $a = 40, b = 100, c = 40, d = 40$

10 a a°, alternate **b** b°, alternate **c** sum to 180°

11 a i 50° **ii** 130°

b i 20° **ii** 160°

c i 0° **ii** 180°

Exercise 7C

1 Parallelograms, incl. squares, rectangles and rhombuses.

2 a square, rectangle, rhombus, parallelogram

b rectangle, square, parallelogram, rhombus, kite

c rhombus, square, parallelogram, rectangle

d trapezium

e kite

f square, rectangle

g square, rectangle

h square, rhombus, kite

3 a $a = 144$ **b** $b = 79$ **c** $c = 54$

4 a $x = 20$ **b** $x = 110$ **c** $x = 240$

d $x = 125$ **e** $x = 30$ **f** $x = 65$

5 a $x = 60$ (co-interior angles in parallel lines)

$\therefore y = 120$ (opposite angles in a parallelogram)

$z = 60$ (co-interior angles in parallel lines)

b $x = 110$ (co-interior angles in parallel lines)

$y = 110$ (co-interior angles in parallel lines)

$z = 70$ (co-interior angles in parallel lines)

c $x = 30$ (co-interior angles in parallel lines)

$y = 150$ (co-interior angles in parallel lines)

$z = 30$ (co-interior angles in parallel lines)

d $x = 45$ (angle sum of a quadrilateral)

e $x = 100$ (angle sum of a quadrilateral)

f $x = 25$ (angle sum of a quadrilateral)

g $x = y = z = 90$ (angles in a square)

h $x = 100$ (co-interior angles in parallel lines)

$y = 140$ (co-interior angles in parallel lines)

i $x = 75$ (co-interior angles in parallel lines)

$y = 20$ (co-interior angles in parallel lines)

6 a 115 **b** 60 **c** 30

d 50 **e** 90 **f** 140

7 a It has two equal side lengths.

b i 120 **ii** 40

c It has two equal side lengths and two pairs of equal angles and one pair of parallel sides.

8 b 65°

9 a 125 **b** 118 **c** 110

10 a $a = 30, b = 120, c = 60, d = 60, e = 30$

b $a = 80, b = 100, c = 80, d = 50$

c $a = 40, b = 20, c = 50, d = 110$

d $b = 50, c = 70$

e $a = 60, b = 20$

f $a = 10, b = 80$

Exercise 7D

1 a 4 **b** 8 **c** 10 **d** 7

e 9 **f** 6 **g** 5 **h** 12

2 a 540° **b** 720° **c** 900°

d 1080° **e** 1260° **f** 1440°

3 All sides are equal. All angles are equal.

4 a 720°, 110 **b** 540°, 130 **c** 540°, 30

d 900°, 105 **e** 720°, 30 **f** 360°, 30

5 a 24 cm **b** 720° **c** 120° **d** 60°

6 a 28 cm **b** 1080° **c** 135°

7 a 120° **b** 60°

8 a 1620° **b** 3240°

9 a 144° **b** 165.6°

10 a 120° **b** 60°

11 a 72° **b** 108°

12 a $x = 60, y = 60$ **b** $x = 45, y = 225$

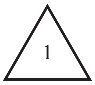
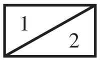
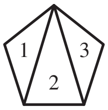
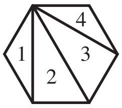
13 a *See table on the next page.*

b i $S = (n - 2) \times 180$

ii $A = \dfrac{(n - 2) \times 180}{n}$

iii 360

iv $E = \dfrac{360°}{n}$

Polygon	No. of sides	Diagram	No. of triangles	Interior angle sum (S)	Single interior angle (A)	Exterior angle sum (S)	Single exterior angle (E)
triangle	3		1	180°	60°	360°	120°
quadrilateral	4		2	360°	90°	360°	90°
pentagon	5		3	540°	108°	360°	72°
hexagon	6		4	720°	120°	360°	60°
…							
n-gon	n		$n - 2$	$(n - 2) \times 180$	$\frac{(n-2) \times 180}{n}$	360°	$\frac{360°}{n}$

Exercise 7E

1 **a** false **b** false **c** true **d** true

2 SSS, SAS, AAS, RHS

3 **a** E **b** AC **c** $\angle EDF$

4 **a** $\Delta ABC \equiv \Delta DEF$ (SSS)

b $\Delta ABC \equiv \Delta DEF$ (SAS)

c $\Delta XYZ \equiv \Delta STU$ (RHS)

d $\Delta XYZ \equiv \Delta STU$ (SSS)

e $\Delta ABC \equiv \Delta DEF$ (AAS)

f $\Delta MNO \equiv \Delta PQR$ (AAS)

5 **a** $AB = DE$ (S)
$BC = EF$ (S)
$AC = DF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (SSS)

b $AC = DF$ (S)
$AB = DE$ (S)
$BC = EF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (SSS)

c $AB = DE$ (S)
$\angle BAC = \angle EDF$ (A)
$AC = DF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (SAS)

d $AB = DE$ (S)
$\angle BAC = \angle EDF$ (A)
$AC = DF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (SAS)

e $\angle CAB = \angle FDE$ (A)
$\angle CBA = \angle FED$ (A)
$BC = EF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (AAS)

f $\angle ABC = \angle DEF$ (A)
$\angle BAC = \angle EDF$ (A)
$AB = DE$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (AAS)

g $\angle BAC = \angle EDF = 90°$ (R)
$BC = EF$ (H)
$AB = DE$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (RHS)

h $\angle BAC = \angle EDF = 90°$ (R)
$BC = EF$ (H)
$AC = DF$ (S)
$\therefore \Delta ABC \equiv \Delta DEF$ (RHS)

6 (D, G), (C, E)

7 **a** 25°, 75° **b** yes, AAS

8 **a** $a = 4$ **b** $x = 3, y = 5$

c $a = 60, b = 7$ **d** $x = 55, y = 4$

e $x = 6$ **f** $a = 70, b = 7$

g $c = 3, d = 4$ **h** $a = 30, b = 5$

i $a = 20, b = 70$

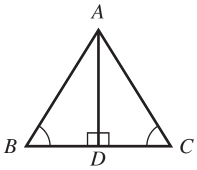
9 **a** $AB = ED$ (S)
$BC = DF$ (H)
$\angle BAC = \angle DEF = 90°$ (R)
$\therefore \Delta ABC \equiv \Delta EDF$ (RHS)

b 6 m

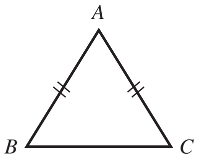
c **i** 37° **ii** 53°

10 AC, ADC, ABD, ACD

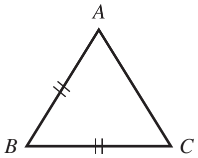
11 Construct $AD \perp BC$.
In ΔABD and ΔACD:
$\angle B = \angle C$ (given) (A)
$\angle ADB = \angle ADC$ (since $AD \perp BC$) (A)
AD is common. (S)
$\therefore \Delta ABD \equiv \Delta ACD$ (AAS)
$\therefore AB = AC$ (matching sides in congruent triangles)



12



$AB = AC$ (given)
$\therefore \angle ABC = \angle ACB$



$AB = BC$ (given)
$\therefore \angle ACB = \angle BAC$

$\therefore \angle ABC = \angle ACB = \angle BAC = 180° \div 3 = 60°$

13 In ΔABC and ΔCDA:
$\angle DAC = \angle ACB$ (alternate angles in parallel lines) (A)
$\angle BAC = \angle ACD$ (alternate angles in parallel lines) (A)
AC is common. (S)
$\therefore \Delta ABC = \Delta CDA$ (AAS)
$\therefore \angle ABC = \angle ADC$ (matching angles in congruent triangles)

Similarly, $\angle DAB = \angle BCD$.

$\therefore$ The opposite angles in a parallelogram are equal.

Exercise 7F

1 There are four tests for similarity.

2 If two pairs of angles are corresponding and equal, then the third pair must be equal due to the angle sum of a triangle (180°).

3 **a** 1.5 **b** 1.5, the same **c** 1.5

4 **a** $\angle BAC = \angle EDF$
$\angle ABC = \angle DEF$
$\angle ACB = \angle DFE$
$\therefore \Delta ABC \,|||\, \Delta DEF$

b $\angle BAC = \angle EDF$
$\angle ACB = \angle DFE$
$\angle ABC = \angle DEF$
$\therefore \Delta ABC \,|||\, \Delta DEF$

c $\frac{DE}{AB} = 2$
$\frac{DF}{AC} = 2$
$\frac{EF}{BC} = 2$
$\therefore \Delta ABC \,|||\, \Delta DEF$

d $\frac{DE}{AB} = 3$
$\frac{DF}{AC} = 3$
$\frac{EF}{BC} = 3$
$\therefore \Delta ABC \,|||\, \Delta DEF$

e $\frac{AB}{DE} = 1.5$
$\angle BAC = \angle EDF$
$\frac{AC}{DF} = 1.5$
$\therefore \Delta ABC \,|||\, \Delta DEF$

f $\frac{DE}{AB} = 1.5$
$\angle BAC = \angle EDF$
$\frac{DF}{AC} = 1.5$
$\therefore \Delta ABC \,|||\, \Delta DEF$

g $\angle CAB = \angle FDE = 90°$
$\frac{EF}{BC} = 1.5$
$\frac{DE}{AB} = 1.5$
$\therefore \Delta ABC \,|||\, \Delta DEF$

h $\angle CAB = \angle FDE = 90°$
$\frac{BC}{EF} = 2$
$\frac{AB}{DE} = 2$
$\therefore \Delta ABC \,|||\, \Delta DEF$

5 **a** $x = 8$ **b** $x = 21$
c $x = 4$ **d** $x = 1.5$

6 **a** ΔABC, ΔADE
b $\angle A$ is common and $\angle ABC = \angle ADE$.
c 2.5 **d** 3.75 m

7 **a** $x = 1.5$ **b** $x = 9$ **c** $x = 2.2$

8 **a** $\angle BAC = \angle DEC$ (alternate), $\angle ABC = \angle EDC$ (alternate), $\angle ACB = \angle ECD$ (vertically opposite)
b **i** $DC = 6$ cm **ii** $AC = 6$ cm

Exercise 7G

1 **a** $\angle A$ is common and $\angle DEA = \angle BCA$.
b $\angle BAC = \angle DEC$, $\angle ABC = \angle EDC$

2 **a** $\angle ABC = \angle ADE$, $\angle ACB = \angle AED$
b 2 **c** 3

3 **a** Two pairs of angles are equal.
b 2 **c** 30 cm

4 **a** Two pairs of angles are equal.
b 1.5 **c** 4.5 m

5 **a** $\frac{88}{5} = 17.6$ **b** 2

6 **a** ΔABC, ΔDEC; $\angle C$ is common and $\angle CAB = \angle CDE$.
b 1.25 m

7 **a** Two pairs of angles are equal.
b 5 **c** 5 m

8 **a** ΔABD, ΔCBE; two pairs of angles are equal.
b $\frac{6}{5} = 1.2$ **c** 13.2 m

9 1.90 m

10 Answers will vary.

11 **a** Two pairs of angles are equal.
b 1.5 **c** 20 m
d Let $AE = x$
$1.5x = x + 10$
$\therefore x = 20$

Exercise 7H

1 **a** 4:9 **b** 8:27

2 **a** 2:5 **b** 32 cm^2, 200 cm^2
c 4:25 ($= 2^2{:}5^2$)
d 12 cm^3, 187.5 cm^3
e 8:125 ($= 2^3{:}5^3$)

3 **a** 2 cm **b** 1500 **c** 5 cm **d** 75 m

4 **a** 5 cm **b** 1500 **c** 4 cm **d** 60 m

5 **a** 16 cm^2 **b** 45 m^2

6 **a** 3 mm^2 **b** 3 cm^2

7 **a** 2 cm^3 **b** 8 m^3

8 **a** 108 cm^3 **b** 156.25m^3

9 **a** **i** 1 km **ii** 3 km
b **i** 10 cm **ii** 1 cm **c** 2 km

10 **a** **i** 3:4 **ii** 9:16 **b** 450 cm^2

11 **a** 1:8 **b** 240 cm^3

12 **a** **i** 2:3 **ii** 4:9 **iii** 8:27
b 90 cm^2 **c** 54 cm^3

13 **a** 1:27 000 000 **b** 54 000 000 m^3 **c** 9 m^2

Puzzles and games

1 30

2 CONGRUENCE

3 110°

4 **a** 7 **b** 11

5 20 m

Multiple-choice questions

1 B **2** A **3** D **4** E **5** E
6 D **7** B **8** A **9** C **10** B

Short-answer questions

1 **a** $x = 70, y = 110$ **b** $x = 120, y = 120$
c $x = 65, y = 115$ **d** $x = 30, y = 150$
e $x = 90, y = 120$ **f** $x = 45$

2 **a** 20 **b** 30 **c** 77 **d** 20 **e** 60
f 30 **g** 130 **h** 70 **i** 160

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3 **a** square, rectangle, rhombus, parallelogram
b parallelogram, square, rhombus, rectangle
c kite **d** square, rhombus, kite
4 **a** $a = 90$ **b** $a = 40$ **c** $a = 110, b = 30$
d $a = 90, b = 130$ **e** $a = 40, b = 140$
f $a = 110$
5 **a** $S = 540°, x = 60$ **b** $S = 720°, x = 100$
c $S = 900°, x = 120$
6 **a** 10 m **b** 540° **c** 108° **d** 72°
7 **a** $\angle BAC = \angle EDF = 90°(\text{R})$
$BC = EF(\text{H})$
$AB = DE(\text{S})$
$\therefore \Delta ABC \equiv \Delta DEF(\text{RHS})$
b $AB = DE(\text{S})$
$AC = DF(\text{S})$
$BC = EF(\text{S})$
$\therefore \Delta ABC \equiv \Delta DEF(\text{SSS})$
c $\angle ACB = \angle DFE(\text{A})$
$\angle CAB = \angle FDE(\text{A})$
$AB = DE(\text{S})$
$\therefore \Delta ABC \equiv \Delta DEF(\text{AAS})$
d $AB = DE(\text{S})$
$\angle BAC = \angle EDF(\text{A})$
$AC = DF(\text{S})$
$\therefore \Delta ABC \equiv \Delta DEF(\text{SAS})$
8 **a** $\angle BAC = \angle EDF$
$\angle ABC = \angle DEF$
$\angle ACB = \angle DFE$
$\therefore \Delta ABC \mathrel{|||} \Delta DEF$
b $\frac{AB}{DE} = 2$
$\frac{AC}{DF} = 2$
$\frac{BC}{EF} = 2$
$\therefore \Delta ABC \mathrel{|||} \Delta DEF$
c $\frac{DE}{AB} = 1.5$
$\angle EDF = \angle BAC$
$\frac{DF}{AC} = 1.5$
$\therefore \Delta ABC \mathrel{|||} \Delta DEF$
d $\angle BAC = \angle EDF = 90°$
$\frac{EF}{BC} = 2.5$
$\frac{DE}{AB} = 2.5$
$\therefore \Delta ABC \mathrel{|||} \Delta DEF$
9 **a** $\Delta ABE, \Delta ACD$
b Two pairs of equal angles.
c 2.5 **d** 7.5 m
10 **a** Two pairs of equal angles.
b 6.25 **c** 187.5 cm
11 **a** 2 cm **b** 5000 **c** 5 cm **d** 250 m
12 **a** **i** 2:3 **ii** 4:9 **iii** 8:27
b 32 cm^3

Extended-response questions

1 **a** 60, 60, 30
b Two pairs of equal angles.
c 2.5 **d** 8 cm **e** 4:25 **f** 6.25
2 **a** 2:125 **b** 281.25 cm
c 4:15 625 **d** 0.00128 L

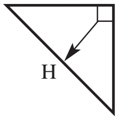
Chapter 8

Pre-test

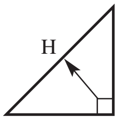
1 **a** 15.84 **b** 164.87 **c** 0.87 **d** 0.58
e 0.17 **f** 0.71 **g** 12.99 **h** 14.30
2 **a** 25 **b** 46.24 **c** 361
d 225 **e** 43.25 **f** 81
3 **a** 2.8 **b** 2.6 **c** 3.9
d 3.2 **e** 3.6 **f** 3.0
g 1.9 **h** 14.1
4 **a** c **b** p **c** y
d PQ **e** BC **f** XY
5 **a** $x = 3$ **b** $x = 4$ **c** $x = 12$
d $x = 35$ **e** $x = 108$ **f** $x = 9$
6 **a** $m = 3.65$ **b** $m = 1.2$ **c** $m = 4.4$
d $m = 5.2$ **e** $m = 18.848$ **f** $m = 5.724$
7 **a** $x = 0.6$ **b** $x = 0.2$ **c** $x = 2.1$
d $x = 0.4$ **e** $x = 2.4$ **f** $x = 9.2$
8 **a** $x = 4$ **b** $x = 20$ **c** $x = 13$ **d** $x = 4$
9 **a** 30° **b** 50° **c** 54° **d** 90° **e** 45°
f 30° **g** 82° **h** 62° **i** 35°

Exercise 8A

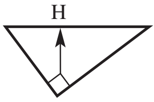
1 B, C
2 **a**



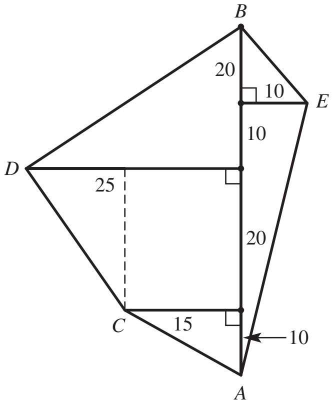
b



c



3 **a** $z^2 = x^2 + y^2$ **b** $t^2 = m^2 + n^2$ **c** $s^2 = p^2 + r^2$
4 **a** 25 **b** 34 **c** 45
5 **a** 5 **b** 17 **c** 13 **d** 25 **e** 41 **f** 10
6 **a** 5.8 cm **b** 7.3 mm **c** 18.0 m
d 11.2 km **e** 8.6 cm **f** 12.8 cm
7 **a** 8.91 cm **b** 3.62 m **c** 5.02 km
d 13.95 mm **e** 17.49 cm **f** 24.21 cm
8 181.5 cm
9 35.3 m
10 13 m
11 5.28 m
12 2.64 m
13 494.97 m
14 **a** no **b** no **c** yes **d** yes **e** no **f** yes
15 **a** **i** $AC = 11.2$ **ii** $BC = 30.4$
iii $DB = 21.2$ **iv** $AD = 29.2$
b 92 m **c** 400 m^2
16 $P = 143.0$ m

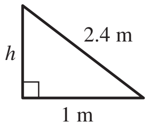


Exercise 8B

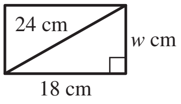
1 a i 10 **ii** 24 **iii** 41 **iv** 1.5
b i $10^2 = w^2 + 6^2$ **ii** $24^2 = x^2 + 6^2$
iii $41^2 = y^2 + 9^2$ **iv** $1.5^2 = x^2 + 1.2^2$
2 a $w^2 = 10^2 - 6^2$ **b** $x^2 = 13^2 - 5^2$ **c** $p^2 = 30^2 - 18^2$
3 a $17^2 = 8^2 + w^2$ **b** $13^2 = m^2 + 5^2$ **c** $15^2 = x^2 + 9^2$
4 a 4 **b** 7 **c** 8 **d** 5 **e** 14 **f** 4.8
5 a 7.1 **b** 13.3 **c** 12.3 **d** 6.2 **e** 6.6 **f** 16.2
6 a 7.14 **b** 13.90 **c** 3.87
d 133.84 **e** 17.89 **f** 39.19
7 5.66 m
8 2.2 m
9 3.2 m
10 a i 3 cm **ii** 5.2 cm **b** 15.6 cm^2
11 7.4 cm
12 a 7.1 **b** 4.5 **c** 5.2

Exercise 8C

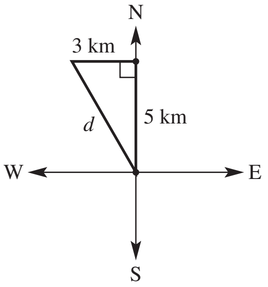
1 a



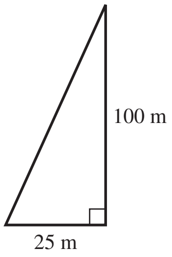
b



c



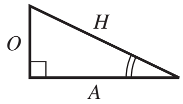
2 a ΔADE **b** ΔPRO and ΔRQO **c** ΔAOB
3 a *AB* **b** *AB* **c** *FH* **d** *BG* **e** *RT* **f** *EB*
4 a 100 m
b



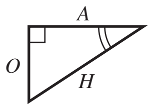
c 103.08 m
5 a 8.6 m **b** 13 m **c** 10 m
6 6.9 km
7 a 10 km **b** 41 km **c** 17 km
8 a 10.6 **b** 10.8 **c** 15.8 **d** 4.2
9 25.04 m
10 a 11.18 m **b** 12.2 m
11 horizontal = 45.25 cm, vertical = 71.66 cm
12 a 4.77 m **b** 4.90 cm
13 a 11.2 m **b** 8.1 cm
14 a 1.41 cm **b** 1.73 cm
15
- ΔPQR is a right-angled isosceles triangle
- With $\angle P = \angle R = 45^\circ$
- the hypotenuse = $\sqrt{200}$ cm
- $PQ = QR = 10$ cm
- perimeter = 34.1 cm
- area = 50 cm^2

Exercise 8D

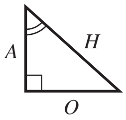
1 a



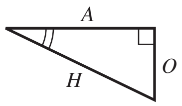
b



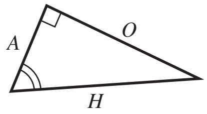
c



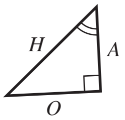
d



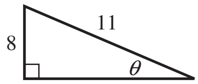
e



f



2 a *PR* **b** *TP* **c** *TP*
d *PR* **e** *TR* **f** $\angle T$
3 a *BC* **b** *CA* **c** *BA* **d** *BA*
4 a $\frac{3}{5}$ **b** $\frac{4}{5}$ **c** $\frac{4}{5}$
5 a i $\frac{b}{a}$ **ii** $\frac{c}{a}$ **iii** $\frac{b}{c}$
b i $\frac{n}{p}$ **ii** $\frac{m}{p}$ **iii** $\frac{n}{m}$
c i $\frac{y}{z}$ **ii** $\frac{x}{z}$ **iii** $\frac{y}{x}$
d i $\frac{4}{5}$ **ii** $\frac{3}{5}$ **iii** $\frac{4}{3}$
e i $\frac{24}{26} = \frac{12}{13}$ **ii** $\frac{10}{26} = \frac{5}{13}$ **iii** $\frac{24}{10} = \frac{12}{5}$
f i $\frac{12}{13}$ **ii** $\frac{5}{13}$ **iii** $\frac{12}{5}$
6 a $\frac{a}{c}$ **b** $\frac{y}{z}$ **c** $\frac{b}{a}$
d $\frac{6}{10} = \frac{3}{5}$ **e** $\frac{40}{41}$ **f** $\frac{1}{\sqrt{3}}$
g $\frac{8}{6} = \frac{4}{3}$ **h** $\frac{9}{41}$ **i** $\sqrt{3}$
7 a



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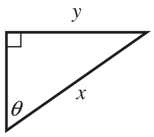

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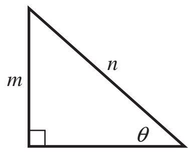

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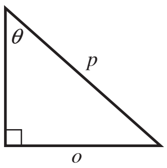
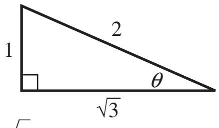


8 **a** $\frac{y}{x}$ **b** $\frac{z}{x}$ **c** $\frac{z}{x}$
d $\frac{y}{x}$ **e** $\frac{y}{z}$ **f** $\frac{z}{y}$

9 **a** $\sin\theta$ **b** $\tan\theta$ **c** $\sin\theta$
d $\cos\theta$ **e** $\cos\theta$ **f** $\tan\theta$

10 **a** $QR = 13$ m **b** $\sin\theta = \frac{5}{13}$

11 **a**



b $\sqrt{3}$
c **i** $\cos\theta = \frac{\sqrt{3}}{2}$ **ii** $\tan\theta = \frac{1}{\sqrt{3}}$

12

Angle (θ)	$\sin\theta$	$\cos\theta$
0°	0	1
5°	0.087	0.996
10°	0.174	0.985
15°	0.259	0.966
20°	0.342	0.940
25°	0.423	0.906
30°	0.5	0.866
35°	0.574	0.819
40°	0.643	0.766
45°	0.707	0.707
50°	0.766	0.643
55°	0.819	0.574
60°	0.866	0.5
65°	0.906	0.423
70°	0.940	0.342
75°	0.966	0.259
80°	0.985	0.174
85°	0.996	0.087
90°	1	0

a 45°
b **i** 85 **ii** 80 **iii** 30 **iv** 0
c If angles θ and α sum to 90°, then $\sin\theta = \cos\alpha$.
d It's the same as the complement of sine.

Exercise 8E

1 **a** 0.1736 **b** 0.9848 **c** 0.1763
d 0.5774 **e** 0.7660 **f** 0.9397
g 0.1719 **h** 0.8541 **i** 0.9870
j 0.8682 **k** 0.6401 **l** 1.7379

2 **a** 2.12 **b** 5.07 **c** 31.18
d 46.43 **e** 8 **f** 18.79
g 2.05 **h** 4.83 **i** 8.47

3 **a** sin **b** cos **c** tan
d cos **e** tan **f** sin

4 **a** $x = 1.37$ **b** $x = 5.12$ **c** $x = 91.44$
d $x = 13.86$ **e** $x = 9.21$ **f** $x = 9.17$

5 **a** 0.39 **b** 4.50 **c** 2.60
d 11.15 **e** 16.80 **f** 5.78
g 7.83 **h** 13.49 **i** 1

6 **a** 2.11 **b** 4.04 **c** 1.88

7 **a** 5.36 **b** 1.27 **c** 0.52

8 **a** 5.49 **b** 8.51 **c** 9.23

9 **a** 3.76 **b** 2.12 **c** 2.82
d 4.94 **e** 4.14 **f** 0.75

10 **a** 26.33 m **b** 52.66 m

11 6.96 m

12 **a** $b = 1.27, l = 2.72$ **b** $b = 0.68, l = 1.88$
c $b = 3.06, l = 2.57$

13 **a** $a = 3.5, b = 3.2, x = 1.4$
b $a = 3.464, b = 3.139, x = 1.327$
c It is better not to round off during the process as sometimes it can change the final answer.

Exercise 8F

1 **a** 17.32 **b** 13.86 **c** 106.73
d 19.84 **e** 24.58 **f** 13.44

2 **a** $x = 2$ **b** $x = 5$ **c** $x = \frac{1}{2}$
d $x = 1$ **e** $x = 0.1$ **f** $x = 0.1$

3 **a** $\frac{10}{x}$ **b** $\frac{1.4}{m}$ **c** $\frac{19}{x}$ **d** $\frac{2.8}{w}$

4 **a** 8.77 **b** 9.44 **c** 8.49

5 **a** 4.62 **b** 23.39 **c** 2.86

6 **a** 5.96 **b** 1.62 **c** 1.72

7 **a** 4.73 **b** 6.15 **c** 6.14
d 2.98 **e** 26.08 **f** 27.82

8 2.54 m

9 13.9 m

10 **a** $AB = 42.89$ cm, $BC = 20$ cm
b $AB = 5.32$ m, $BC = 1.82$ m
c $AB = 14.62$ cm, $BC = 13.74$ cm

11 **a** 7.464 m **b** 7.727 m

12 **a** 30.5 m **b** 17.5 m

13 **a** 17.16 **b** 30 **c** 4.01
d 59.78 **e** 51.13 **f** 38.09

Exercise 8G

1 $\theta = 30°$

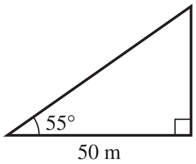
2 **a** 30° **b** 60° **c** 45°

3 **a** $\cos\theta = \frac{5}{12}$ **b** $\sin\theta = \frac{7}{10}$ **c** $\tan\theta = \frac{4}{3}$

4 **a** 30° **b** 53° **c** 61°
d 45° **e** 41° **f** 53°
g 48° **h** 6° **i** 37°
j 81° **k** 73° **l** 60°
m 42° **n** 48° **o** 34°
5 **a** 60° **b** 45° **c** 64.16°
d 48.59° **e** 53.13° **f** 68.20°
6 **a** 41°49′ **b** 56°15′ **c** 63°37′
d 48°49′ **e** 53°45′ **f** 67°23′
7 10°37′
8 15°57′
9 46°39′
10 **a** 36.9°, 53.1° **b** 34.8°, 55.2° **c** 36.9°, 53.1°
d 26.6°, 63.4° **e** 68.2°, 21.8°
11 pitch $A = 47°$, pitch $B = 43°$
12 **a** 5.54 m **b** 5.97 m
13 **a** 12° **b** yes **c** 286.4 cm

Exercise 8H

1 **a** 50 **b** 38 **c** 56
2 **a** 30° **b** 30° **c** 60°
3 **a**



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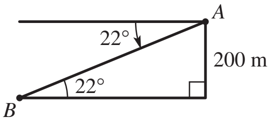
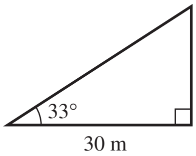


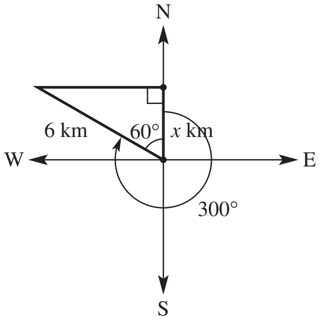
c



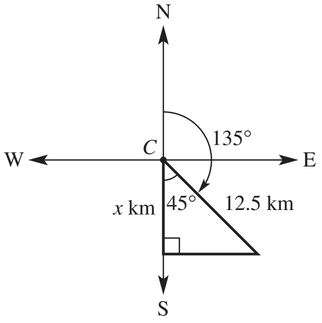
4 **a** 21.88 m **b** 43.5 m **c** 23.41 m
d 6.06 m **e** 536.29 m **f** 38.97 m
5 **a** 112.0 **b** 49 m **c** 86 m
d 105 m **e** 9260 m
6 **a** 26.6° **b** 29.7° **c** 5.7°
d 47.1° **e** 48.3°
7 38.35 m
8 1.25 km
9 280.04 m
10 **a** 30° **b** 30°
c equal due to parallel lines **d** 1.7
11 Answers will vary.

Exercise 8I

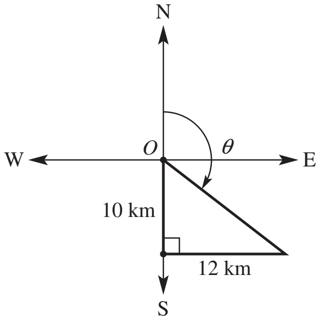
1 **a** S **b** W **c** N **d** SW
2 **a** C **b** F **c** D **d** B
e A **f** E
3 **a** 130° **b** 340° **c** 090°
d 128° **e** 313° **f** 355°
4 **a** north **b** east **c** west
d 060° **e** 240°
5 **a**



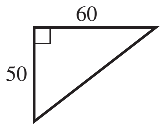
b



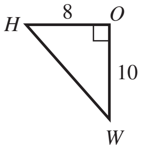
c



6 6.9 km
7 3.86 km
8 93.97 km
9 **a** 51.42 km **b** 61.28 km **c** 320°
10 **a**



b 78.10 km
c 50° **d** 050°
11 **a**



b 12.8 km **c** 39° **d** 321°
12 3.25 km

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13 115 km

14 a 18.03 km
 b 146°

Puzzles and games

1 a west **b** SW **c** NW
 d 198° **e** 120°

2 63.29 m

3 Answers will vary.

4

S														H
I	D	E	P	R	E	S	S	I	O	N				Y
N		E												P
E			G			S								O
				R		I	A	D	J	A	C	E	N	T
					E	D				A	N	G	L	E
						E							O	N
		T	R	I	A	N	G	L	E				P	U
	T	R	I	G	O	N	O	M	E	T	R	Y	P	S
		C	G	B						A	A		O	E
		O	H		E					N	T		S	
		S	T			A				G	I		I	
		I					R			E	O		T	
		N						I		N			E	
E	L	E	V	A	T	I	O	N	N	T				
					P	Y	T	H	A	G	O	R	A	S

Multiple-choice questions

1 B **2** E **3** C **4** B **5** C
6 C **7** D **8** E **9** A **10** C

Short-answer questions

1 No, $8^2 \neq 4^2 + 6^2$

2 15.17 m

3 a i BC **ii** AB **iii** AC
 b i AC **ii** AB **iii** BC

4 a 0.57 **b** 0.96 **c** 8.39

5 a 4.50 **b** 1.5 **c** 0.93

6 a 6.31 **b** 12.94 **c** 4.12

7 a 3.63 m **b** 1.69 m

8 567.13 m

9 a 41°49′ **b** 59°0′ **c** 72°15′

10 a 45° **b** 42.4 m

Extended-response questions

1 a 54.46° **b** 130.25 m **c** 187 m

2 a 539 km **b** 68° **c** 248°

Chapter 9

Pre-test

1 a 3 **b** 9 **c** -18
 d 36 **e** 9 **f** 0

2 a 9 **b** 14 **c** 6
 d 26 **e** -16 **f** 32

3 a $3a$ **b** $3m$ **c** $8p$
 d 0 **e** $-5m$ **f** $7x + y$
 g $9p$ **h** $6m$

4 a $15x$ **b** $16p$ **c** $32xy$
 d $-30a$ **e** ab **f** x
 g 1 **h** $2a$ **i** 3

5 a 5 **b** 3 **c** 5
 d 1 **e** 4 **f** 2
 g 3 **h** 2 **i** 4
 j 3 **k** 6 **l** 10

6 a a **b** w **c** w
 d z **e** $8n$ **f** x
 g $2p$ **h** $\frac{x}{2}$ **i** x

7 a $x + 3$ **b** $n + 6$ **c** $2w$
 d $\frac{x}{2}$ **e** $2x + 6$ **f** $x - 7$
 g $2(x + 3)$ **h** $3x + 1$

8 a $8x$ **b** $4x + 16$ **c** $3x + 4$

9 b, e, f, g, i

Exercise 9A

1 a yes **b** no **c** no
 d no **e** yes **f** yes

2 a $t = 3$ **b** $m = 6$ **c** $x = 6$
 d $m = -7$ **e** $x = 8$ **f** $x = -4$
 g $m = 32$ **h** $a = -6$ **i** $m = 15$

3 a $x = 6$ **b** $x = 9$ **c** $x = 17$
 d $x = 3$ **e** $x = -6$ **f** $x = 12$
 g $x = 36$ **h** $x = 120$ **i** $x = 101$

4 a $p = 3$ **b** $c = 6$ **c** $d = 9$
 d $m = 8$ **e** $z = 25$ **f** $w = 9$
 g $p = 1$ **h** $m = -7$ **i** $p = -\frac{1}{2}$

5 a $x = 50$ **b** $m = 21$ **c** $a = -12$
 d $z = 0$ **e** $x = -8$ **f** $w = -27$
 g $r = 56$ **h** $w = \frac{3}{2}$ **i** $m = \frac{1}{2}$

6 a $x = 3$ **b** $x = 9$ **c** $x = -11$
 d $x = 10$ **e** $x = 14$ **f** $x = 10$
 g $x = 3$ **h** $x = 4$ **i** $x = 50$
 j $x = 20$ **k** $x = 21$ **l** $x = 7$

7 a $x = 1$ **b** $x = 3$ **c** $x = 3$ **d** $x = -2$
 e $x = -1$ **f** $x = -9$ **g** $x = 4$ **h** $x = 8$
 i $x = 8$ **j** $x = -2$ **k** $x = -3$ **l** $x = 5$

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8 a $x = 9$ **b** $x = 0$ **c** $x = 56$

d $x = 20$ **e** $x = 35$ **f** $x = 90$

g $x = -32$ **h** $x = -20$ **i** $x = 22$

9 a $m = 5$ **b** $a = 7$ **c** $x = 1$

d $x = 1$ **e** $n = 9$ **f** $m = 22$

g $w = -7$ **h** $m = 7$ **i** $w = 27$

j $a = 1$ **k** $a = -37$ **l** $m = -5$

10 a $x + 4 = 6, x = 2$ **b** $x + 12 = 8, x = -4$

c $x - 5 = 5, x = 10$ **d** $\frac{x}{3} + 2 = 8, x = 18$

e $2x + 3 = 9, x = 3$ **f** $\frac{x - 3}{5} = 6, x = 33$

g $3x + 4 = 16, x = 4$

11 a 13 cm **b** 22 mm

12 a 3 **b** 5 **c** 28

d 42 **e** 82

13 a 11, 12 **b** 25, 44 **c** 8 m

14 a $C = 60h + 40$ **b** \$280

c \$1120 **d** 6 h

15 a $V = 6t + 5$ **b** 3 min **c** 11 min

Exercise 9B

1 a $3x - 3$ **b** $5x + 15$ **c** $-2x - 4$

d $-3x + 12$ **e** $-8x + 4$ **f** $5x + 13$

g $7x + 26$ **h** $9x + 9$ **i** $-x - 19$

j $-6x + 13$

2 a subtract $2x$ **b** subtract x

c subtract $3x$ **d** add x

e subtract $2x$ **f** subtract $3x$

g add $2x$ **h** add $3x$

3 a $x = 1$ **b** $x = 5$ **c** $x = -1$

d $a = 5$ **e** $a = 1$ **f** $x = 15$

g $m = 4$ **h** $d = 1$ **i** $a = 10$

j $a = 0$ **k** $x = 0$ **l** $a = 3$

4 a $x = 1$ **b** $x = 2$ **c** $x = 3$

d $x = 2$ **e** $x = 3$ **f** $x = 2$

g $x = -2$ **h** $x = -1$

5 a $x = 1$ **b** $x = 1$ **c** $x = 0$

d $x = 0$ **e** $x = 3$ **f** $x = 1$

g $x = 3$ **h** $x = -2$

6 a $x = 2$ **b** $x = 12$ **c** $x = -3$

d $x = 20$ **e** $x = 4$ **f** $x = 8$

g $x = 4$ **h** $x = -4$ **i** $x = -1$

j $x = 11$ **k** $x = 1$ **l** $x = -1$

7 a $x = 13$ **b** $x = 6$ **c** $x = 13$

d $x = 11$ **e** $x = 10$ **f** $x = 5$

g $x = 6$ **h** $x = 8$ **i** $x = -2$

8 a $x = 12$ **b** $x = 18$ **c** $x = 60$

d $x = 9\frac{1}{3}$ **e** $x = 5$ **f** $x = -6$

9 a $x = 10$ **b** $x = \frac{5}{3}$ **c** $x = 45$

10 a $x = 3$ **b** $x = 5$ **c** $x = 10$

d $x = 30$ **e** $x = 7$

11 a $x = 7$ **b** $x = 3$ **c** $x = 5$

d $x = 2$ **e** $x = 5$ **f** $x = 6$

g $x = 11$

12 a $C = 850 + 156h$ **b** 7 hours

c 8:15 p.m.

13 a $x = 1$ **b** $x = -3$ **c** $x = 2\frac{2}{5}$

d $x = 8$ **e** $x = 3$ **f** $x = -\frac{8}{17}$

Exercise 9C

1 a I **b** F **c** V **d** A **e** c **f** P

2 a $m = 60$ **b** $A = 48$ **c** $A = 36$

d $v = 14.3$ **e** $m = 3.7$

3 a $t = 4$ **b** $t = 4$ **c** $t = 10$ **d** $t = 8$

4 a $b = 10$ **b** $b = 9$ **c** $b = 17$ **d** $b = 1.3$

5 a $h = 5$ **b** $h = 12$ **c** $h = 3$ **d** $h = 7$

6 a $b = 15$ **b** $b = 16$ **c** $b = 12$ **d** $b = 32$

7 a $h = 8$ **b** $h = 8$ **c** $h = 12$ **d** $h = 28$

8 a $m = 4$ **b** $m = 40$ **c** $m = 72$ **d** $m = 4$

9 a $h = 5.7$ **b** $h = 5.1$ **c** $h = 5.7$ **d** $h = 16.0$

10 a 86°F **b** −1.1°C **c** 212°F **d** −17.8°C

11 a \$32 **b** 60 km

12 a $P = 750$ **b** $t = 3.125$ **c** $R = 0.075$

13 a 1.5 tablets **b** 1250 mg

14 a 75 mL/h **b** $\frac{1}{3}$h = 20 min

15 a number of hours **b** 7.5 hours

16 $P = 27.32$ cm, $A = 28.87\text{cm}^2$

Exercise 9D

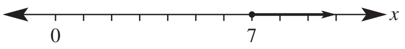
1 a 3 **b** 2 **c** 1 **d** 5 **e** 4

2 a $x \geqslant 1$ **b** $x < 7$ **c** $x \leqslant 4$ **d** $x > -9$

e $x \leqslant 1$ **f** $x > 8$ **g** $x < -7$ **h** $x \geqslant 1\frac{1}{2}$

i $x < 1$ **j** $x > 0$

3 a



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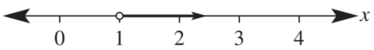

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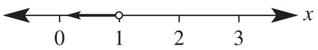

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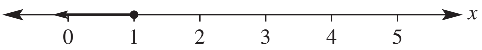

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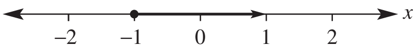

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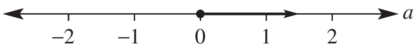
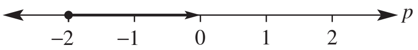
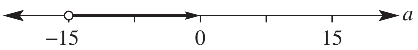


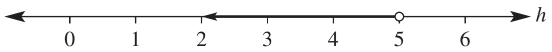
g



h



i



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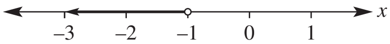
4 **a** $x \geqslant -1$ **b** $x < 1$ **c** $a < 6$
d $a \geqslant -2$ **e** $w \leqslant 5$ **f** $w > -3$
g $x \leqslant 3$ **h** $x > -3.5$

5 **a** $x \leqslant 6$

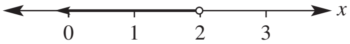
b $x \leqslant -3$

c $x > 4$

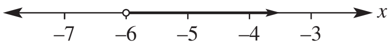
d $x < -1$



e $x < 2$

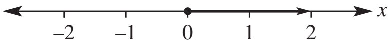


f $x > -6$



g $x \geqslant 5$

h $x \geqslant 0$

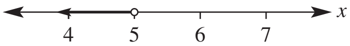


6 **a** $n > 100000$ **b** $n \geqslant 50$ **c** $n > 3$
d $n > 100$ **e** $n \leqslant 30$

7 **a** $x < 0; -6, -2, -\frac{1}{2}$ **b** $x > 10; 15, 24$
c $x \geqslant 10; 10, 15, 24$ **d** $x \leqslant 0; -6, -2, -\frac{1}{2}, 0$
e $x \geqslant -1, -\frac{1}{2}, 0, 2, 5, 7, 10, 15, 24$
f $x < 10; -6, -2, -\frac{1}{2}, 0, 2, 5, 7$

8 **a** $x > 5$

b $x < 5$



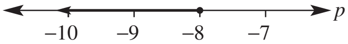
c $x > 5$

d $x \geqslant 16$

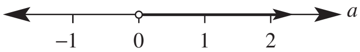
e $x > 7$

f $x < 7$

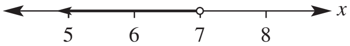
g $p \leqslant -8$



h $a > 0$

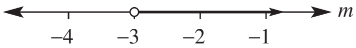


i $x < 7$

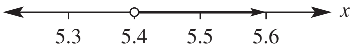


j $x \leqslant 7$

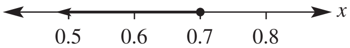
k $m > -3$



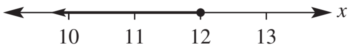
l $d > 5.4$



m $x \leqslant 0.7$



n $x \leqslant 12$



o $x > 4$

9 **a** $a \leqslant 2$ **b** $y > 3$ **c** $p > 5$
d $x \geqslant 4$ **e** $x < 1$ **f** $w \geqslant \frac{3}{2}$
g $x < 1$ **h** $x \geqslant 1$ **i** $p < 1$

10 **a** $x \leqslant 2$ **b** $a \leqslant 1$ **c** $x \geqslant 28$
d $x > -15$ **e** $x < 4$ **f** $x < 30$
g $x > \frac{19}{2}$ **h** $x < -\frac{1}{2}$ **i** $x \geqslant -\frac{8}{3}$
j $x > 1$ **k** $x \geqslant \frac{3}{2}$ **l** $x < -\frac{9}{2}$

11 **a** $3x < 9, x < 3$ **b** $\frac{3x}{4} < 6, x < 8$
c $2x + 15 > 20, x > \frac{5}{2}$ **d** $x + x + 4 < 24, x < 10$
e $4x + 7 \leqslant 27, x \leqslant 5$

12 **a** $x > -1$ **b** $x \leqslant -3$ **c** $p \geqslant -7$
d $a > 19$ **e** $w \leqslant -6$ **f** $p > -6$
g $x > -1$ **h** $a \leqslant -\frac{6}{7}$

13 **a**

4	6	4 < 6	T or F?
$4 + 3$	$6 + 3$	$7 < 9$	T
$4 - 3$	$6 - 3$	$1 < 3$	T
4×2	6×2	$8 < 12$	T
$4 \div 2$	$6 \div 2$	$2 < 3$	T
$4 \times (-2)$	$6 \times (-2)$	$-8 < -12$	F
$4 \div (-2)$	$6 \div (-2)$	$-2 < -3$	F

b subtract, divide, positive, inequality, multiply, divide, number, true

Exercise 9E

1 **a** (0, 3) **b** (1, 2)
c no point of intersection **d** (2, 8)
e no point of intersection **f** (4, 3)
g (2, 5) **h** (0, 4)
i no point of intersection

2 **a** $y = 0$ **b** $x = 0$

3 **a** (2, 3) **b** (2, 8) **c** (0, 9) **d** (−3, 8)

4 **a** (2, 3) **b** (3, −2)

5 **a** (3, 9) **b** (1, −3)

6 **a** (1, −4) **b** (1, 1)

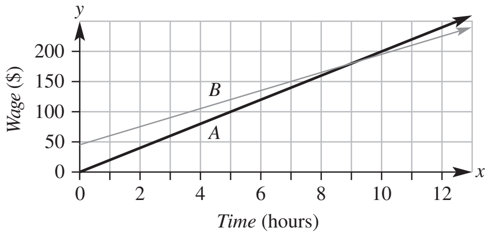
7 **a** 200 km **b** $1400
c Best removals, $100 cheaper
d A$^+$ removals, $200 cheaper

8 **a**

Time in hours	0	1	2	3	4	5	6
Wage of company A	$0	$20	$40	$60	$80	$100	$120
Time in hours	7	8	9	10	11	12	
Wage of company A	$140	$160	$180	$200	$220	$240	

Time in hours	0	1	2	3	4	5	6	7	8	9	10	11	12
Wage of company B	$45	$60	$75	$90	$105	$120	$135	$150	$165	$180	$195	$210	$225

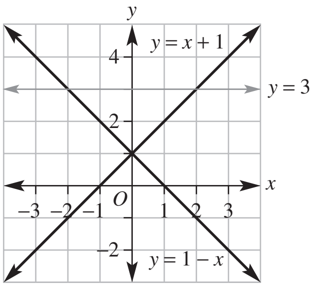
b



c 9 hours

d $180

9 a



b (−2, 3), (0, 1), (2, 3)

c 4 units, $\sqrt{8}$ units, $\sqrt{8}$ units

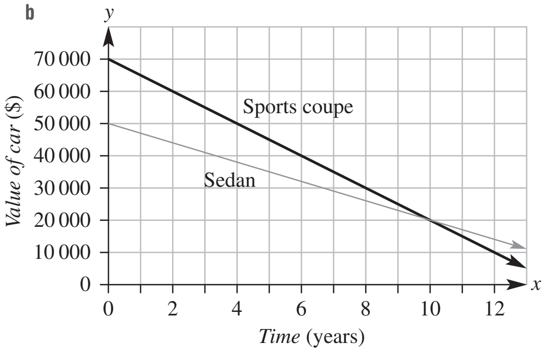
d isosceles right-angled triangle

10 a

Time in years	0	2	4	6	8	10	12
Value of luxury sports coupe	$70 000	$60 000	$50 000	$40 000	$30 000	$20 000	$10 000

Time in years	0	2	4	6	8	10	12
Value of sedan	$50 000	$44 000	$38 000	$32 000	$26 000	$20 000	$14 000

b



c 10 years **d** $20 000

11 a no

b parallel lines

d (−6, −12), (−5, −9), (−4, −6), (−3, −3)

12 a yes (0, −1)

b same *y*-intercept

d (−2, −3), parallel, (2, 5), (1, 3)

Exercise 9F

1 a (2, 10) **b** (−5, −15) **c** (−4, −8)
d (1, 4) **e** (2, 2) **f** (2, 12)

2 a (3, 4) **b** (1, 3) **c** (2, 1)
d (4, 3) **e** (−5, −3) **f** (1, 6)
g (4, 1) **h** (−1, −5)

3 a (−1, 2) **b** (3, −1) **c** (4, 4)
d (2, 4) **e** (11, −2) **f** (4, 0)

4 a (2, 4) **b** (−3, 2) **c** (7, −1)
d (4, 4) **e** (−2, −7) **f** (−1, 2)

5 a (1, 5) **b** (4, 10) **c** (2, 1) **d** (2, 9)

6 Paul: 43 years old, Mary: 38 years old

7 length = 18 cm, breadth = 6 cm

8 vanilla thick shake: $5, fruity twirl: $3

9 Carlos: 37 years old, Ella: 17 years old

10 a i Joe's: $60, Paul's: $150

ii Joe's: 20c/km, Paul's: 10c/km

iii Joe's $C = 0.2k + 60$, Paul's $C = 0.1k + 150$

iv 900 km

b Joe's if you are travelling less than 900 km and Paul's for more than 900 km.

Exercise 9G

1 a − **b** + **c** +

2 a $6x - 4y = -2$ **b** $9x - 6y = -3$
c $12x - 8y = -4$

3 a (6, 1) **b** (3, 4) **c** (2, 7)

4 a (7, 2) **b** (3, 8) **c** (4, 1)

5 a (2, 5) **b** (2, 3) **c** (4, 2) **d** (2, 2)

6 a (1, 1) **b** (2, 1) **c** (2, −1)

7 a (−2, 4) **b** (1, 1) **c** (2, 0)
d (1, 1) **e** (3, −1) **f** (1, 1)

8 **a** (1, 1) **b** (4, 2) **c** (3, 4)
d (2, 1) **e** (3, −1) **f** (−2, 5)
9 **a** (3, 1) **b** (1, −10) **c** (−2, −3)
d (0, 1) **e** (−1, 2) **f** (5, −2)
g (2, 2) **h** (1, 1)
10 Bob: 36 years old, Francene: 20 years old
11 **a** $x + y = 16, x - y = 2, x = 9, y = 7$
b $x + y = 30, x - y = 10, x = 20, y = 10$
c $2x + y = 12, x + y = 7, x = 5, y = 2$
12 **a** Let a be the number of apples and m be the number of mangos. $10a + 5m = 1250$,
$15a + 4m = 1350$
b apples: 50 cents, mangos: $1.50
c $8.00
13 **a** Let m be the number of multiple-choice and s be the number of short-answer questions.
b $2m + 3s = 50$, $m + s = 22$
c 16 multiple-choice questions
14 children: 2500, adults: 2500
15 **a** $x = 1, y = 2$
b $x = 2, y = 2$
16 **a** **i** $g + 30$ **ii** $d + 30$
b $g = d + 31$, $g + 30 = 2(d + 30)$
c Gary is 32 and his daughter is 1.
17 **a** (4, −3) **b** (1, 1) **c** (3, 4)
d (2, 2) **e** $\left(\frac{1}{2}, -1\right)$ **f** $\left(-3, \frac{1}{3}\right)$

Puzzles and games

1 Each row, column and diagonal adds to 6.

9	−5	−4	6
−2	4	3	1
2	0	−1	5
−3	7	8	−6

2 **a** 64 **b** 8 **c** 29.3
d 18 years old
3 Many possible equations; e.g.
$3x + 2 = -4$; $\frac{5x}{2} = -5$; $2(x + 5) = 6$
4 Toowoomba
5 Many possible simultaneous equations; e.g.
$x + y = 1$, $2x - y = 8$
6 **a** 4.5 hours
b 117 km
7 Talia was jogging at 11.5 km/h and cycling at 23 km/h.

Multiple-choice questions

1 C **2** B **3** C **4** D **5** B
6 C **7** D **8** B **9** C **10** D
11 A **12** E **13** B **14** D **15** A
16 A **17** E

Short-answer questions

1 **a** $a = 8$ **b** $m = -30$ **c** $x = -8$
d $x = 8$ **e** $m = 0$ **f** $w = 15$
g $m = -0.2$ **h** $w = 4$ **i** $r = 6$
2 **a** $m = 2$ **b** $w = 8$ **c** $m = 10$
d $w = 8$ **e** $m = 14$ **f** $m = \frac{4}{3} = 1\frac{1}{3}$
g $a = \frac{3}{2} = 1\frac{1}{2}$ **h** $x = 1$ **i** $x = 3$
3 **a** $m = 3$ **b** $a = 7$ **c** $x = 4$
d $x = \frac{3}{2} = 1\frac{1}{2}$ **e** $m = 2\frac{1}{2}$ **f** $x = \frac{7}{8}$
g $x = 2$ **h** $x = 8$
4 **a** $p = 4$ **b** $p = 4$ **c** $p = -9$
d $p = -2$ **e** $p = -5$ **f** $p = 2$
5 **a** $b = 8$ **b** $b = 3.5$ **c** $x = 2.4$
d $m = 10$ **e** $C = 35$
6 **a** $m > -2$ **b** $n \leqslant 0.5$ **c** $x \geqslant -1$
d $x > 0$ **e** $x < 15$
7 **a** $x \geqslant -18$ **b** $m < 3.5$ **c** $x > 2$
d $x < 3$ **e** $x \leqslant 8$ **f** $m \geqslant 10$
8 **a** $x \geqslant -2$ **b** $x \geqslant -2$ **c** $x < 0$
d $x > -1$ **e** $x < -3$ **f** $x \leqslant -20$
9 **a** (1, 2) **b** (2, 3)
c no point of intersection
10 **a** (1, 6) **b** (3, 2) **c** (0, 0)
11 **a** (3, 2) **b** (5, 15) **c** (2, 1)
12 **a** (−2, −3) **b** (2, 1) **c** (−2, 2)
13 **a** (−3, −6) **b** (−1, −3) **c** (2, 1)
d (−3, 9) **e** (6, 2) **f** (−3, −5)
14 **a** $6x = 420$, the number is 70
b $x + 8 = 5$, the number is −3
c $\frac{a}{9} = 12$, the number is 108
d $3x + 7 = 16$, the number is 3
e $2(x + 6) = 18$, the number is 3
15 **a** $120
b $(96 + 2$n$)
c $96 + 2n = 308$, 106 packages sold
16 **a** x: number of 20-cent coins, y: number of 50-cent coins;
$x + y = 160$, $20x + 50y = 5000$
b Number of 20-cent coins = 100
Number of 50-cent coins = 60
17 50 children

Extended-response questions

1 **a** $P = 6x - 4$
i $x = 22$
ii 20 cm, 27 cm, 37 cm, 7 cm, 30 cm, 7 cm
b **i** $x = 26$; 24 cm, 31 cm, 45 cm, 7 cm, 38 cm, 7 cm
ii $x = 38$; 36 cm, 43 cm, 69 cm, 7 cm, 62 cm, 7 cm
2 **a** **i** $C = 70t + 50$ **ii** $C = 100 + 60t$
b (5, 400)

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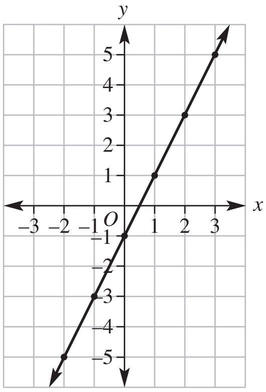
Chapter 10

Pre-test

1 **a** 3 **b** 2 **c** 5
2 **a** $4x + 2y$ **b** $2xy - x$ **c** $2ab$
3 **a** $2a$ **b** $-2m$ **c** $18a^2$
d $-6x^2y$ **e** $-\frac{1}{3}$ **f** $2x$
4 **a** $4m + 4n$ **b** $-6x + 12$ **c** $6x^2 + 2x$
d $4a - 8a^2$ **e** $3x - 7$ **f** $-2x + 1$
5 **a** $7(x + 1)$ **b** $-9x(1 + 3x)$ **c** $a(a + b)$
6 **a** $-\frac{1}{2}$ **b** 3 **c** 5

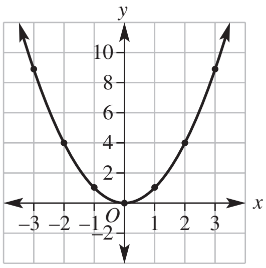
7

x	–2	–1	0	1	2	3
y	–5	–3	–1	1	3	5



8

x	–3	–2	–1	0	1	2	3
y	9	4	1	0	1	4	9



Exercise 10A

1 **a** perfect square
b difference of two squares
c difference of two squares
d perfect square
2 **a** $6x$ **b** $-20x$ **c** $2x^2$
d $-4x^2$ **e** $\frac{x}{2}$ **f** $\frac{x}{3}$
g $-4x$ **h** $-3x$ **i** $-18x$
j $7x$ **k** $5x$ **l** $-13x$
3 **a** $x^2 + 2x$ **b** $x^2 + 4x + 3$ **c** $x^2 + 8x + 16$
4 **a** $2x + 10$ **b** $3x - 12$ **c** $-5x - 15$
d $-4x + 8$ **e** $6x - 3$ **f** $12x + 4$
g $-10x + 6$ **h** $-20x - 15$ **i** $2x^2 + 5x$
j $3x^2 - x$ **k** $2x - 2x^2$ **l** $6x - 3x^2$
m $-6x^2 - 4x$ **n** $-18x^2 + 6x$ **o** $-10x + 10x^2$
p $-4x + 16x^2$
5 **a** $x^2 + 10x + 16$ **b** $x^2 + 7x + 12$
c $x^2 + 12x + 35$ **d** $x^2 + 5x - 24$
e $x^2 + x - 30$ **f** $x^2 + x - 6$
g $x^2 - 4x - 21$ **h** $x^2 - 10x + 24$
i $x^2 - 13x + 40$ **j** $6x^2 + 13x + 5$
k $12x^2 + 23x + 10$ **l** $10x^2 + 41x + 21$
m $9x^2 - 9x - 10$ **n** $20x^2 + 2x - 6$
o $6x^2 + 5x - 25$
6 **a** $x^2 + 10x + 25$ **b** $x^2 + 14x + 49$
c $x^2 + 12x + 36$ **d** $x^2 - 6x + 9$
e $x^2 - 16x + 64$ **f** $x^2 - 20x + 100$
g $4x^2 + 20x + 25$ **h** $25x^2 + 60x + 36$
i $49x^2 - 14x + 1$
7 **a** $x^2 - 16$ **b** $x^2 - 81$ **c** $x^2 - 64$
d $9x^2 - 16$ **e** $4x^2 - 9$ **f** $64x^2 - 49$
g $16x^2 - 25$ **h** $4x^2 - 81$ **i** $25x^2 - 49$
8 **a** 6 **b** 7 **c** 16 **d** 4 **e** 4 **f** 6
9 **a** 3 **b** 3 **c** 3 **d** 8 **e** 1 **f** 2
10 **a** $(x^2 - 12x + 36)$ cm^2 **b** $(x^2 + 10x - 200)$ cm^2
11 **a** $-x^2 + 7x$ **b** $10a - 28$
c $x^2 - 81$ **d** $4x^2 + 12x + 9$
12 **a** **i** $x^2 + 5x$ **ii** $x^2 + 13x + 36$ **iii** $8x + 36$
b **i** 36 m^2 **ii** 68 m^2

Exercise 10B

1 **a** $2(x + 3)$ **b** $-4(x - 1)$
c $(x + 2)(x - 2)$ **d** $(3x + 2)(3x - 2)$
2 **a** 7 **b** 6 **c** 8 **d** -5
e $2a$ **f** $3a$ **g** $-5a$ **h** $-3xy$
3 **a** $3(x - 6)$ **b** $4(x + 5)$ **c** $7(a + b)$
d $3(3a - 5)$ **e** $-5(x + 6)$ **f** $-2(2y + 1)$
g $-3(4a + 1)$ **h** $-b(2a + c)$ **i** $x(4x + 1)$
j $x(5x - 2)$ **k** $6b(b - 3)$ **l** $7a(2a - 3)$
m $5a(2 - a)$ **n** $6x(2 - 5x)$ **o** $-x(2 + x)$
p $-4y(1 + 2y)$
4 **a** $(x + 3)(x - 3)$ **b** $(x + 5)(x - 5)$
c $(y + 7)(y - 7)$ **d** $(y + 1)(y - 1)$
e $(a + 4)(a - 4)$ **f** $(b + 6)(b - 6)$
g $(y + 12)(y - 12)$ **h** $(z + 20)(z - 20)$
i $(2x - 3)(2x + 3)$ **j** $(6a - 5)(6a + 5)$
k $(1 + 9y)(1 - 9y)$ **l** $(10 - 3x)(10 + 3x)$
m $(5x - 2y)(5x + 2y)$ **n** $(8x - 5y)(8x + 5y)$
o $(3a + 7b)(3a - 7b)$ **p** $(12a - 7b)(12a + 7b)$
5 **a** $(2 + x)(2 - x)$ **b** $(3 + y)(3 - y)$
c $(6 + a)(6 - a)$ **d** $(10 + 3x)(10 - 3x)$

e $(b + a)(b - a)$ **f** $(20 + 5a)(20 - 5a)$
g $(2a + 3b)(2a - 3b)$ **h** $(4y + 11x)(4y - 11x)$
6 a $2(x + 4)(x - 4)$ **b** $5(x + 3)(x - 3)$
c $6(y + 2)(y - 2)$ **d** $3(y + 4)(y - 4)$
e $3(x + 5y)(x - 5y)$ **f** $3(a + 10b)(a - 10b)$
g $3(2x + 3y)(2x - 3y)$ **h** $7(3a + 4b)(3a - 4b)$
i $3(6x - 7y)(6x + 7y)$
7 a i 100 m **ii** 96 m **iii** 36 m
b $(10 + t)(10 - t)$
c i 100 m **ii** 96 m **iii** 36 m
d 10 seconds
8 a 60 **b** 35 **c** 69 **d** 104
e 64 **f** 40 **g** 153 **h** 1260
9 a i x^2 cm^2 **ii** $(1600 - x^2)$ cm^2
b $(40 + x)(40 - x)$ cm^2
c i 1200 cm^2 **ii** 1500 cm^2
d $x = 30$

Exercise 10C

1 a $x^2 + 5x + 6$ **b** $x^2 - 2x - 8$ **c** $x^2 - 10x + 21$
d $x^2 - 2x + 1$ **e** $x^2 + 10x + 25$ **f** $x^2 - 12x + 36$
2 a 9, 2 **b** 10, 2 **c** 5, −3 **d** 4, −3
e −8, 3 **f** −10, 3 **g** −2, −5 **h** −12, −3
3 a i 5, 3 **ii** $(x + 5)(x + 3)$
b i 5, −2 **ii** $(x + 5)(x - 2)$
c i −4, −2 **ii** $(x - 4)(x - 2)$
4 a $(x + 6)(x + 1)$ **b** $(x + 3)(x + 2)$
c $(x + 3)^2$ **d** $(x + 5)(x + 2)$
e $(x + 4)(x + 3)$ **f** $(x + 9)(x + 2)$
g $(x - 1)(x + 6)$ **h** $(x + 3)(x - 2)$
i $(x + 4)(x - 2)$ **j** $(x - 1)(x + 4)$
k $(x + 10)(x - 3)$ **l** $(x + 11)(x - 2)$
m $(x - 2)(x - 5)$ **n** $(x - 4)(x - 2)$
o $(x - 4)(x - 3)$ **p** $(x - 1)^2$
q $(x - 6)(x - 3)$ **r** $(x - 2)(x - 9)$
s $(x - 6)(x + 2)$ **t** $(x - 5)(x + 4)$
u $(x - 7)(x + 2)$ **v** $(x - 4)(x + 3)$
w $(x + 8)(x - 4)$ **x** $(x - 5)(x + 2)$
5 a $(x - 2)^2$ **b** $(x + 3)^2$ **c** $(x + 6)^2$
d $(x - 7)^2$ **e** $(x - 9)^2$ **f** $(x - 10)^2$
g $(x + 4)^2$ **h** $(x + 10)^2$ **i** $(x - 15)^2$
6 a $2(x + 5)(x + 2)$ **b** $3(x + 4)(x + 3)$
c $2(x + 9)(x + 2)$ **d** $5(x - 2)(x + 1)$
e $4(x - 5)(x + 1)$ **f** $3(x - 5)(x + 2)$
g $-2(x + 4)(x + 3)$ **h** $-3(x - 2)(x - 1)$
i $-2(x - 7)(x + 2)$ **j** $-4(x - 2)(x + 1)$
k $-5(x + 3)(x + 1)$ **l** $-7(x - 6)(x - 1)$
7 a $2(x + 11)^2$ **b** $3(x - 4)^2$ **c** $5(x - 5)^2$
d $-3(x - 6)^2$ **e** $-2(x - 7)^2$ **f** $-4(x + 9)^2$
8 a i $(x^2 + 3x)$ m^2 **ii** $(x^2 + 3x - 10)$ m^2
b $(x + 5)(x - 2)$ m^2
c i 30 m^2 **ii** 60 m^2

9 a $x + 6$ **b** $x - 3$ **c** $x - 3$
d $\dfrac{1}{x + 7}$ **e** $\dfrac{1}{x - 5}$ **f** $\dfrac{1}{x - 6}$
g $x - 2$ **h** $x + 1$ **i** $x - 8$

Exercise 10D

1 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144
2 a 16 **b** 49 **c** 81 **d** 121
e 9 **f** 25 **g** 64 **h** 144
3 a 6 **b** 8 **c** −7 **d** −5
e −10 **f** −1 **g** 0 **h** 11
4 a $c > 0$ **b** $c = 0$ **c** $c < 0$
5 a $x = \pm 5$ **b** $x = \pm 9$ **c** $x = \pm 6$
d $x = \pm 7$ **e** no solutions **f** no solutions
g $x = \pm 20$ **h** $x = \pm 12$ **i** $x = \pm 5$
j $x = \pm 4$ **k** $x = \pm 1$ **l** no solutions
m $x = \pm 8$ **n** $x = \pm 9$ **o** $x = \pm 6$
p no solutions
6 a i $x = \pm\sqrt{14}$ **ii** $x = \pm\sqrt{22}$
iii $x = \pm\sqrt{17}$ **iv** no solutions
v $x = \pm\sqrt{5}$ **vi** $x = \pm\sqrt{6}$
vii $x = \pm\sqrt{21}$ **viii** $x = \pm\sqrt{6}$
b i $x = \pm 3.5$ **ii** $x = \pm 5.9$
iii $x = \pm 5.5$ **iv** $x = \pm 7.9$
7 a $x = \pm 2$ **b** $x = \pm 9$ **c** no solutions
d no solutions **e** $x = \pm 3$ **f** $x = \pm\sqrt{15}$
g $x = \sqrt{3}$ **h** $x = \pm 1$ **i** $x = \sqrt{2}$
j $x = -\sqrt{7}$ **k** no solutions
8 a $x = \pm 4$ **b** $x = \pm 3$ **c** $x = \pm 3$
d $x = \pm 5$ **e** $x = \pm 2$ **f** no solutions
9 24 m
10 4 seconds
11 a $x = \sqrt{29}$ **b** $x = 8$
c $x = \sqrt{17}$ **d** $x = \sqrt{2}$
12 2.5 m
13 a $r = \pm 2.8$
b Since, in this practical scenario, r is the radius, then r must be greater than 0; i.e. $r = 2.8$.
14 a $b > 0$ **b** $b = 0$ **c** $b < 0$
15 a $b < 0$ **b** $b = 0$ **c** $b > 0$
16 a $x = \pm 5$
b i $-5 < x < 5$
ii $x > 5$ or $x < -5$
17 a $x = -4, 2$ **b** $x = -10, 4$ **c** $x = 0, 4$
d $x = 1, 9$ **e** $x = -3, 2$ **f** $x = 0, 1$
g $x = 0, \dfrac{4}{3}$ **h** $x = -\dfrac{3}{2}, 3$

Exercise 10E

1 a 1 **b** −3 **c** −7 **d** 5
e 0 **f** 0 **g** −2 **h** $\dfrac{7}{2}$

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2 a

x	-3	-2	-1	0	1	2
$(x+2)(x-1)$	4	0	-2	-2	0	4

b $1, -2$ **c** $-3, 2$

3 a $x - 2, 2$ **b** $x + 4, 1, -4$

c $x + 6, 2x - 7, -6, 7, -6, \frac{7}{2}$

4 a $x = 0, -1$ **b** $x = 0, 5$ **c** $x = 0, 4$

d $x = 3, -2$ **e** $x = -5, 4$ **f** $x = -1, 1$

g $x = 2, -1$ **h** $x = \frac{2}{3}, 7$ **i** $x = 0, -\frac{5}{4}$

j $x = \frac{1}{2}, -\frac{7}{3}$ **k** $x = \frac{5}{4}, -\frac{2}{5}$ **l** $x = -\frac{3}{8}, -\frac{3}{4}$

5 a $x = 0, 4$ **b** $x = 0, 3$ **c** $x = 0, -2$

d $x = 0, 4$ **e** $x = 0, 5$ **f** $x = 0, -2$

6 a $x = -5, 5$ **b** $x = 6, -6$ **c** $x = 10, -10$

d $x = \frac{3}{2}, -\frac{3}{2}$ **e** $x = \frac{4}{3}, -\frac{4}{3}$ **f** $x = \frac{9}{7}, -\frac{9}{7}$

7 a $x = -2, -1$ **b** $x = -3, -2$ **c** $x = 2, 4$

d $x = 5, 2$ **e** $x = -6, 2$ **f** $x = -5, 3$

g $x = 5, -4$ **h** $x = 8, -3$ **i** $x = 4, 8$

j $x = -2$ **k** $x = -5$ **l** $x = 4$

m $x = 7$ **n** $x = 12$ **o** $x = -9$

8 a 2 **b** 2 **c** 1 **d** 1 **e** 2

f 2 **g** 1 **h** 1 **i** 1

9 a i 3.2 m **ii** 4.8 m

b 0, 10 **c** 10 seconds

10 a $x = -2, -6$ **b** $x = -1, 11$

c $x = 3$ **d** $x = 2$

11 a 150 cm^2

b i $x(x + 5)$ cm^2 $= (x^2 + 5x)$ cm^2

ii $(x^2 + 5x - 150)$ cm^2

c $(x + 15)(x - 10)$ cm^2

d 10 **e** 20

Exercise 10F

1 a $x + 4$ **b** $x + 10$ **c** $x - 7$

d $x - 2$ **e** $x + 6$

2 a $x^2 + 2x - 3 = 0$

b $x^2 - 3x - 5 = 0$

c $x^2 + 7x - 4 = 0$

3 a $x = 3$ **b** $x = 5$ **c** $x = 4$

4 b $(x + 5)$ m

c $x(x + 5) = 24$

d $x^2 + 5x - 24 = 0, x = -8, 3$

e breadth = 3 m, length = 8 m

5 a breadth = 6 m, length = 10 m

b breadth = 9 m, length = 7 m

c breadth = 14 mm, length = 11 mm

6 a $A = \frac{1}{2}x(x + 2)$ **b** $\frac{1}{2}x(x + 2) = 4$

c $x^2 + 2x - 8 = 0$ **d** $x = 2, h = 4$

7 height = 2 m, base = 7 m

8 a $x^2 + x - 132 = 0$

b $-12, 11$

c $-12, -11$ and $11, 12$

9 8 and 9 or -9 and -8

10 15

11 1 m

12 a 3.75 m

b $t = 1$ second, 3 seconds

c The ball will reach this height both on the way up and on the way down.

d $t = 0$ seconds, 4 seconds

e $t = 2$ seconds

f The ball reaches a maximum height of 4 m.

g No, 4 metres is the maximum height. If $h = 5$, there is no solution.

13 a $x = 0, 100$

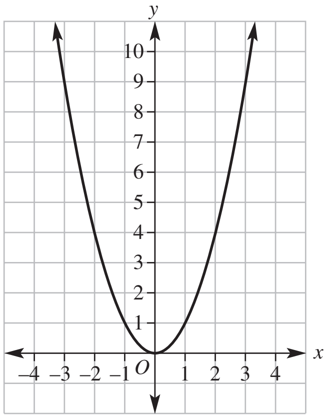
b The rocket starts at the launching site (i.e. at ground level) and hits the ground again 100 metres from the launching site.

c 2 m or 98 m

Exercise 10G

1

x	-3	-2	-1	0	1	2	3
y	9	4	1	0	1	4	9



2 a maximum **b** $(-2, 9)$ **c** 5

d -5 and 1 **e** $x = -2$

3 a i $(2, -5.4)$, minimum **ii** $x = 2$

iii -1 and 5 **iv** -3

b i $(2, 0)$, maximum **ii** $x = 2$

iii 2 **iv** -1

c i $(2, 5)$, minimum **ii** $x = 2$

iii no x-intercepts **iv** 7

d i $(-3, 0)$, minimum **ii** $x = -3$

iii -3 **iv** 4

e i $(2, -2)$, minimum **ii** $x = 2$

iii 1 and 3 **iv** 6

f i $(0, 3)$, maximum **ii** $x = 0$

iii -3 and 3 **iv** 3

4

	Formula	Max or min	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 3x^2$	min	no	(0, 0)	$y = 3$	narrower
b	$y = \frac{1}{2}x^2$	min	no	(0, 0)	$y = \frac{1}{2}$	wider
c	$y = 2x^2$	min	no	(0, 0)	$y = 2$	narrower
d	$y = -4x^2$	max	yes	(0, 0)	$y = -4$	narrower
e	$y = -\frac{1}{3}x^2$	max	yes	(0, 0)	$y = -\frac{1}{3}$	wider
f	$y = -2x^2$	max	yes	(0, 0)	$y = -2$	narrower

5

	Formula	Turning point	Axis of symmetry	y-intercept ($x = 0$)	x-intercept
a	$y = (x + 3)^2$	(−3, 0)	$x = -3$	9	−3
b	$y = (x - 1)^2$	(1, 0)	$x = 1$	1	1
c	$y = (x - 2)^2$	(2, 0)	$x = 2$	4	2
d	$y = (x + 4)^2$	(−4, 0)	$x = -4$	16	−4

6

	Formula	Turning point	y-intercept ($x = 0$)	y value when $x = 1$
a	$y = x^2 + 3$	(0, 3)	3	$y = 4$
b	$y = x^2 - 1$	(0, −1)	−1	$y = 0$
c	$y = x^2 + 2$	(0, 2)	2	$y = 3$
d	$y = x^2 - 4$	(0, −4)	−4	$y = -3$

7 a F **b** C **c** E **d** D **e** A **f** B

8 a $y = x^2 + 2$ **b** $y = -x^2$

c $y = (x + 1)^2$ **d** $y = (x - 5)^2$

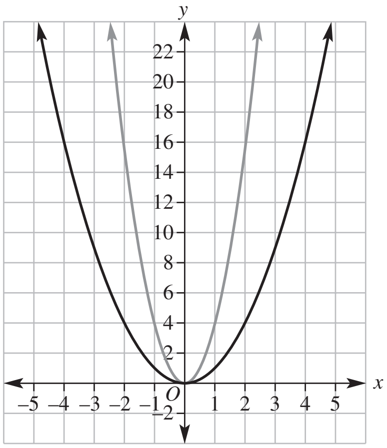
9 a $\pm\sqrt{14}$ **b** ± 3

c

$$\begin{aligned} y &= x^2 - 9 \\ -10 &= x^2 - 9 \\ -1 &= x^2 \\ x^2 &= -1 \end{aligned}$$

This has no solutions; therefore, there is no point on the curve for which the y value is −10.

10 a i



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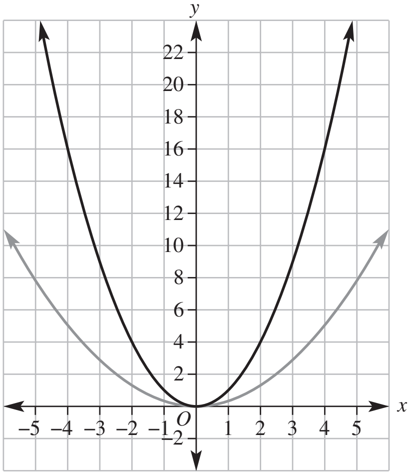

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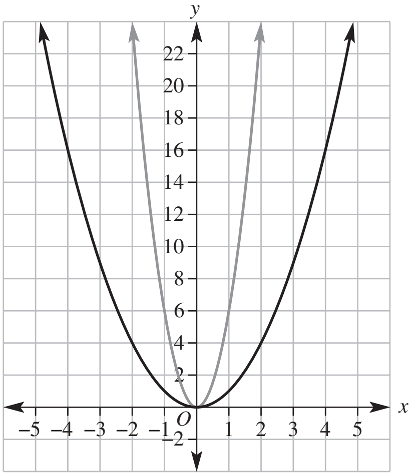
iii



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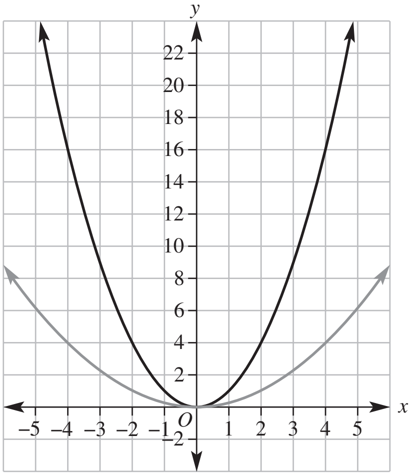

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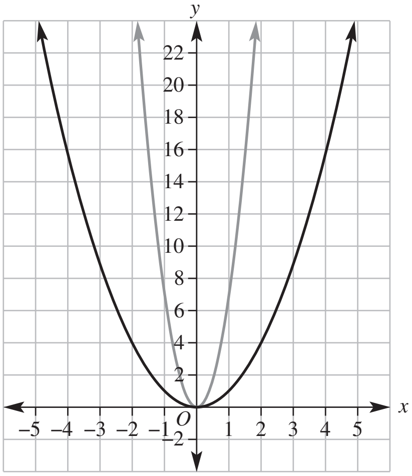

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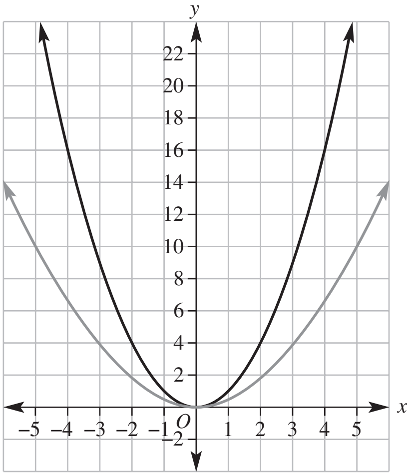
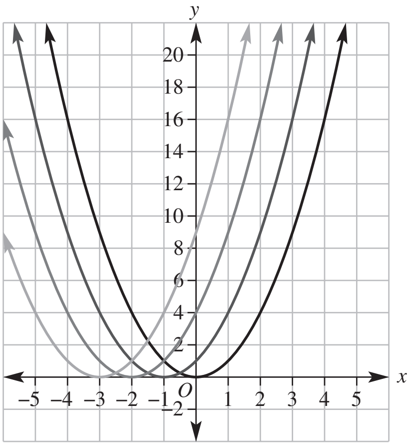


b The constant *a* determines the narrowness of the graph.

11 a i



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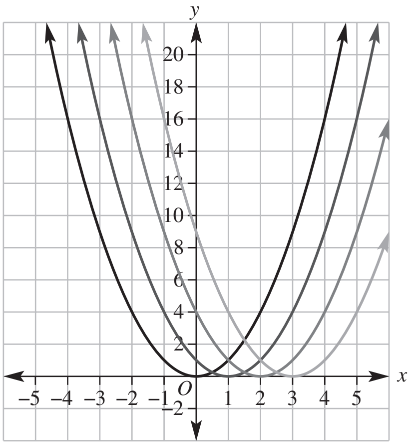

b The constant *h* determines whether the graph moves left or right from $y = x^2$.

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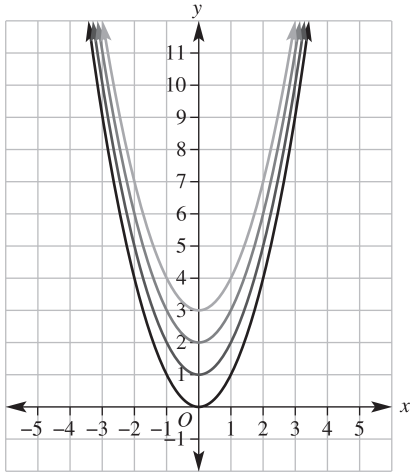
12 a i



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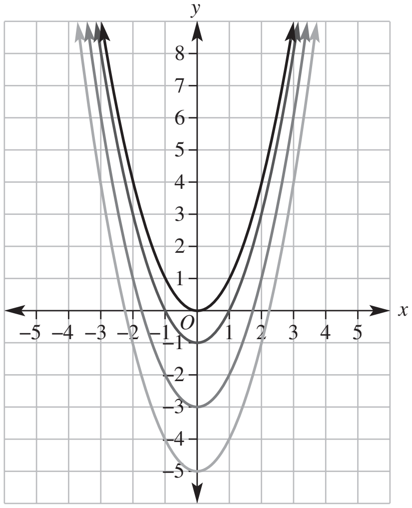


b The constant k determines whether the graph moves up or down from $y = x^2$.

Exercise 10H

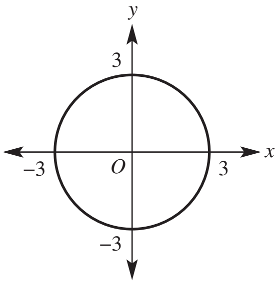
1 a (0, 0), $r = 3$ **b** (0, 0), $r = 6$
c (−1, 0), $r = 2$

2 a ±2.2 **b** ±4 **c** ±3.3

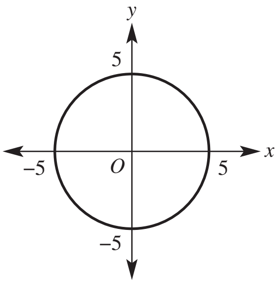
3 a (0, 0) **b** r

4 a 1 **b** 2 **c** 16 **d** 1 **e** 3
f 27 **g** 1 **h** 16 **i** 1 **j** 25

5 a (0, 0) **b** $r = 3$ **c** $y = \pm 2.2$ **d** $x = \pm 3$
e



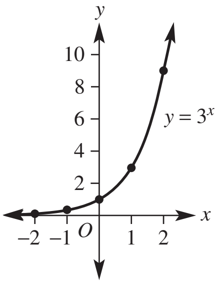
6 a (0, 0) **b** $r = 5$ **c** $y = \pm 3$ **d** $x = \pm 5$
e



7 a

x	−2	−1	0	1	2
y	$\frac{1}{9}$	$\frac{1}{3}$	1	3	9

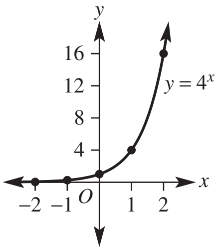
b



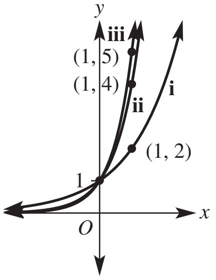
8 a

x	−2	−1	0	1	2
y	$\frac{1}{16}$	$\frac{1}{4}$	1	4	16

b



9 a



b the same point (0, 1)
c makes it rise more quickly

10 a $r = 6$ **b** $r = 9$ **c** $r = 12$
d $r = \sqrt{5}$ **e** $r = \sqrt{14}$ **f** $r = \sqrt{20}$

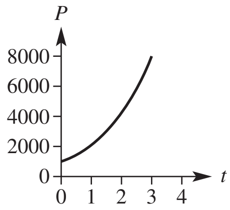
11 $x^2 + y^2 = 49$

12 a C **b** A **c** B

13 a 1000
b i 2000 **ii** 8000

c **i** 2 years **ii** 4 years

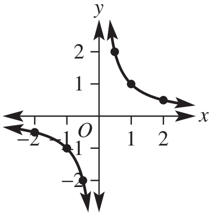
d



14 **a**

x	−2	−1	$-\frac{1}{2}$	$\frac{1}{2}$	1	2
y	$-\frac{1}{2}$	−1	−2	2	1	$\frac{1}{2}$

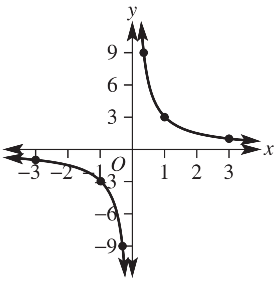
b



15 **a**

x	−3	−1	$-\frac{1}{3}$	$\frac{1}{3}$	1	3
y	−1	−3	−9	9	3	1

b



Puzzles and games

1 PARABOLA

2 **a** $(x + 4)^2\text{m}^2 = (x^2 + 8x + 16)\ \text{m}^2$

b 6

3 14 cm by 20 cm

4 12, 14 or −14, −12

5 64 and 8

6 5 cm

7 **a** $7x - 6$ **b** $-4x$ **c** $x - 3$

8 25 km/h

Multiple-choice questions

1 E **2** D **3** B **4** C **5** B **6** C

7 B **8** D **9** D **10** E **11** C

Short-answer questions

1 **a** $-2x - 2$ **b** $x^2 + 3x$

c $x^2 + x - 2$ **d** $3x^2 + 11x - 20$

e $x^2 - 16$ **f** $25x^2 - 4$

g $x^2 + 4x + 4$ **h** $x^2 - 12x + 36$

i $12x^2 - 23x + 10$

2 **a** $x^2 + 3x$ **b** $x^2 + 4x + 4$

c $4x^2 + 18x$

3 **a** $3(x - 3)$ **b** $-4(x + 4)$

c $x(x + 2)$ **d** $b(a - 1)$

e $7x(1 - 2x)$ **f** $-ab(a + 6)$

4 **a** $(x + 7)(x - 7)$ **b** $(3x + 4)(3x - 4)$

c $(2x + 1)(2x - 1)$ **d** $3(x + 5)(x - 5)$

e $2(x + 3)(x - 3)$ **f** $(2x + 9)(2x - 9)$

5 **a** $(x + 2)(x + 3)$ **b** $(x - 3)(x + 2)$

c $(x - 6)(x - 2)$ **d** $(x + 12)(x - 2)$

e $(x + 10)(x - 5)$ **f** $(x - 8)(x - 4)$

g $(x - 3)^2$ **h** $(x + 10)^2$

i $(x + 20)^2$

6 **a** $x = \pm 6$ **b** $x = \pm\sqrt{15}$ **c** $x = \pm 5$

d no solutions **e** no solutions **f** $x = \pm\sqrt{22}$

g $x = \pm 4$ **h** $x = \pm\sqrt{2}$

7 **a** $x = -1, 2$ **b** $x = 3, -7$ **c** $x = \frac{1}{2}, -4$

d $x = 0, 3$ **e** $x = 0, -6$ **f** $x = 0, \frac{5}{2}$

8 **a** $x = 0, -4$ **b** $x = 0, 3$ **c** $x = 5, -5$

d $x = \pm\frac{4}{3}$ **e** $x = -3, -5$ **f** $x = 3, 7$

g $x = 4$ **h** $x = -5$ **i** $x = -9, 4$

9 3.1 cm

10 length = 8 m, breadth = 6 m

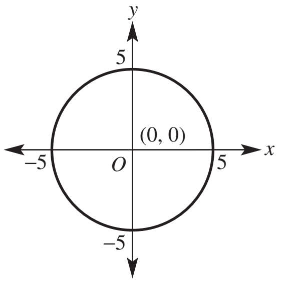
11 **a** minimum at (1, −4) **b** $x = 1$

c −1 and 3 **d** −3

12

	Formula	Maximum or minimum	Reflected in the x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y - x^2$
a	$y = 2x^2$	min	no	(0, 0)	2	narrower
b	$y = -\frac{1}{2}x^2$	max	yes	(0, 0)	$-\frac{1}{2}$	wider
c	$y = (x - 2)^2$	min	no	(2, 0)	1	same
d	$y = x^2 - 2$	min	no	(0, −2)	−1	same

13 a



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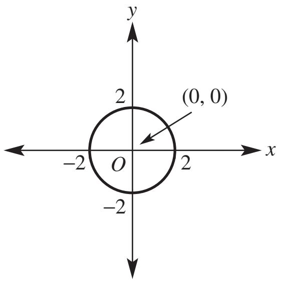
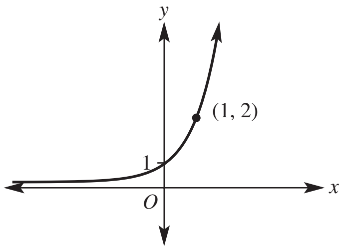


14 a



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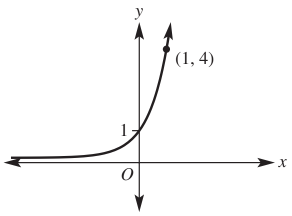


Extended-response questions

1 a i x^2 m^2 **ii** $(100 - x^2)$ m^2

b $(10 + x)(10 - x)$ m^2

c i 96 m^2 **ii** 84 m^2

d $x = 5$

2 a i $(16 + 2x)$ m **ii** $(12 + 2x)$ m

b Area $= (4x^2 + 56x + 192)$ m^2

c Trench $= (4x^2 + 56x)$ m^2

d Minimum width is 2 m.

Semester review 2

Linear relationships

Multiple-choice questions

1 D **2** E **3** B

4 A **5** D

Short-answer questions

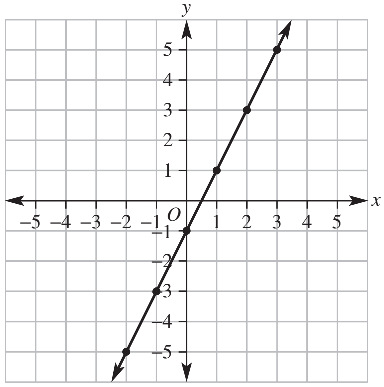
1 a i 16 km **ii** 24 km **iii** 32 km

b 16 km/h **c** 1.5 hours **d** 45 km

e 2.5 hours **f** 18 km/h **g** 90 km

2

x	−2	−1	0	1	2	3
y	−5	−3	−1	1	3	5



3 a AB midpoint (1, 2) **b** PQ midpoint (−1, −1)

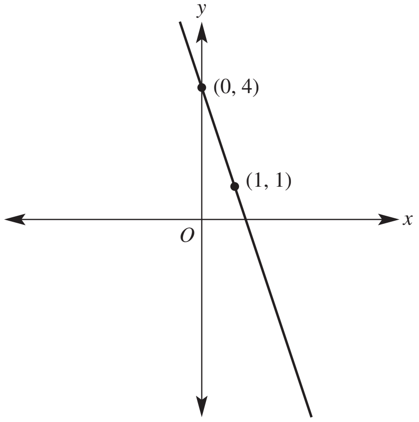
4 a $m = 2$, length $= \sqrt{20}$ **b** $m = -3$, length $= \sqrt{90}$

c $m = -\frac{5}{4}$, length $= \sqrt{41}$ **d** $m = \frac{8}{5}$, length $= \sqrt{89}$

5 a Line J: $y = 2x - 2$; Line K: $y = -\frac{2}{3}x + 6$

b (3, 4)

6 a



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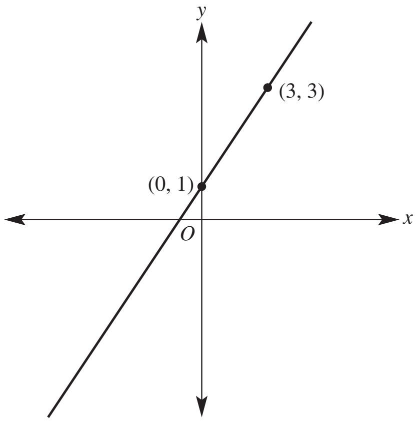

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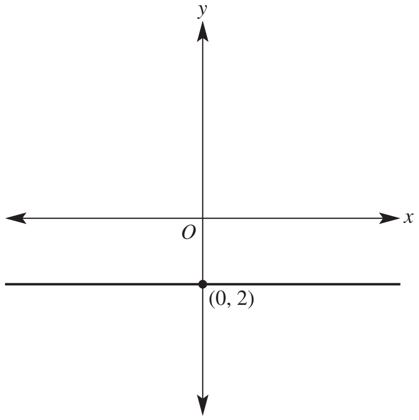
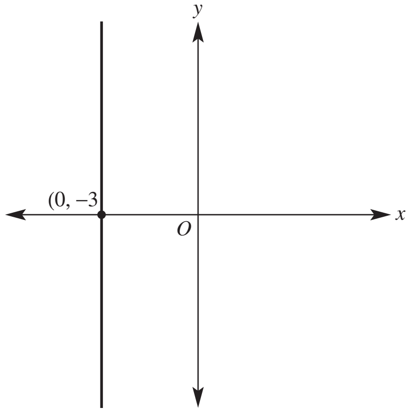
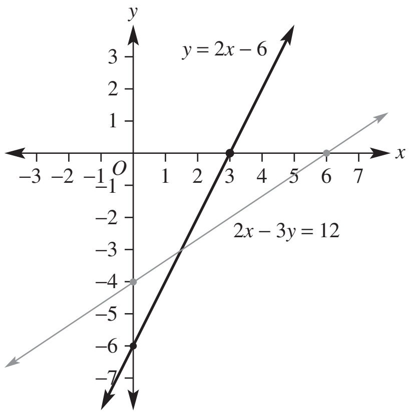


d



7 **a** 3 and –6   **b** 6 and –4



8 **a** $y = 3x$ **b** $y = -x - 2$ **c** $y = -x + 1$

d $y = \frac{1}{2}x - 5$ **e** $y = -2x + 5$ **f** $y = -\frac{1}{5}x - 2$

9 **a** 13 lb   **b** 16 kg

c 20 lb = 9 kg, rate = 2.2 lb/kg

d $k = 2.2$ lb/kg

e $y = 2.2x$ **f** 88 lb   **g** 65 kg

Extended-response question

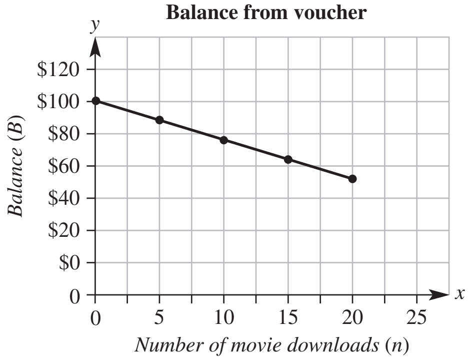
1 **a** $B = 100 - 2.4n$

b **i** $76   **ii** 30 movies

c

Number of movies (n)	0	5	10	15	20
Balance (B)	$100	$88	$76	$64	$52

d



e 41 movies, $1.60 remaining on voucher

Properties of geometrical figures

Multiple-choice questions

1 C   **2** E   **3** C   **4** A   **5** D

Short-answer questions

1 **a** 39   **b** 61   **c** 127   **d** 75

e 70   **f** 117   **g** 71   **h** 84

i 110   **j** 120   **k** 135   **l** 50

2 **a** $\Delta ABC \equiv \Delta DEF$(SAS)

b $\Delta ABC \equiv \Delta DEF$(RHS)

c $\Delta STU \equiv \Delta MNO$(AAS)

d $\Delta XYZ \equiv \Delta ABC$(SSS)

3 **a** yes   **b** yes

c yes   **d** yes

4 $x = 1.8$, $y = 5$

Extended-response question

1 **a** two pairs of equal angles

b 2.5

c 5 m

Right-angled triangles

Multiple-choice questions

1 E   **2** C   **3** A   **4** B   **5** D

Short-answer questions

1 **a** $\frac{y}{x}$ **b** $\frac{z}{x}$ **c** $\frac{y}{z}$

2 **a** 11.4   **b** 10.2   **c** 0.8

d 6.0   **e** 27.0   **f** 21.2

3 14 m

4 8.95 m

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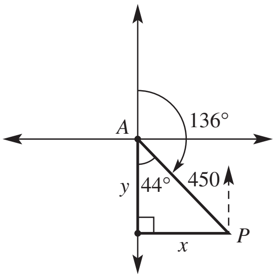
5 **a** 60° **b** 37° **c** 77°

6 177.9 m

7 259.8 m

Extended-response question

1 **a**



b 312.6 km **c** 323.7 km **d** 316°

Equations, formulas and inequalities

Multiple-choice questions

1 C **2** D **3** A **4** B **5** E

Short-answer questions

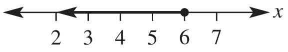
1 **a** $p = 2$ **b** $a = 4$
c $x = 12$ **d** $x = 20$

2 **a** $x = 8$ **b** $k = 3$ **c** $m = 9$
d $x = 5$ **e** $a = -4$ **f** $x = 4$

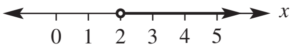
3 **a** $x - 5 = 8; x = 13$
b $4x + 8 = 20; x = 3$
c $2(3x - 6) = 18; x = 5$

4 **a** $b = 10$ **b** $P = 400$

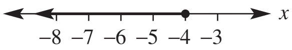
5 **a** $x \leqslant 6$



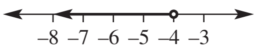
b $x > 2$



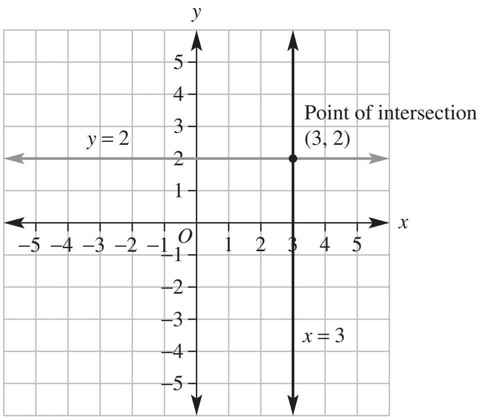
c $x \leqslant -4$



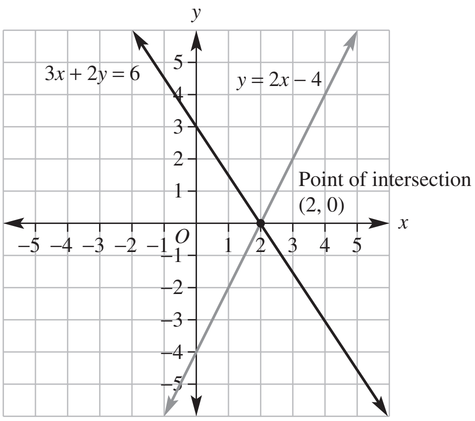
d $x < -4$



6 **a** (3, 2)



b (2, 0)



7 **a** (1, 2)
b (3, 9)
c (−1, 4)

8 **a** (1, 1)
b (2, 4)
c (3, 1)

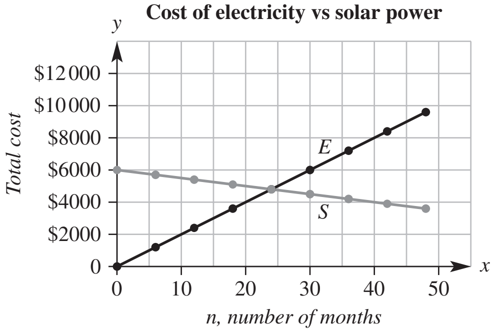
9 **a** Let a = Oliver's age, b = Ruby's age (Any pronumeral selection is correct.)
b $a - b = 7, a + b = 45$
c Oliver is 26 years old, Ruby is 19 years old.

Extended-response question

1 **a**

n	E	S
0	\$0	\$6000
6	\$1200	\$5700
12	\$2400	\$5400
18	\$3600	\$5100
24	\$4800	\$4800
30	\$6000	\$4500
36	\$7200	\$4200
42	\$8400	\$3900
48	\$9600	\$3600

b



c $n = 24$ months, $E = S = \$4800$

d $E = 200n$, $S = 6000 - 50n$

e 24 months **f** \$6000 **g** 27 months

Quadratic expressions, quadratic equations and non-linear relationships

Multiple-choice questions

1 B **2** C **3** E **4** A **5** D

Short-answer questions

1 **a** $-2x + 2$ **b** $x^2 - x - 6$
c $2x^2 - x - 21$ **d** $x^2 - 4$
e $x^2 - 6x + 9$ **f** $4x^2 + 4x + 1$

2 **a** $3(x - 4)$ **b** $-x(2 + x)$
c $(x + 5)(x - 5)$ **d** $(3x + 10)(3x - 10)$
e $(x + 3)(x + 4)$ **f** $(x - 3)(x + 2)$
g $(x + 4)(x - 2)$ **h** $(x - 4)^2$
i $(x + 3)^2$

3 **a** $x = 0, 3$ **b** $x = 0, -2$ **c** $x = -2, 2$
d $x = -\frac{3}{2}, \frac{3}{2}$ **e** $x = 3, \frac{1}{2}$ **f** $x = 5, -4$
g $x = -3, -7$ **h** $x = -4$ **i** $x = 7$

4 **a** $(-1, -1)$, minimum **b** $x = -1$
c -2 and 0 **d** 0

6 **a** $x = \pm 8$ **b** no solutions **c** $x = \pm 4$
d $x = \pm\sqrt{15}$ **e** $x = \pm\sqrt{17}$ **f** no solutions
g $x = \sqrt{5}$ **h** $x = -\sqrt{3}$

Extended-response question

1 **a** **i** $x^2\,\text{m}^2$ **ii** $(400 - x^2)\,\text{m}^2$
b $(20 + x)(20 - x)\,\text{m}^2$
c **i** $384\,\text{m}^2$ **ii** $319\,\text{m}^2$
d **i** 15 **ii** 10

5

	Formula	Maximum or minimum	Reflected in x-axis (yes/no)	Turning point	y value when $x = 1$	Wider or narrower than $y = x^2$
a	$y = 3x^2$	minimum	no	(0, 0)	3	narrower
b	$y = -\frac{1}{2}x^2$	maximum	yes	(0, 0)	$-\frac{1}{2}$	wider
c	$y = (x + 2)^2$	minimum	no	(−2, 0)	9	same
d	$y = x^2 - 3$	minimum	no	(0, −3)	−2	same

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