Practical Investigation

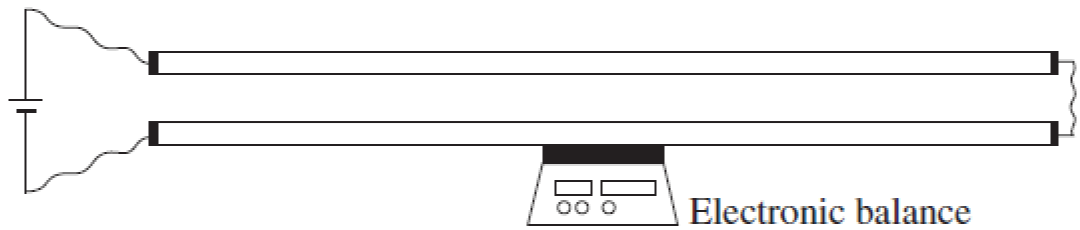
- **independent, dependent and controlled variables**

Definitions

Independent, dependent and controlled variables
The independent variable is the variable that the experimenter changes, to find out what changes occur to the dependent variable.

Controlled variables are unchanged throughout the experiment.

A student performed an experiment using two identical metal rods connected to a power supply. Rod *A* was placed at different distances from Rod *B*, and the measurements on the electronic balance were recorded.



Example 6.1: NSW 2011 Question 10 (1 mark)

Which is the independent variable?

A The length of the rods

B The current in Rod *A*

C The mass recorded on the balance

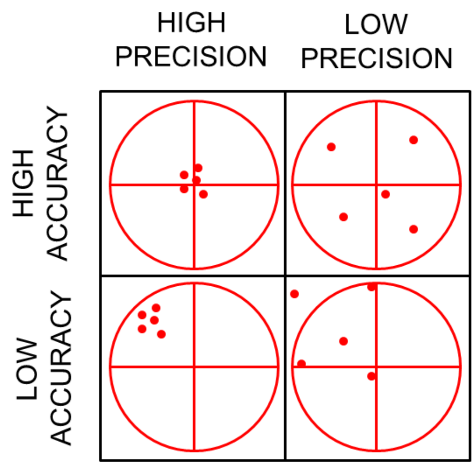
D The distance between the two rods

Practical Investigation

- **the physics concepts specific to the investigation and their significance, including definitions of key terms, and physics representations**
- **the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments (gravity, magnetism, electricity, Newton's laws of motion, waves) and/or the construction and evaluation of a device; precision, accuracy, reliability and validity of data; and the identification of, and distinction between, uncertainty and error**
- **identification and application of relevant health and safety guidelines**

Definitions

Precision, accuracy, reliability and validity of data;
Precision is the closeness of the data to itself. Accuracy is the closeness to the true value.
Reliability is a measure of close repeated experiments give the same result. Validity refers to how well a test measures what it is purported to measure.



Uncertainty and error
Uncertainty is the margin of error of a measurement. Error is the difference between a measured value and the true value.

Hypothesis, model or theory
A hypothesis is an idea that can be tested experimentally. A model is an evidence based representation of something that cannot be displayed directly. It is often said that a good model predicts things that are previously unknown. A theory is often a set of principles used to explain a set of facts or phenomena, it is based on repeated verification.

<u>Types of error</u>

Random

Caused by unknown and unpredictable changes in the experiment. Random error can occur in measuring instruments or environmental conditions. The amount of random error limits the precision of the experiment.

Systematic

Systematic errors usually come from measuring instruments, for example if there is something wrong with the instrument/data handling, or if the instrument is used incorrectly. The amount of systematic error limits the accuracy of the experiment. Systematic errors can be more difficult to detect than random errors.

To test the reception of television signals, a technician measures the average current *I* flowing in an aerial when it is placed at various distances *d* from the transmitter. The following results are obtained.

d **(km)**	10	20	30	40	50	60	70	100
I **(μA)**	127	38	17.4	10.5	6.9	4.7	3.4	1.65

Example 6.2: 1981 Question 34 (1 mark)

The relationship between *I* and *d* is best represented by

A. $I = kd + c.$

B. $I = \frac{k}{d}.$

C. $I = \frac{k}{d^2}$ (k, c are constants)

D. $I = \frac{k}{\sqrt{d}}$

E. $I = kd^2$

Example 6.3: 1981 Question 35 (1 mark)

This relationship fits the data

A. equally well for all values of *d.*

B. better at larger values of *d* than smaller values.

C. better at smaller values of *d* than larger values.

D. better at moderate values of *d* than at larger or smaller values.

Practical Investigation

- **methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of uncertainty and error, and limitations of data and methodologies**

Definitions

Uncertainties

No measurement is exact. When a quantity is measured, the outcome depends on the measuring system, the measurement procedure, the skill of the operator, the environment, and other effects. Even if the quantity were to be measured several times, in the same way and in the same circumstances, a different measured value would in general be obtained each time, assuming the measuring system has sufficient resolution to distinguish between the values.

Measuring devices:

Different measuring devices have different levels of uncertainty. The standard rule is ± ½ the smallest division.

Example 6.4: 1968 Question 27 (1 mark)

The speed of sound in air, S m/sec, is related to the temperature, t^o C, by the relationship

$$S = S_0(1 + kt)$$

where S_0 is the speed of sound at 0º C and k is a constant. A graph of S plotted against t would be

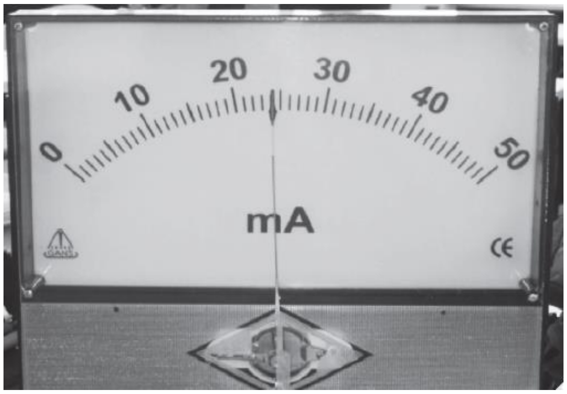
A. a curve, whose shape depends on the value of k

B. a straight line of gradient S_0

C. a straight line of gradient k

D. a straight line of gradient S_0k

An ammeter is a device that is used to determine the magnitude of an electric current. The unknown current is passed through a coil of wire in a magnetic field. The turning effect of the current-carrying coil is balanced by a spring and a corresponding value is read from the meter.



Example 6.5: WA 2013 Question 14b (3 marks)

Current: __________mA

Absolute uncertainty: ______

Relative uncertainty: _______

Spheres are allowed to fall vertically through a tank of oil, and are timed between fixed points 1 metre apart. The times to fall 1 m, for spheres of various radii and densities are given in the following table:

Density of sphere ρ_s	Radius of sphere r	Time to fall 1 metre t
4 gm/cm^3	1.00 cm	9 sec
4 gm/cm^3	0.75 cm	16 sec
4 gm/cm^3	0.25 cm	144 sec
7 gm/cm^3	0.25 cm	72 sec
10 gm/cm^3	0.25 cm	48 sec
Density of oil, ρ_o, is 1 gm/cm^3		

Example 6.6: 1967 Question 68 (1 mark)

Which of the following graphs would be most useful in predicting the time to fall 1 metre for spheres of various radii, all of fixed density 4 gm/cm^3?

A. t against r

B. t against r^2

C. t against $\frac{1}{r}$

D. t against $\frac{1}{r^2}$.

Example 6.7: 1967 Question 69 (1 mark)

Which of the following graphs would be most useful in predicting the time to fall 1 metre for spheres of various densities, all of fixed radius 0·25 cm?

A. t against ρ_s

B. t against $\frac{1}{\rho_s}$

C. t against $\frac{1}{\rho_s}$

D. t against $(\rho_s - \rho_o)$

E. t against $\frac{1}{\rho_s - \rho_o}$

F. t against $(\rho_s + \rho_o)$

To which of the following is t directly proportional?

Example 6.8: **1967 Question 70** **(1 mark)**

A. $r^2 (\rho_s - \rho_o)$

B. $(\rho_s - \rho_o)/ r^2$

C. $\dfrac{1}{\rho_s r^2}$

D. $\dfrac{1}{(\rho_s + \rho_o)r^2}$

E. $\dfrac{r^2}{\rho_s}$

F. $\dfrac{1}{r^2(\rho_s - \rho_o)}$

G. None of the above

Question 6.9

Four students carried out an experiment using a thermometer to record the temperature of a solution. The students repeated the experiment four times. Their teacher suggested that their results showed evidence of a systematic error. A systematic error

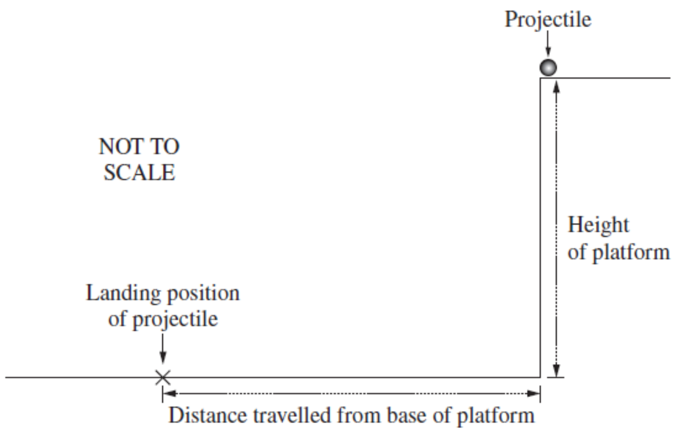
A. may have been caused by using an incorrectly calibrated thermometer throughout the experiment.

B. will be shown by large variations in the individual temperature readings obtained by the students.

C. can be reduced if the students gathered more data by repeating the experiment many more times.

D. happens when the students take turns recording the temperature of the solution.

A projectile is fired horizontally from a platform.

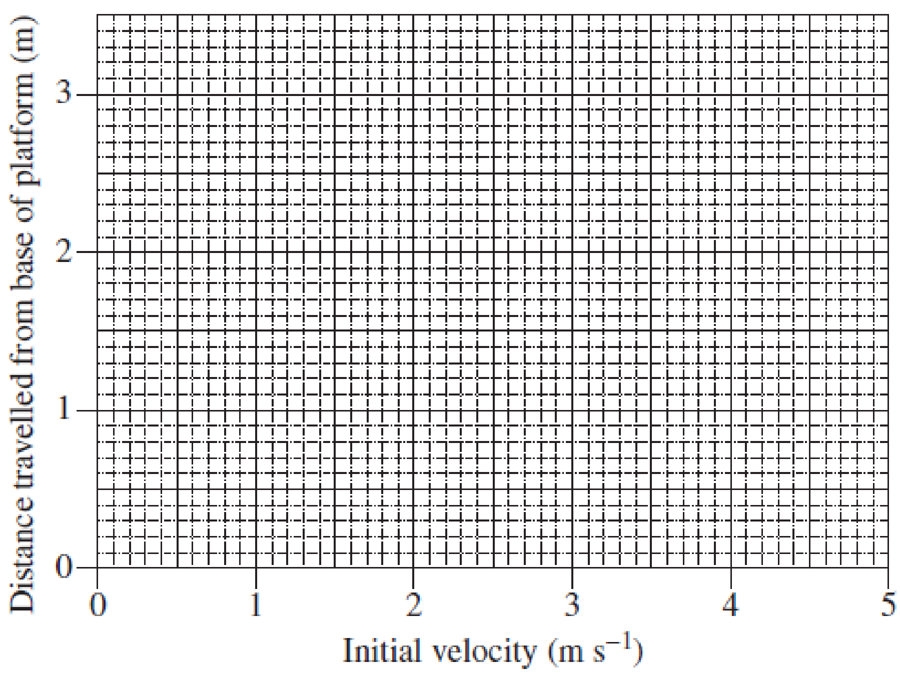


Measurements of the distance travelled by the projectile from the base of the platform are made for a range of initial velocities.

Initial velocity of projectile ($m\ s^{-1}$)	*Distance travelled from base of platform* (m)
1.4	1.0
2.3	1.7
3.1	2.2
3.9	2.3
4.2	3.0

Example 6.10: NSW 2015 Question 21a (2 marks)

Graph the data on the grid provided and draw the line of best fit.



Example 6.11: NSW 2015 Question 21b (2 marks)

Calculate the height of the platform.

Andrew and Sarah were at the park and noticed a tyre-swing hanging in a tree. They realised that it would behave as a pendulum and would complete one swing (return to its starting point for one complete cycle) with a period (T) in seconds.
They had previously discussed pendulums in class and been given the equation:

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad \text{[Where } \ell \text{ = length in metres]}$$

Andrew and Sarah decided to conduct an investigation to determine the relationship between the length of a pendulum and its period.
An incomplete table of results for this investigation is shown below:

Length of pendulum ℓ (m)	Time for ten swings (s)	Time for one swing T (s)	Period squared T^2 (s^2)
0.10	5.5		
0.20	6.9		
0.30	10.9		
0.40	12.5		
0.50	15.0		
0.60	18.5		

Example 6.12: WA 2013 Question 15b (i) (2 marks)

Complete the above table.

Example 6.13: WA 2013 Question 15b (ii) (4 marks)

Use the data from the table to plot a straight line graph on the grid provided to demonstrate the relationship between the length of the pendulum and the square of the period (plot ℓ on the x-axis).

Example 6.14: WA 2013 Question 15b (iii) (3 marks)

Use your graph to determine the pendulum length that gives a period of 1.0 s

Example 6.15: WA 2013 Question 15b (iv) (4 marks)

Determine the gradient of your graph using a line of best fit.

Example 6.16: WA 2013 Question 15b (v) (3 marks)

Use your gradient to determine the experimental value of g.

Students undertook an experiment to determine the strength of a magnet. They placed a horseshoe magnet on electronic scales and arranged a length of wire so that it was perpendicular to the magnetic field. The current flowing through the wire was set to 1.5 A. The measurement on the scales was used to determine the force. The students obtained measurements for different lengths of wire.

Length of Wire L (cm)	Mass Measurement Shown on Scales m ($\times 10^{-4}$ kg)	Force F (N)
1.0	2.4	
1.5	3.0	
2.0	4.2	
2.5	5.3	
3.0	5.9	

The data collected in the experiment are shown in the table:

Example 6.17: SA 2015 Question 26a (2 marks)

Using $F = mg$, complete the table above by calculating the values for the force, where m is the mass measurement shown on the scales.

Example 6.18: SA 2015 Question 26b ` (6 marks)

Plot a graph of force versus length. Include a line of best fit.

Example 6.19: SA 2015 Question 26c (3 marks)

Calculate the gradient of your line of best fit. Include the units of the gradient.

Example 6.20: SA 2015 Question 26d (3 marks)

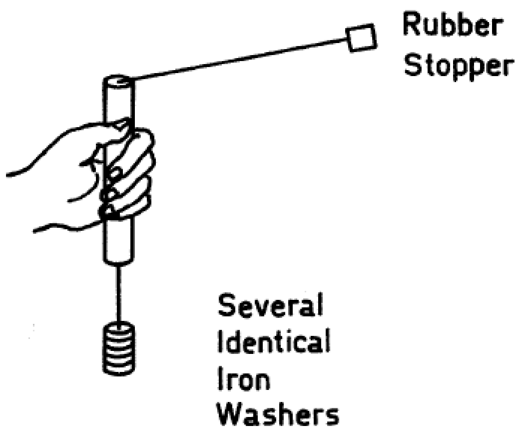
Using the gradient of your line of best fit, determine the magnitude of the magnetic field.

Example 6.21: **SA 2015 Question 26e (1 mark)**

At the conclusion of the experiment, the magnetic field of the magnet was measured as 0.13 T. Comment on the accuracy of the experiment.

Practical Investigation

- **models and theories, and their use in organising and understanding observed phenomena and physics concepts including their limitations**



A rubber stopper of mass m is whirled in a horizontal circle of radius r.
An experiment is performed to investigate the relationship between m, r, the speed of the stopper v, and the centripetal force, F, acting on the stopper.

Example 6.22: 1976 Question 26 (1 mark)

The centripetal force acting on the stopper can be measured during the experiment by

A. finding the mass of the stopper and multiplying by g, the acceleration due to gravity.

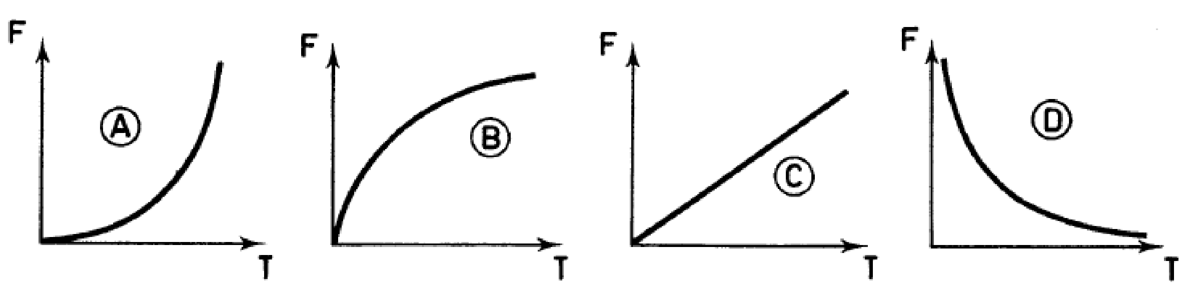
B. finding the mass of the stopper and multiplying by $\frac{v^2}{r}$.

C. multiplying the weight, mg, of the stopper by $\frac{v^2}{r}$.

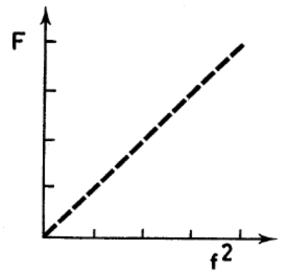
D. counting the number of iron washers on the end of the string.

Example 6.23: 1976 Question 27 (1 mark)

In one series of measurements, r and m were kept constant, and the relationship between the force F and the period T is investigated. Which of the graphs (**A - D**) below best represents the relationship between F and T?

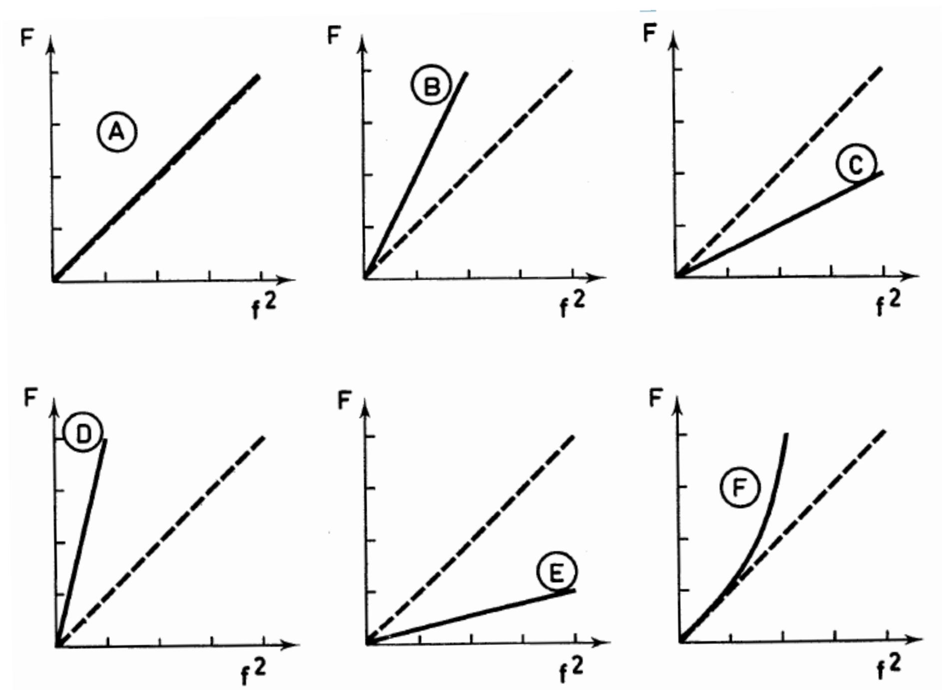


The graph shows the relationship between F and the particular square of the frequency of revolution , f, for values of r and m.



Example 6.24: 1976 Question 28 (1 mark)

If the radius were now doubled, what would the new graph of F versus f^2 be?



Example 6.25: 1976 Question 29 (1 mark)

In another series of measurements, *r* and v are kept constant, and the mass *m* is varied. What is the relationship between *F* and *m*?

A. F α m.

B. F α m^2.

C. F α $\frac{1}{m}$

D. F α $\frac{1}{m^2}$

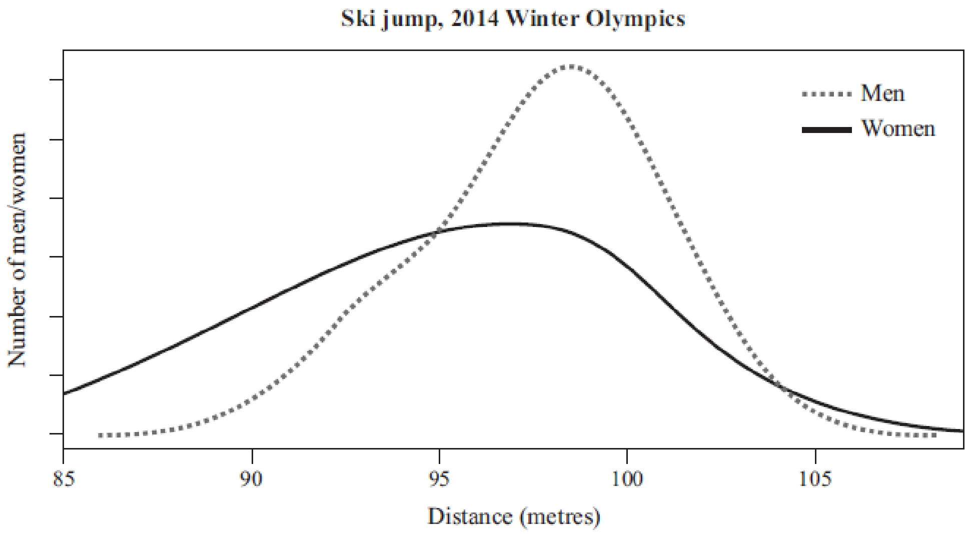
E. F = mg.

F. None of these. F is independent of m.

Practical Investigation

- **the nature of evidence that supports or refutes a hypothesis, model or theory**

The graphs below show the distance recorded for men and women who completed a ski jump at the 2014 Winter Olympics.



Example 6.26: Qld 2015 Question 1 (2 marks)

Label each statement below as either supported (S) or unsupported (U) by the data in the graphs.

a. Men generally reached a higher altitude during the jump.

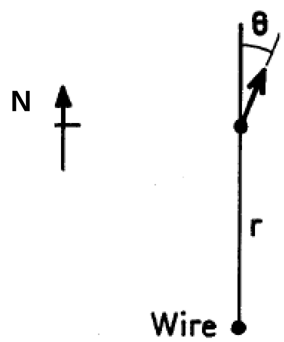
b. A larger number of women than men jumped more than 105 m.

c. In terms of distance jumped, the mode for women is less than the mode for men.

d. The average velocity of the men was higher than the average velocity of the women.

Practical Investigation

- **the key findings of the selected investigation and their relationship to concepts associated with waves, fields and/or motion**



A student is investigating the magnetic field, B, of a current in a long straight wire.
The wire is vertical, and carries a constant current.
The student places a small compass needle at various points along a line running magnetic north of the wire, and records the distance, r, that the centre of the needle is from the wire, and the deflection, θ, of the needle from magnetic north.

He obtains the following results

r (cm)	$\theta°$
5·0	45
10·0	27
20·0	14

Example 6.27: 1973 Question 78 (1 mark)

The results indicate

A. B is inversely proportional to r.

B. B is inversely proportional to r squared.

C. B decreases as r increases, but in a complex manner.

D. no relation between B and r.

Example 6.28: 1973 Question 79 (1 mark)

What value of θ should the student expect for r = 3.0 cm?

The actual value of θ that the student observed was somewhat larger than the expected value for r = 3.0 cm. He found that this was consistently the case over a large number of repetitions of the experiment.

Example 6.29: 1973 Question 80 (1 mark)

The most likely explanation of this observation is

A. the student placed the needle less than 3.0 cm from the wire.

B. the student measured the 3.0 cm from the surface of the wire instead of from its centre.

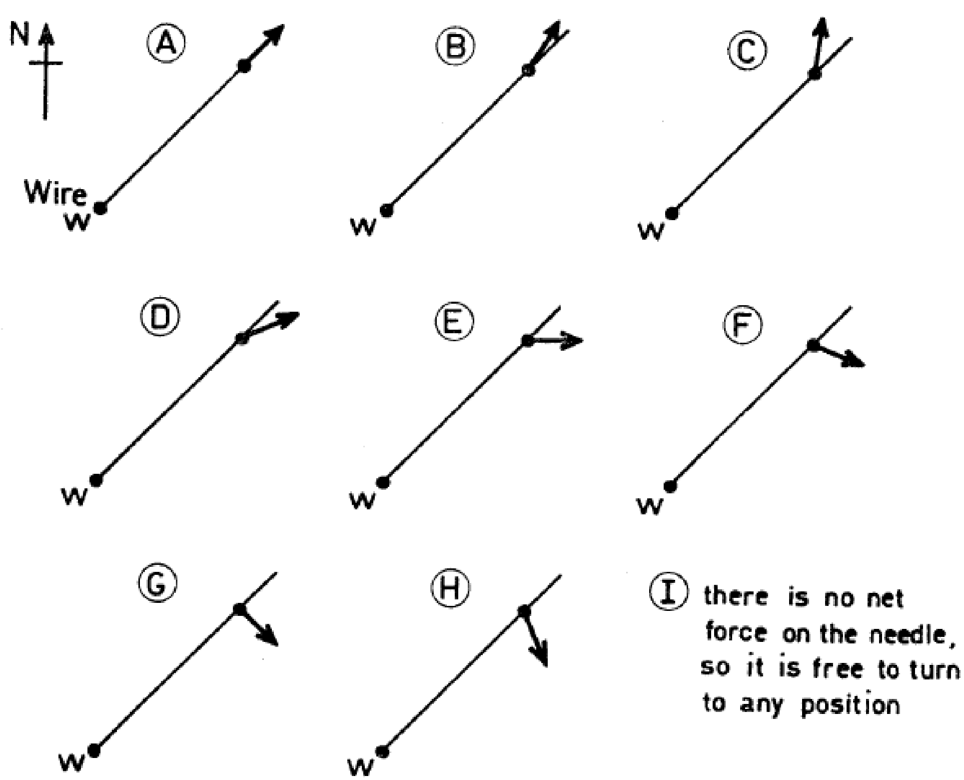
C. the formula for magnetic field of a current changes for small values of r.

D. the average value of the fields at the ends of the needle is slightly greater than the field at its centre.

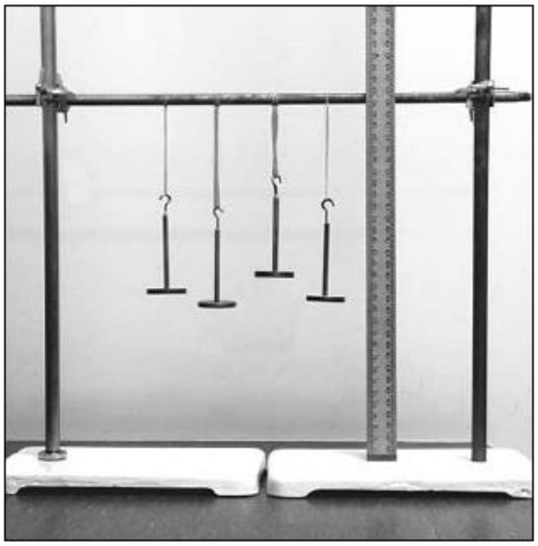
E. there is greater error in measuring large deflections.

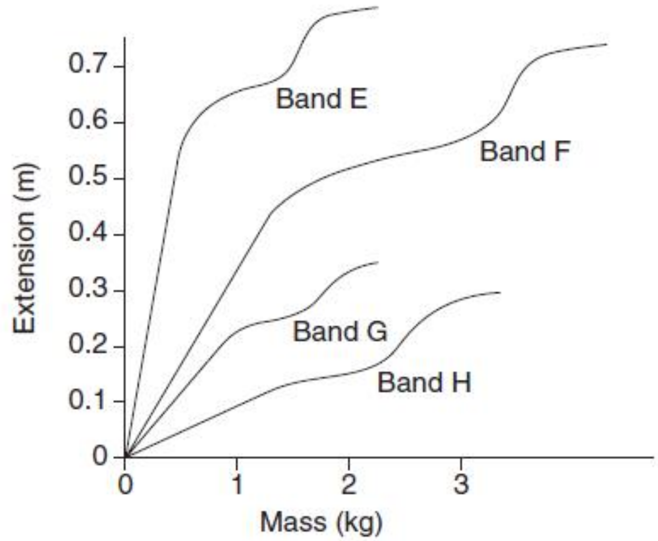
Example 6.30: 1973 Question 81 (1 mark)

The student now places the needle 5.0 cm from the wire, to the north-east of it.
Which diagram shows the direction in which the needle points?



An experiment was conducted to investigate the flexibility* and strength** of different types of rubber bands, all with the same initial length. A mass was attached to each band and the extension was measured. Masses were gradually increased, and the extensions measured until each band broke. The photograph was taken during the experiment. The results are summarised in the graph.





* Flexibility: *The more flexible the rubber band, the greater its extension for a given mass*
** Strength: *The stronger the rubber band, the more mass it is able to hold before breaking*

Example 6.31: NSW 2009 Question 24a (2 marks)

Which rubber band is the most flexible? Justify your answer with reference to the graph.

Example 6.32: NSW 2009 Question 24b (2 marks)

Identify the strongest rubber band and state the mass range in which the extension appears to be directly proportional to the attached mass.

Practical Investigation

- **the conventions of scientific report writing and scientific poster presentation, including physics terminology and representations, symbols, equations and formulas, units of measurement, significant figures, standard abbreviations and acknowledgment of references.**

Scientific form and significant figures

- All non-zero digits are significant
- Zeros between non-zero digits are significant.
- Leading zeros are never significant.
- In a number with a decimal point, trailing zeros, those to the right of the last non-zero digit, are significant.
- In a number without a decimal point, trailing zeros may or may not be significant.

A series of measurements were taken during an experiment to determine the acceleration (*a*) of an object.

Initial velocity (*u*) 3.57 m s^{-1}

Final velocity (*v*) 12.50 m s^{-1}

Time (*t*) 5.401 s

The equation for acceleration in this case is

$$a = \frac{v - u}{t}$$

Example 6.33: Qld 2014 Question 1 (1 mark)

How many significant figures should be present in the answer?

A 1

B 2

C 3

D 4

A series of measurements were taken during an experiment to determine the power delivered by an engine. The equation used to determine the power is

$$P = \frac{W}{t}$$

where, in this case power (P) = ? work (W) = 102.5 J time (t) = 0.05 s

Example 6.34: Qld 2015 Question 1 (1 mark)

How many significant figures should be present in the answer?

A 1

B 2

C 3

D 4

Example 6.35: Qld 2013 Question 1 (2 marks)

List the number of significant figures in each of these examples.

a. 4495

b. 6.023×10^{23}

c. 0.0034

d. 8.239

Example 6.36: Qld 2013 Question 2 (2 marks)

Convert these percentage errors into absolute errors.

a. 45.6 ± 1.4% cm

b. 7.45 ± 12% kg

State the number of significant figures in each of these examples.

Example 6.37: Qld 2014 Question 1 (2 marks)

a. 0.6743

b. 9.0×10^{15}

Example 6.38: Qld 2014 Question 2 (2 marks)

Convert the percentage error below into an absolute error.

423.6 ± 2.0% m

State the number of significant figures in each of these examples.

Example 6.39: Qld 2015 Question 1 (1 mark)

a. 103.50

b. 0.05×10^{15}

Example 6.40: Qld 2015 Question 2 (1 mark)

Convert the percentage error below into an absolute error.

1050 ± 3.0% m

Example 6.41: Qld 2016 Question 1 (1 mark)

Give the number of significant figures in each of these examples.

a. 0.590

b. 0.2×10^{-23}

Example 6.42: Qld 2016 Question 2 (1 mark)

Convert the percentage error below into an absolute error.

235 ± 5.0% m
