1

Physics Revision

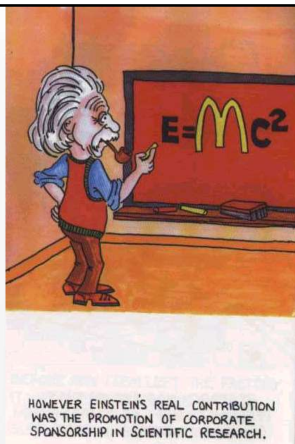
by

Colin Hopkins OAM
Sandor Kazi
Paul Cuthbert
Craig Anderson
Dan O'Keeffe OAM
Dr. Barbara McKinnon

for **VicPhysics**

67 days to the exam

2



3

Program

10:00	Introduction, Exam preparation
10:20	Motion
10:50	Break, question time
11:00	Relativity, Fields, Electricity
11:50	Lunch break, Tours, question time
1:00	Waves, Light
1:50	Break, question time
2:00	Matter, EPI
2:50	Finish

4

5

6

You need to work smarter, not harder.

You need to know what you know, and know what you don't know. Then work on your areas of weakness.

Quality, not quantity, is the secret. Be SMART (specific, measurable, achievable, relevant and timely)

You need to practise the way you intend to perform on the exam.

7

Question 3 (5 marks)

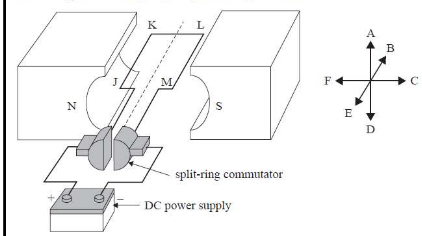
Figure 2 shows a schematic diagram of a simple DC motor.

It consists of two magnets, a single 9.0 V DC power supply, a split-ring commutator and a rectangular coil of wire consisting of 10 loops.

The total resistance of the coil of wire is 6.0 Ω.

The length of the side JK is 12 cm and the length of the side KL is 6.0 cm.

The strength of the uniform magnetic field is 0.50 T.



8

a. Determine the size and the direction (A–F) of the force acting on the side JK.

____

9

The Exam

70% should be familiar if you have completed enough past papers.
25% for high performance students
5% to sort out the top students

OR

25% easy
50% in the middle
25% hard

10

2017 Exam structure

48% calculations
31% short answer
21% annotation graphs etc

2018 Exam structure

60% calculations
28% short answer
12% annotation graphs etc

2019 Exam structure

50% calculations
39% short answer
11% annotation graphs etc

2021 Exam structure

~52% calculations
~38% short answer
~10% annotation graphs etc

2022 Exam structure

~56% calculations
~23% short answer
~21% annotation graphs etc

11

They remove the staples, by guillotining the paper. This removes all of the paper on the inside of the writing section.

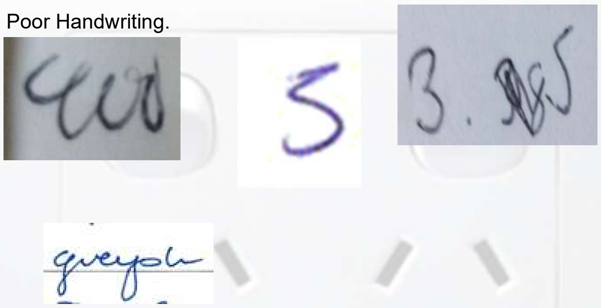
YOU must ONLY write within the prescribed space.

Write only in BLACK or BLUE pen.

The markers don't see your entire paper, so make sure that your writing is legible at all times.

12

Poor Handwriting.



13

$F = mg$

$= 250 \times 9.8$

$= 2450$

2450 N

14

$M_{satellite} = 2.27 \times 10^3\ kg$ $M_{Earth} = 5.98 \times 10^{24}\ kg$

$r_{Earth} = 6.37 \times 10^6\ m$ $r_{orbit} = 2.637 \times 10^7\ m$

$$\frac{4\pi^2 rm}{T^2} = \frac{GMm}{r^2}$$

$$\frac{4\pi^2 \times (2.637 \times 10^7)(2.27 \times 10^3)}{T^2} = \frac{6.67 \times 10^{-11} \times (5.98 \times 10^{24})(2.27 \times 10^3)}{(2.637 \times 10^7)^2}$$

$T^2 = 1.814 \times 10^9$

$T = 4.26 \times 10^4\ s$

15

PHYSICS
Written examination

Wednesday 9 November 2022

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	20	20	20
B	17	17	110
			Total 130

A formula sheet will be provided with the examination.

Answers to Section A are to be recorded on the answer sheet provided for multiple-choice questions.

Answers to Section B are to be recorded in the spaces provided in the question and answer book.

16

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 42 pages
- Formula sheet
- Answer sheet for multiple-choice questions

Instructions
- Write your student number in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

17

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

18

Instructions for Section B

Answer **all** questions in the spaces provided.

Where an answer box is provided, write your final answer in the box.

If an answer box has a unit printed in it, give your answer in that unit.

In questions where more than one mark is available, appropriate working **must** be shown.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of *g* to be 9.8 m s^{-2}.

19

Physics Approved materials and equipment

one scientific calculator

one folded A3 sheet or two A4 sheets bound together by tape, single or double-sided. Notes may be typed or handwritten and from any source (including commercially available notes).

20

21

Examiner's report

Many students lose marks due to contradictions in their answer.

Answers MUST relate to question, need a specific link to question, not just transposed from cheat sheet.

Data dumping.

Use of scientific calculators.

It is important to show numbers substituted into formulas/equations.

Answers in simplified decimal form.

22

In general:

1 mark questions:

1 mark for correct answer.

2 mark questions:

1 mark for correct formula and substitution.

1 mark for correct answer.

3 mark questions:

1 mark for initial derivation or conversion of information.

1 mark for final formula/substitution.

1 mark for correct answer.

23

4 mark questions:

1st mark for calculation or some recognition, i.e. substitution or statement.

2nd and 3rd marks are for process not for outcome, usually attached to a formula and/or substitution that demonstrate the next step in the solution process. Not contingent on the mark before it. If your understanding is correct, you can still get the two middle marks without the first and last marks.

4th mark for correct answer.

Hint

Avoid algebraic rearrangement.
Make it easier for markers to award the "formula & substitution" mark(s)

24

Exam preparation.

Theory suggests you remember

- ~ 10% of what you hear
- ~ 25% of what you read
- ~ 40% of what you write
- ~ 70% of what you do
- ~ 85% of what you teach

25

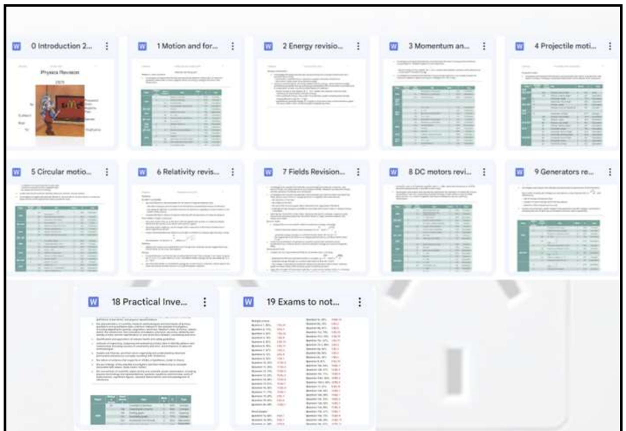
Revision process

There are two steps:

firstly, you need to master the content,

and then master the exam process.

26



27

• Investigate and apply theoretically and practically Newton's three laws of motion in situations where two or more coplanar forces act along a straight line and in two dimensions

Paper	Multiple choice	Short Answer	Idea	Marks	%	Type
2022	7		Newton's third law	1	47%	Concept
	9		Newton's third law	1	52%	Concept
		7a i	Inclined plane	2	78%	Calculation
		7a ii	Inclined plane, friction force	2	53%	Calculation
2022 NHT	7		SUVAT	1	NA	Calculation
2021		4	Newton's third law	2	9%	Explanation
		8a	$F_{net} = ma$	3	49%	Calculation
2021 NHT		8a	Inclined plane, draw forces	3	NA	Concept
		8b	$F_{net} = 0$, $a = 0$	3	NA	Calculation
2020	9		Newton's third law	1	49%	Explanation
2019	11		$F_{net} = 0$	1	62%	Calculation
2019 NHT		9	Vertical connected bodies	1	NA	Calculation
2018	5		Forces	1	74%	Calculation
	6		Graphs	1	69%	Calculation
		8a	Horizontal connected bodies	2	35%	Calculation
		8b	Horizontal connected bodies	2	75%	Concept
2018 NHT	8		Connected bodies	1	NA	Calculation
	9		Connected bodies	1	NA	Calculation
2017	7		Newton's Laws	1	95%	Calculation
	9		SUVAT	1	87%	Calculation

28

Worked example 8: Horizontal collision, Inelastic/elastic.

2008 Question 10, 3 marks

Was this collision elastic or inelastic?

Support your conclusion by appropriate calculation.

Solution	Current study design:
If the collision is elastic, then $KE_{final} = KE_{initial}$. $KE_{initial} = \frac{1}{2}mv^2$ $= \frac{1}{2} \times 20 \times 10^3 \times 8^2$ $= 64 \times 10^4$ $= 6.4 \times 10^5$ J $KE_{final} = \frac{1}{2}mv^2$ $= \frac{1}{2} \times 80 \times 10^3 \times 2^2$ $= 1.6 \times 10^5$ $KE_{final} < KE_{initial}$ ∴ KE is lost **∴ Collision is inelastic (ANS), (73%)**	**2022 Question 7b ii (69%)** **2020 Question 10b (64%)** **2019 NHT Question 7c** **2018 Question 9 (71%)** **2018 NHT Question 7** **2017 Question 12 (63%)**

29

Use the last file to master the exam process.

30

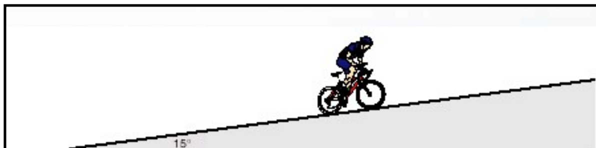
2022

Multiple choice			
Question 1, 80%,	7:Ex 27	Question 5c, 60%	10:Ex 10
Question 2, 73%,	9:Ex 3	Question 6a, 78%	9:Ex 2
Question 3, 83%	7:Ex 32	Question 6b, 61%	9:Ex 6
Question 4, 18%	7:Ex 4	Question 7a i, 78%	1:Ex 10
Question 5, 62%	9:Ex 10	Question 7a ii, 53%	1:Ex 10
Question 6, 78%	3:Ex 11	Question 7b i, 67%	3:Ex 11
Question 7, 47%	1:Ex 3	Question 7b ii, 69%	3:Ex 8
Question 8, 72%	2:Ex 4	Question 8a, 80%	5:Ex 2
Question 9, 52%	1:Ex 3	Question 8b, 84%	5:Ex 2
Question 10, 85%	11:Ex 5	Question 8c, 42%	5:Ex 2
Question 11, 85%	11:Ex 2	Question 9, 47%	6:Ex 13
Question 12, 51%	13:Ex 6	Question 10a, 84%	18:Ex 1
Question 13, 63%	12:Ex 4	Question 10b, 87%	18:Ex 5
Question 14, 68%	16:Ex 2	Question 10c, 71%	18:Ex 6
Question 15, 81%	15:Ex 1	Question 10d i, 84%	18:Ex 2
Question 16, 80%	13:Ex 2	Question 10d ii, 42%	18:Ex 8
Question 17, 73%	15:Ex 1	Question 11, 41%	6:Ex 12
Question 18, 82%	6:Ex 1	Question 12a, 30%	14:Ex 1
Question 19, 85%	6:Ex 8	Question 12b, 64%	14:Ex 1
Question 20, 84%	18:Ex 1	Question 12c, 53%	14:Ex 2
		Question 12d, 42%	14:Ex 3
Short answer		Question 13a, 49%	13:Ex 4
Question 1a, 62%	8:Ex 7	Question 13b, 57%	13:Ex 7
Question 1b, 66%	8:Ex 7	Question 14a, 73%	15:Ex 9
Question 1c, 84%	8:Ex 6	Question 14b, 89%	15:Ex 10
Question 2a, 18%	7:Ex 18	Question 14c. 67%	15:Ex 11

31

How fast can things go?

32



A cyclist pedals up a 15^0 slope at a constant speed as shown. The total mass of rider and bicycle is 100 kg.

What is the magnitude of the **net** force on the bicycle and rider when travelling up the slope?

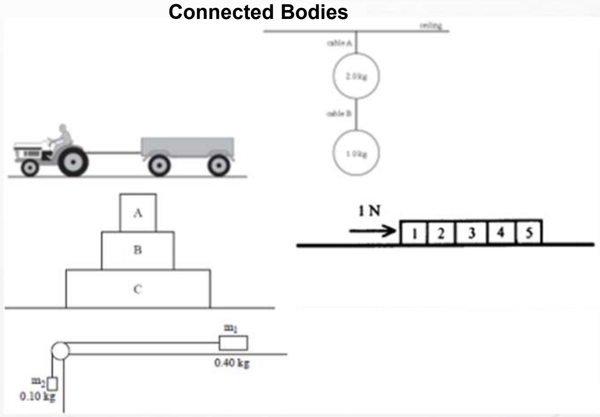
46%, (2)

33

Always think $F_{net} = ma$

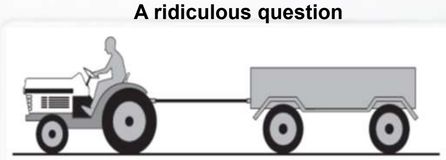
34

Connected Bodies



35

A ridiculous question

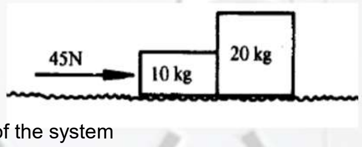


A tractor, including the driver, has a mass of 500 kg and is towing a trailer of mass 2000 kg. The tractor and the trailer are accelerating at 0.50 m s^{-2}. Ignore the mass of the towing rope.

What is the tension in the rope connecting the tractor and trailer?

36

Two masses are placed in contact on a rough surface.
A force of 45 N is acting on the 10 kg mass.
The frictional force acting on the 10 kg mass is 10 N and the frictional force acting on the 20 kg mass is 20 N.



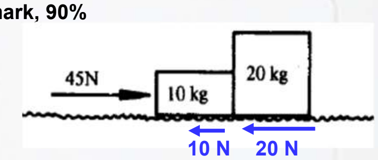
What is the acceleration of the system of two masses?

What is the force exerted by the 20 kg mass on the 10 kg mass while they are in motion?

35%, (1) **75%, (1)**

37

Section 1 Example 12
1984 Question 28, 1 mark, 90%



$F_{net} = ma$

$F_{net} = 45 - F_{friction}$

$= 45 - 30$

$= 15$ N

$\therefore 15 = (10 + 20)a$

$\therefore a = \frac{15}{30}$

= 0.5 m s^{-2} (ANS)

38

Section 1 Example 13
1984 Question 29, 1 mark, 21%

The force exerted by the 20 kg mass on the 10 kg mass is equal and opposite to the force exerted by the 10 kg mass on the 20 kg mass.

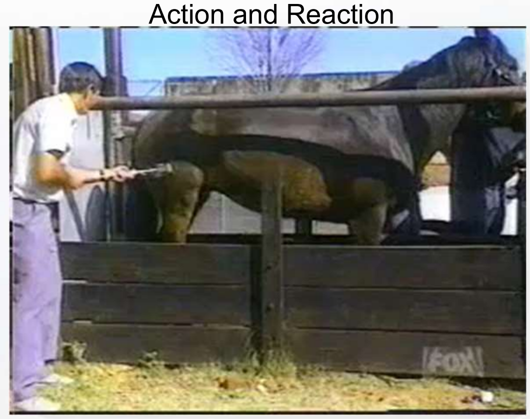
Since the 20 kg mass is accelerating at 0.5 m s^{-2}, the net force on it must be $F_{net} = ma$.
$\therefore F_{net} = 20 \times 0.5 = 10$ N.

The frictional force of 20 N still needs to be overcome, so $F_{10\ on\ 20} = 10 + 20 = 30$ N

The force exerted by the 20 kg mass on the 10 kg mass
= 30 N (ANS)

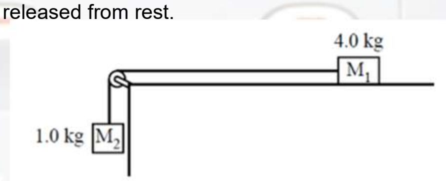
39

Action and Reaction



40

M_1, of mass 4.0 kg, is connected by a light string to a hanging mass, M_2, of 1.0 kg. The system is initially at rest.
The masses are released from rest.



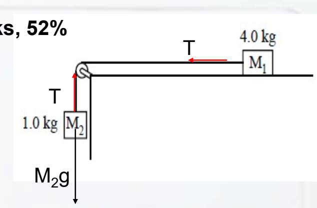
Calculate the acceleration of the block M_1?

Calculate the magnitude of the tension in the string as the masses accelerate.

52%, (1) **54%, (1)**

41

Section 1 Example 15
2015 Question 2a, 2 marks, 52%



For M_2, use $F_{net} = ma$

$\therefore M_2g - T = M_2a$

$\therefore 1 \times 9.8 - T = 1 \times a$

$\therefore 9.8 - T = a$

For M_1, use $F_{net} = ma$

$\therefore T = M_1a$

$\therefore T = 4a$

Combine the two equations to get

$9.8 - 4a = a$

$\therefore 9.8 = 5a$

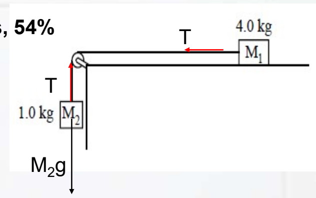
$\therefore a = 1.96$

∴ a = 2 m s^{-2} (ANS)

42

Section 1 Example 15

2015 Question 2b, 2 marks, 54%



Consider M_1,

T = 4 × a

∴ T = 4 × 2

∴ **T = 8 N (ANS)**

43

•analyse transformations of energy between kinetic energy, strain potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material):

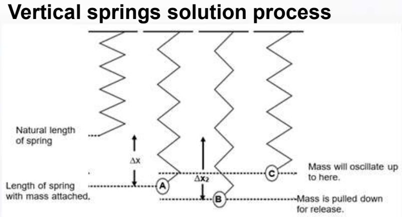
– kinetic energy at low speeds: $E_k = \frac{1}{2}mv^2$; elastic and inelastic collisions with reference to conservation of kinetic energy

– strain potential energy: area under force-distance graph including ideal springs obeying Hooke's Law: $E_s = \frac{1}{2}k\Delta x^2$

– gravitational potential energy: $E_g = mg\Delta h$ or from area under a force-distance graph and area under a field- distance graph multiplied by mass.

44

Vertical springs solution process



Typically, the spring is loaded with masses, and the extension is recorded.
The problem begins as a force question. To solve, use
$k\Delta x = mg$, to find k or m.
The total energy (TE) is constant.

TE is the sum of KE + GPE + EPE

∴ $TE = \frac{1}{2}mv^2 + mgh + \frac{1}{2}k\Delta x_2^2$.

45

A spring has a spring constant, *k*, of 20 N m⁻¹.

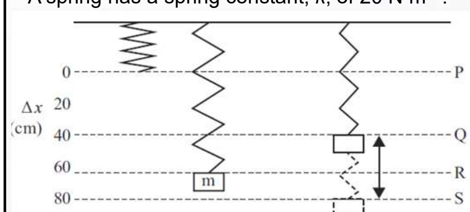


Figure 5a Figure 5b

A mass, m, is hung from the spring.
It extends the spring 0.60 m to point R.
Calculate the mass of m.

50%, (3)

46

Section 2 Example 14

2017 NHT Question 4a, 2 marks

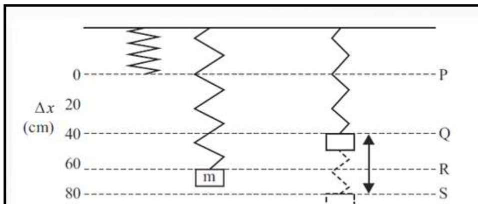
Use $F = k\Delta x$,

where $F = mg$

∴ m × 9.8 = 20 × 0.60

∴ **m = 1.2 kg (ANS)**

47



The mass is raised to point Q and released, it oscillates between points Q and S.

Calculate the change in spring potential energy in moving from point Q to point S.

58%, (3)

48

Section 2 Example 15

2017 NHT Question 4b, 2 marks

Use $EPE = \frac{1}{2}k(\Delta x)^2$, where Q is 0.40 m and S is 0.80 m

$\therefore \Delta EPE = \frac{1}{2} \times 20 \times (0.80^2 - 0.40^2)$

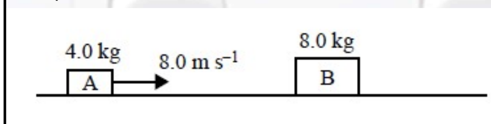
$\therefore \Delta EPE = \frac{1}{2} \times 20 \times (0.64 - 0.16)$

$\therefore \Delta EPE = 4.8$ J (ANS)

49

Momentum

Block A is moving to the right at a speed of 8.0 m s^{-1}.
It collides with a stationary block, B, and rebounds to the left.
Its speed after the collision is 2.0 m s^{-1}.



Calculate the speed of block B after the collision.

Was this collision elastic or inelastic? Support your conclusion by appropriate calculation.

71%, (2) **67%, (6)**

50

Section 3 Example 12

2015 Question 1a, 2 marks, 43%

Momentum is conserved, so the final momentum is equal to the initial momentum.

$p_i = 4.0 \times 8.0 + 8.0 \times 0$

$\therefore p_i = 32.0$

Assume to the right is positive, therefore the final momentum of Block A is negative.

$\therefore 32.0 = 8.0 \times v - 4.0 \times 2$

$\therefore p_f = 32.0$

$\therefore 32 = 8v - 8$

$\therefore v = 5$ m s^{-1} (ANS)

51

Section 3 Example 8

2008 Question 10, 3 marks, 73%

If the collision is elastic, then $KE_{final} = KE_{initial}$

$KE_{initial} = \frac{1}{2} \times 4.0 \times 8.0^2 + 0$

$= 128$ J

$KE_{final} = \frac{1}{2} \times 4.0 \times 2^2 + \frac{1}{2} \times 8.0 \times 5^2$

$= 8 + 100$

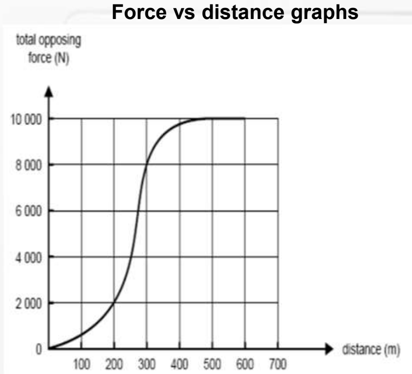
$= 108$ J

$KE_{final} < KE_{initial}$

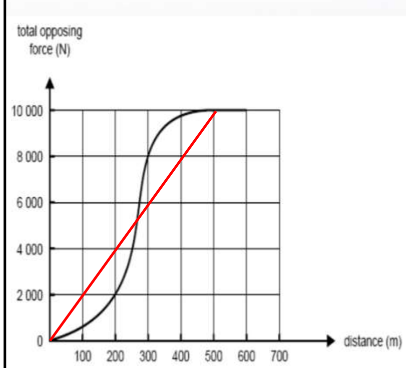
$\therefore$ Collision is inelastic (ANS)

52

Force vs distance graphs



53



54

Momentum – Energy relationships

Start with $p = mv$

Square both sides $p^2 = m^2v^2$

Divide both sides by 2m $\frac{p^2}{2m} = \frac{m^2v^2}{2m}$

Leads to $\frac{p^2}{2m} = \frac{mv^2}{2}$

$$\therefore \frac{p^2}{2m} = KE.$$

Rearranging gives $p^2 = 2mKE$

$$\therefore p = \sqrt{2mKE}$$

Both of these are very useful, but only work if m > 0.

55

Projectile motion

56

Projectile motion

57

Projectile motion

58

Plane landing

59

Projectile motion

Horizontal: velocity always = $v_{horizontal}$
acceleration = 0
displacement $x = v_{horizontal} \times t$

Vertical: Velocity changing $v = u - gt$
acceleration $= -g$
displacement $y = ut - \frac{1}{2}gt^2$

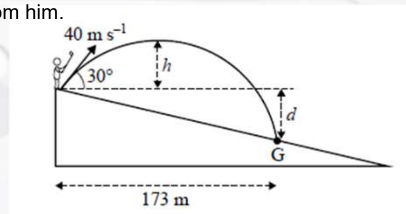
To find the 'total' velocity, add $v_{vertical}$ and $v_{horizontal}$

Symmetrical flights

$$\text{Range} = \frac{v^2 \sin 2\theta}{g}$$

60

A golfer hits a ball on a part of a golf course that is sloping downwards away from him.



The golfer hits the ball at a speed of 40 m s^{-1} and at an angle of 30° to the horizontal.

Calculate the maximum height, *h*.

80%, (1)

61

Section 4 Example 8

2015 Question 5a, 2 marks, 80%

In the vertical direction the initial speed is

$v_v = 40 \times \sin 30^0$

$\therefore v_v = = 20$ m s^{-1}.

At the top of its flight the vertical component of the ball's velocity is zero.

Use $v^2 - u^2 = 2gh$.

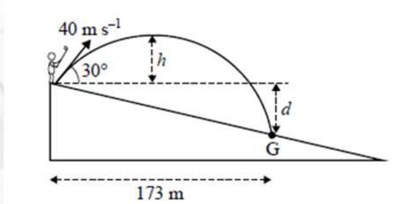
$\therefore 0^2 - 20^2 = 2 \times (-9.8) \times h$

$\therefore 400 = 19.6 \times h$

$\therefore h = 20.4$

$\therefore$ **h = 20 m (ANS)**

62



The ball lands at a point at a horizontal distance of 173 m from the hitting-off point.

Calculate the vertical drop, *d*, from the hitting-off point to the landing point, G.

50%, (2)

63

Section 4 Example 9

2015 Question 5b, 3 marks, 50%

Find the time taken to get to the point G, by using the initial horizontal speed.

In the horizontal direction

$d = v \times t$

$\therefore 173 = 40 \cos 30^0 \times t$

$\therefore t = 4.99$

$\therefore t = 5.$

Use $h = ut - \frac{1}{2}gt^2$ to get the vertical position of the ball at t = 5 s.

$\therefore h = 20 \times 5 - \frac{1}{2} \times 9.8 \times 5^2$

$\therefore h = - 22.5$ m

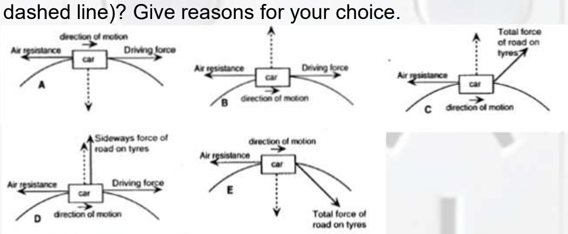
$\therefore$ **d = 23 m (ANS)**

64

Horizontal circular motion

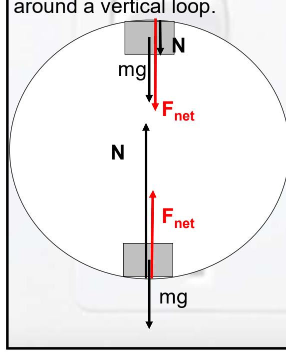
A car is travelling in a horizontal path around a circular curve. The car's speed is constant, and it is travelling from left to right.

Which of the following diagrams best shows the horizontal forces (shown as solid lines) and their resultant force (shown as a dashed line)? Give reasons for your choice.



65

You feel your 'weight' as the normal reaction of the surface on you, because you can only feel things that act on you. So, if the normal reaction increases you 'feel' heavier, and if the normal reaction decreases you 'feel' lighter. Consider an object travelling around a vertical loop.



At the top

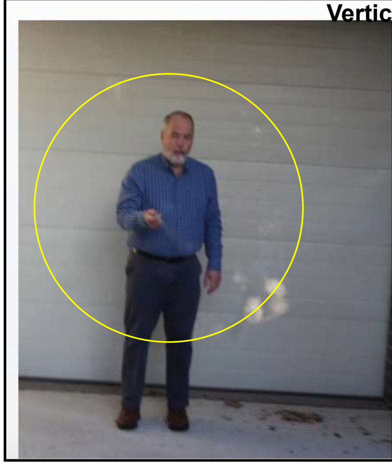
$$F_{net} = N + mg = \frac{mv^2}{r}$$

At the bottom

$$F_{net} = N - mg = \frac{mv^2}{r}$$

66

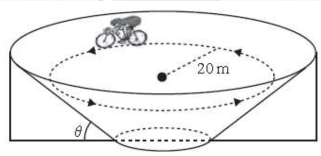
Vertical circular motion



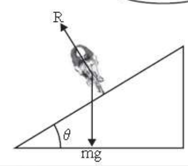
67

Another ridiculous question

A demonstration at a show involves a bike being ridden around a circular banked track. The horizontal path the bike takes is a circle of radius 20 m, and the bike travels at a constant speed of 15 m s^{-1}. The bike and the rider have a total mass of 300 kg.



What is the magnitude of the net force on the bike and rider?



68

Another ridiculous question, deserves a ridiculous response

69

Banked curves

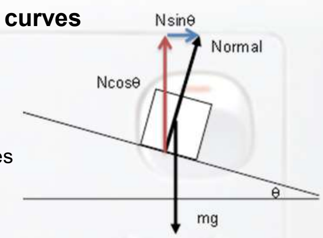
Here Ncosθ = mg and the unbalanced force is Nsinθ.

$\therefore$ N sinθ = $\frac{mv^2}{R}$

dividing by Ncosθ = mg gives

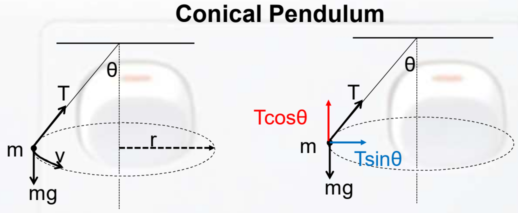
$$\frac{N\sin\theta}{N\cos\theta} = \frac{mv^2}{r} \times \frac{1}{mg}$$

$$\therefore \tan\theta = \frac{v^2}{rg}$$



70

Conical Pendulum

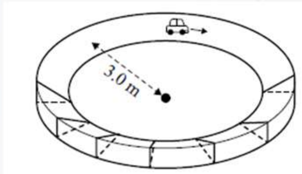


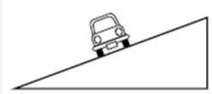
71

72

A model car (2.0 kg) is on a banked circular track. The car follows a path of radius 3.0 m at a constant speed of 2.0 m s^{-1}.

On the diagram below, draw the forces acting on the car using solid lines and label each force. Show the resultant force as a dotted line, labelled F_R.



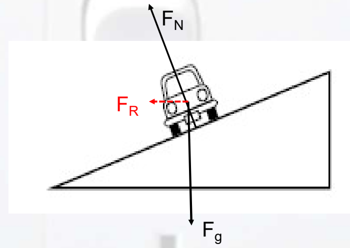


67%, (1)

73

Section 5 Example 4

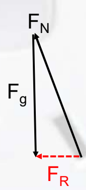
2015 Question 4a, 3 marks, 87%



74

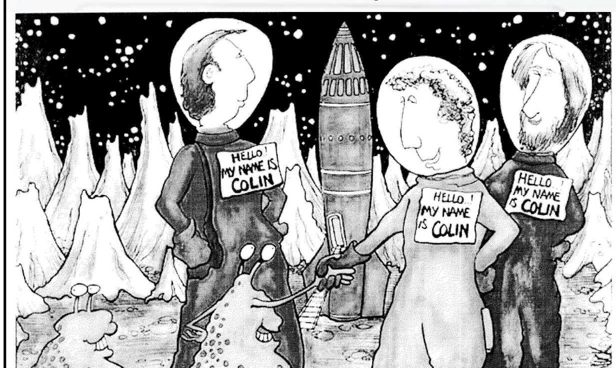
Section 5 Example 4

2015 Question 4a, 3 marks, 87%

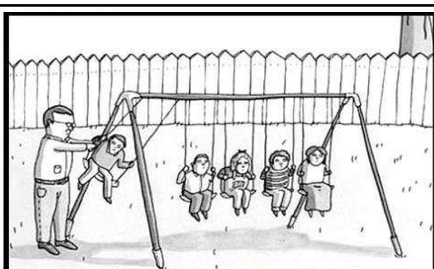


75

The Colinisation of Space



76



Why physics teachers should not be given yard duty

77

Einstein's postulates

The Principle of Relativity

All the laws of physics are the same in all inertial frames. (This compares with Newton's assumptions that the laws of <u>mechanics</u> are the same in all inertial frames)

The Constancy of the Speed of Light

The speed of light in vacuum is the same (3×10^8 m s^{-1}) in all inertial frames (the speed of light is the same regardless of the motion and the source of light).

78

The spaceship *Andromeda* (A) is travelling at 0.7*c* towards the asteroid Ceres (C). It sends a light pulse to the nearby ship *Bradbury* (B), which is approaching the asteroid from the far side at 0.8*c*.

The speed of the light pulse as measured from each body is

A. greatest for A and least for B.

B. greatest for B and least for A.

C. greatest for C and least for B.

D. the same for each body.

40%, (1)

79

Section 6 Example 2

2013 Question 4, 2 marks, 81%

The speed of light is constant, *c*.

∴ **D (ANS)**

80

Proper Time, t_0

The time measured in the frame of reference where the clock is stationary. Proper time is always measured with one clock. If it requires more than one clock to measure the time interval it must be the dilated time interval that is being measured. (Less clocks, less time).

Proper Length, L_0

Is the measured length in the frame where the object (or distance between two events) is stationary.

Note

Proper length and proper time are measured in different frames of reference.
Proper time is measured in the moving frame and proper length in the stationary frame.

81

Time dilation

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{or} \quad t = t_0\gamma$$

Length Contraction

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}} \quad \text{or} \quad L = \frac{L_0}{\gamma}$$

82

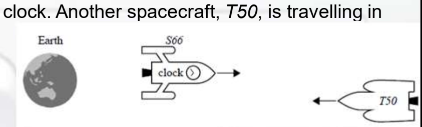
Gamma γ $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

γ	v
1.1	0.140 c
1.5	0.745 c
2	0.866 c
5	0.980 c
10	0.995 c

v	c	γ
0.1 c	10%	1.005
0.5 c	50%	1.155
0.8 c	80%	1.667
0.95 c	95%	3.203
0.99 c	99%	7.089

83

Spacecraft *S66* is travelling at high speed away from Earth carrying a highly accurate atomic clock. Another spacecraft, *T50*, is travelling in the opposite direction to *S66*.



Which one of the following observers will be able to measure proper time using this clock?

A. an astronaut seated on spacecraft *S66* five metres behind the clock's position.

B. a scientist on Earth at the clock's original position.

C. no observer can measure proper time since light within the clock moves at the speed of light.

D. the navigator of the other spacecraft, *T50*, travelling at the moment when that navigator is opposite the clock.

50%, (5)

84

Section 6 Example 6
2015 Question 4, 2 marks, 71%

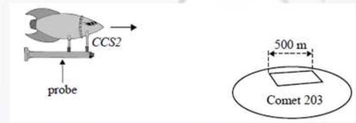
To measure proper time using this clock the two events need to occur at the same location as the clock. This can only occur in the spaceship where the clock is stationary relative to the observer.

∴**A (ANS)**

85

Comet-chasing spacecraft *CCS2* travels at a speed for which γ = 1.5 relative to the nearest stars. It approaches Comet 203, which is effectively stationary relative to the nearest stars. There is a landing probe attached to *CCS2*.

The designated landing area on the comet has length 500 m in the comet's frame and is parallel to spacecraft *CCS2*'s velocity.



What is the length of this landing area, as measured by instruments on *CCS2*?

A. 750 m
B. 500 m
C. 408 m
D. 333 m

63%, (7)

86

Section 6 Example 4
2015 Question 7, 2 marks, 74%

The spacecraft is measuring the length of a relatively moving object, so it measures a contracted length.
The landing area is not moving in the frame of the comet therefore it is the proper length.

Use $L = \frac{L_0}{\gamma}$ with γ = 1.5

$\therefore L = \frac{500}{1.5}$

$\therefore L = 333$

∴**D (ANS)**

87

Spacecraft *CCS2* releases a probe that will land on the comet.
Near touchdown, the probe is at the same velocity as the comet.
Which one of the following is able to measure the proper length for the landing area?

A. the probe when it is travelling at the same velocity as the comet
B. *CCS2* because it has far more accurate radar instruments than the probe
C. *CCS2* at the instant it passes by the landing area on the comet
D. a radar pulse from *CCS2* because the pulse will momentarily be stationary when it bounces off the landing area

63%, (7)

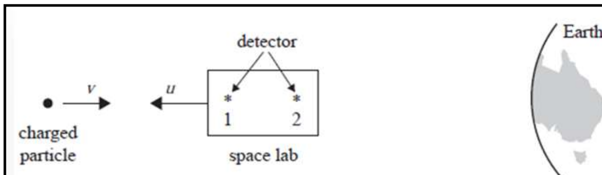
88

Section 6 Example 5
2015 Question 8, 2 marks, 82%

The proper length is measured by an observer at rest relative to the object being measured.

∴**A (ANS)**

89



A space lab travelling at $u = 0.8c$ ($\gamma = 1.67$) away from Earth can record high-energy charged particles passing through its detectors. One particle is travelling towards Earth at $v = 0.91c$ ($\gamma = 2.4$) relative to the space lab.

Two detectors, numbered 1 and 2, are 2.0 m apart in the space lab's frame.

90

How far apart are the two detectors in this particular particle's frame?

A. 0.83 m
B. 1.2 m
C. 3.3 m
D. 4.8 m

40%, (2)

91

Section 6 Example 12
2016 Question 7, 58%

The proper length of the distance between the two detectors is given as L_0 = 2.0 m. In the particles' frame the detector is in relative motion, so they're measuring the length of a relatively moving object, so they're measuring the contracted length, L. The Lorentz factor has been given, γ = 2.4.

Use $L = \frac{L_0}{\gamma}$

$\therefore \gamma = 2.4$

$\therefore L = \frac{2.0}{2.4}$

$\therefore L = 0.833$

∴ **A (ANS)**

92

A pion and its antiparticle, each at rest, annihilate to produce two photons whose total energy is 4.5×10^{-11} J.

Apart from the two photons, nothing else is produced in this process. The masses of a pion and its antiparticle are the same.

The rest mass of the pion is

A. 1.3×10^{-28} kg
B. 2.5×10^{-28} kg
C. 5.0×10^{-28} kg
D. 7.5×10^{-20} kg

57%, (6)

93

Section 6 Example 13
2014 Question 10, 52%

$E_{rest} = mc^2$, so the mass, m, converted to other forms of energy (the two photons) is given by

$4.5 \times 10^{-13} = m \times (3.0 \times 10^8)^2$

$\therefore m = 5.0 \times 10^{-28}$

$\therefore$ mass of pion = 2.5×10^{-28} kg

∴ **B (ANS)**

94

How do things move without contact?

95

Field lines

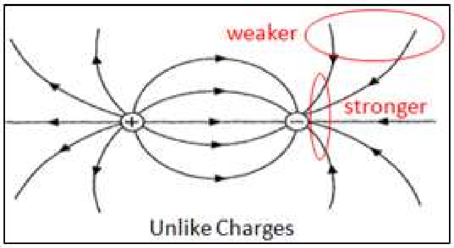
You need to be able to draw field lines for Electric fields, Gravitational fields and Magnetic fields.

When drawing field lines there are four basic principles.

1. Field lines do not touch or cross each other.
2. The arrow shows the direction of the field.
3. The further the field lines are apart, the weaker the field.
4. Field lines start and end perpendicular to the surface.

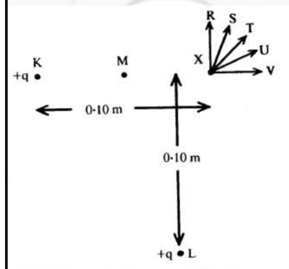
96

Electric field around point charges



97

Two equal point charges are placed at the points K and L and produce a resultant electric field at the point X of magnitude 100 V m^{-1} in the direction of T.



The charge at the point K is then shifted a distance of 0.05 m to M.

Which of the arrows (R - V) now best describes the direction of the resultant electric field at point X?

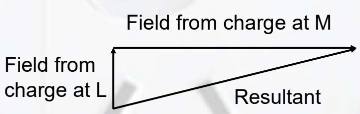
84%, (4)

98

Section 7 Example 2

1984 Question 52, 1 mark, 62%

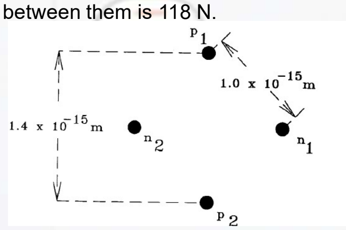
The resultant field is the vector sum of the two individual fields. Since the charge at point K is moved towards X, the field from this charge will increase.



$\therefore$ **U (ANS)**

99

A helium nucleus contains two protons and two neutrons. The protons, p_1 and p_2 each with a charge of $+1.6 \times 10^{-19}$ C are separated by 1.4×10^{-15} m, and the electrostatic force between them is 118 N.



What is the magnitude of the electrostatic force between the neutron n_1 and the proton p_1?

51%, (2)

100

Section 7 Example 4

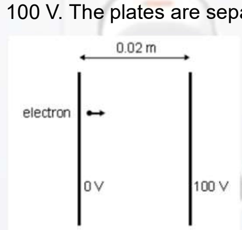
1990 Question 46, 1 mark

The force between the neutron (zero charge) and the proton (+1 charge) is zero.

101

Uniform electric field

An electron is accelerated from rest between two parallel charged plates in a vacuum with a potential difference of 100 V. The plates are separated by a distance of 0.02 m.



Calculate the electric field strength between the parallel plates, (in V m^{-1}).

85%, (5)

102

Section 6 Example 6
2004 Question 4, 2 marks, 85%

Use $E = \frac{V}{d}$

$\therefore E = \frac{100}{2 \times 10^{-2}}$

$\therefore$ **E = 5.0 × 10^3 V m^{-1} (ANS)**

103

In the electron gun of a synchrotron, electrons are accelerated from rest over a distance of 12 cm to reach a final speed of 8.0×10^7 m s^{-1}.

What is the accelerating voltage of the electron gun in kilovolts?

A. 2.67 kV
B. 5.30 kV
C. 6.67 kV
D. 18.2 kV

69%, (8)

104

Section 7 Example 8
2016 Synchrotron Question 2, 2 marks, 58%

Use $E = \frac{1}{2}mv^2$, to find the work done.

$\therefore WD = \frac{1}{2} \times 9.11 \times 10^{-31} \times (8.0 \times 10^7)^2$

$\therefore WD = 2.92 \times 10^{-15}$

Use WD = qV

$\therefore 2.92 \times 10^{-15} = 1.6 \times 10^{-19} \times V$

$\therefore V = 1.82 \times 10^4$ V

$\therefore$ **D (ANS)**

105

Gravitational motion

$a = \frac{v^2}{r}$ $v = \frac{2\pi r}{T}$ $a = \frac{4\pi^2 r}{T^2}$

Using $F = \frac{GMm}{r^2}$ and F = mg

to get $g = \frac{GM}{r^2}$

Kepler's Law

$$\frac{GM}{4\pi^2} = \frac{r^3}{T^2}$$

106

Gravitation question (not on course)

What is the force of attraction between the Sun and the Earth?

A. 10^{42} N
B. 10^{22} N
C. 10^2 N
D. 10^{-22} N

107

Use $F = \frac{GMm}{r^2}$ where $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2},

$M_{Sun} = 2.0 \times 10^{30}$ kg

$M_{Earth} = 6.0 \times 10^{24}$ kg

$r = 1.5 \times 10^{11}$ m

$\therefore F = \frac{6.7 \times 10^{-11} \times 2.0 \times 10^{30} \times 6.0 \times 10^{24}}{(1.5 \times 10^{11})^2}$

$\therefore$ **F = 3.6 × 10^{22} N**

$\therefore F = \frac{6.7 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2}$

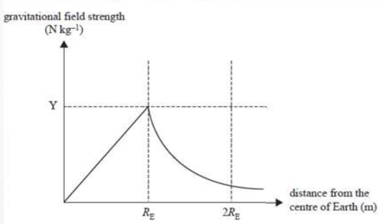
$= \frac{6.7 \times 2 \times 6 \times 10^{-11} \times 10^{30} \times 10^{24}}{(1.5)^2 \times 10^{22}}$

$= \frac{80.4 \times 10^{43}}{2.25 \times 10^{22}}$

$\therefore$ **F = 3.6 × 10^{22} N**

108

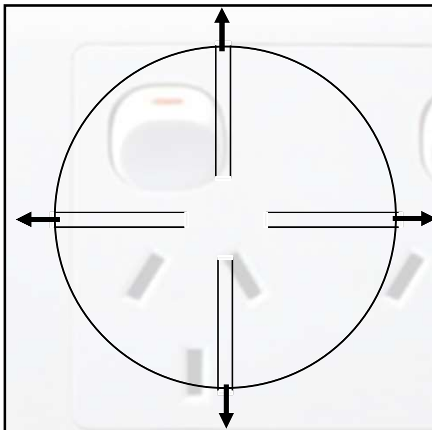
The radius of Earth (R_E) is 6.37×10^6 m. Assume that Earth is a sphere of constant density. A graph of gravitational field strength versus distance from the centre of Earth is shown.



Explain why gravitational field strength is 0 N kg^{-1} at the centre of Earth.

17%, (1)

109



110

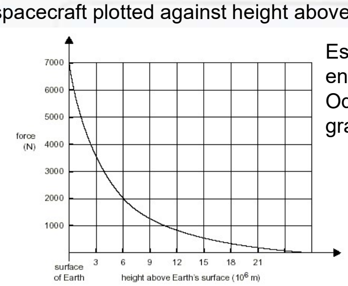
Section 7 Example 13

2019 Question 4b, 1 mark, 17%

Gravitational force is the attraction between two masses. At the centre of the Earth the gravitational force of attraction (from all the mass surrounding the centre) is equal in all directions. Therefore, the vector sum is zero.

111

The gravitational force acting on the 700 kg Mars Odyssey spacecraft plotted against height above Earth's surface.

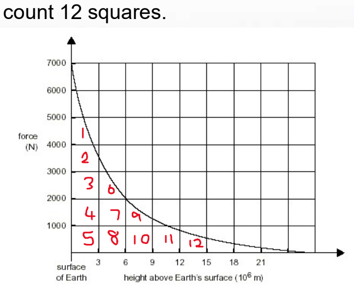


Estimate the minimum launch energy needed for Mars Odyssey to escape Earth's gravitational attraction.

32%, (3)

112

I count 12 squares.



113

Section 7 Example 21

2002 Question 1, 3 marks, 53%

Area under graph is something like 11 to 13 squares

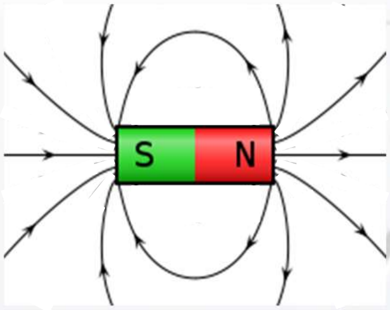
Each square has a value of

$1000 \times 3 \times 10^6 = 3 \times 10^9$ J

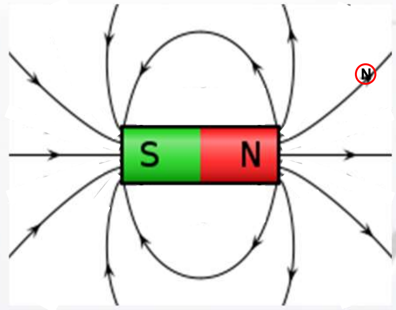
$\therefore$ at least **3.3×10^{10} J (ANS)**

Allowing for a variation in the number of squares counted, a range of values **3.3 to 4.4×10^{10} J**, was accepted.

114



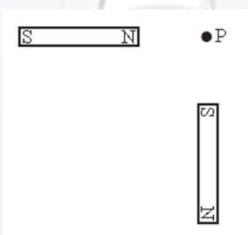
115



116

Two identical bar magnets of the same strength are arranged at right angles and are equidistant from point P.

At point P on the diagram, draw an arrow indicating the direction of the combined magnetic field of the bar magnets.

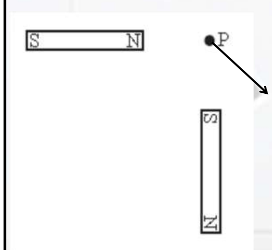


63%, (3)

117

Section 7 Example 28
2011 Question 1, 1 mark, 44%

The direction of the field is given by the sum of the fields from the horizontal magnet (to the right) and from the vertical magnet (down). The two components have the same size, so the angle needed to be 45^0. The arrow also should touch point P.



118

Section 7 Example 28
2011 Question 1, 1 mark, 44%

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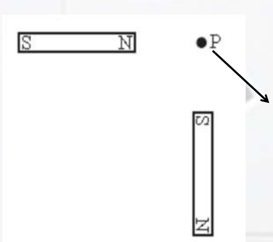

119

Section 7 Example 28
2011 Question 1, 1 mark, 44%

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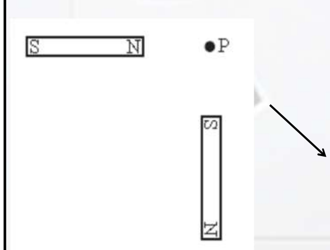

120

Section 7 Example 28
2011 Question 1, 1 mark, 44%

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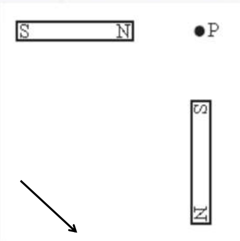
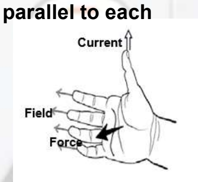


121

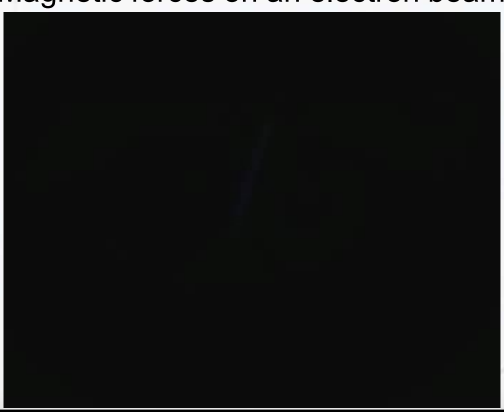
- **investigate and analyse theoretically and practically the force on a current carrying conductor due to an external magnetic field, $F = nIlB$, where the directions of I and B are either perpendicular or parallel to each other.**

Hand rules in electromagnetism
You need to specify exactly what the thumb, fingers, palm etc. are representing. There are MANY 'hand rules', and you need to be ultra-specific.



122

Magnetic forces on an electron beam

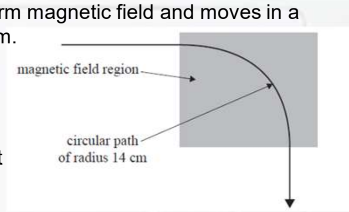


123

Use $Bqv = \frac{mv^2}{r}$

124

An electron leaves the electron gun travelling at 2.7×10^7 m s^{-1}. The electron enters a uniform magnetic field and moves in a circular path of radius 14 cm.



Which of the following best describes the direction of the magnetic field?

A. down the page
B. out of the page
C. up the page
D. into the page

64%, (3)

125

Section 7 Example 32
2012 Question 4 (Synchrotron), 2 marks, 68%

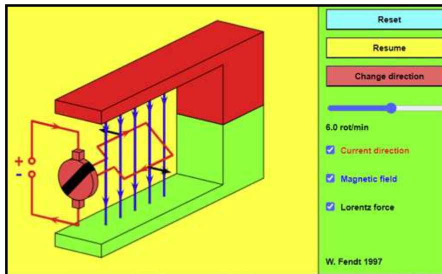
Initially the current is to the left (negative charge), and the force is down the page. This means that the field is into the page.

$\therefore$ **D (ANS)**

126

DC motor

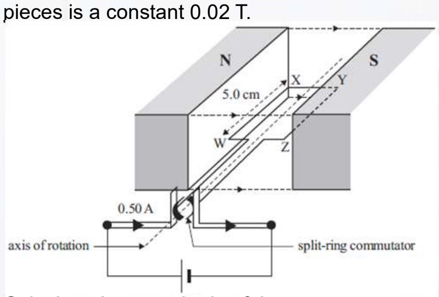
127



https://www.walter-fendt.de/html5/phen/electricmotor_en.htm

128

Students build a simple electric motor consisting of a single coil and a split-ring commutator. The magnetic field between the pole pieces is a constant 0.02 T.



Calculate the magnitude of the force on the side WX.

79%, (4)

129

Section 8 Example 6

2017 NHT Question 13a, 2 marks

Use F = BiL

$\therefore$ F = 0.02 × 0.5 × 0.05

$\therefore$ **F = 5 × 10^{4} N (ANS)**

130

Will the coil rotate in a clockwise or anticlockwise direction as seen by an observer at the split-ring commutator? Explain your answer.

60%, (6)

131

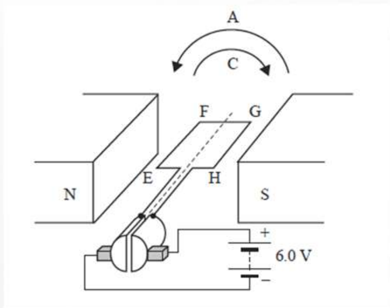
Section 8 Example 7

2017 NHT Question 13b, 2 marks

Using the right-hand force rule, the force on side WX is down and the force on side YZ is up. Therefore, the loop will rotate anticlockwise

Anticlockwise (ANS)

132



133

Explain the role of the split-ring commutator in the operation of the electric motor.

53%, (4)

134

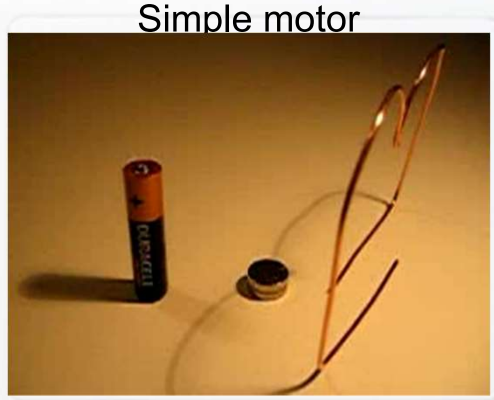
Section 8 Example 8

2017 NHT Question 13c, 2 marks

The role of the commutator is to reverse the direction of the current every half turn, so that the direction of the force on the current carrying wire is reversed every half turn, in order to keep the motor rotating in the same direction. The direction of the current reverses when the coil is at right angles to the field.

135

Simple motor



136

How are fields used to move electricity?

137

- **calculate magnetic flux when the magnetic field is perpendicular to the area, and describe the qualitative effect of differing angles between the area and the field:**

  $\Phi_B = B_{\perp} A.$

- **investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf,**

  $\varepsilon = -N\frac{\Delta\phi_B}{\Delta t}$ **with reference to:**

  - **rate of change of magnetic flux**
  - **number of loops through which the flux passes**
  - **direction of the induced emf in a coil.**

138

Faraday's Law

139

Flux problem solving process

There is a simple 4 step process to answering 'flux' questions

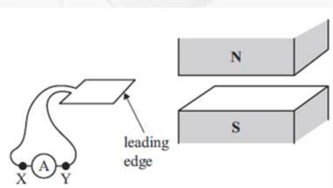
1. Identify the direction of the initial flux
2. Indicate how it is changing, use language of 'increasing/decreasing'
3. State; "The induced EMF will create a current (if the circuit is complete), that has a field that will oppose the change in flux".
4. Apply to the question.

140

A square loop of side 10 cm is allowed to move horizontally through a region of a uniform magnetic field.

Determine whether the current will flow from X to Y or from Y to X through the meter A as the loop moves into the magnetic field.

Explain your answer.



35%, (8)

141

Section 9 Example 5

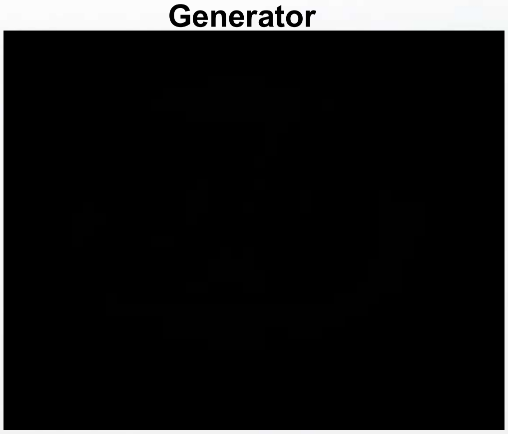
2017 NHT Question 14c, 4 marks

The initial flux through the loop is downwards and increasing.
Lenz's law gives that the induced current will produce a field that will create an increasing, upwards flux to oppose the change in flux. Use the right-hand grip rule to determine that the current will flow anticlockwise through the loop, to produce a field upwards, and hence from X to Y through meter A.

$\therefore$ **X to Y (ANS)**

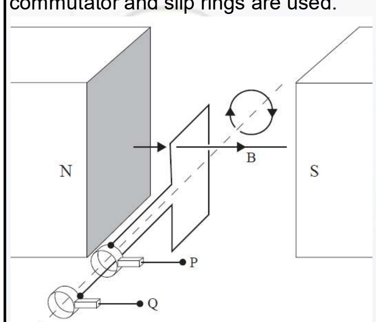
142

Generator



143

Explain the difference in function between a split-ring commutator and slip rings. Describe the situations in which a split-ring commutator and slip rings are used.



50%, (4)

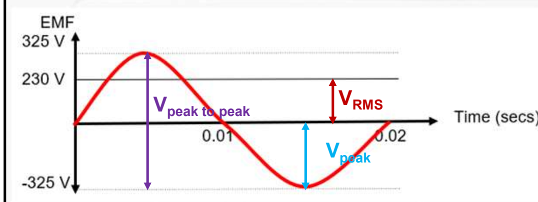
144

Section 9 Example 8
2010 Question 7, 3 marks, 63%

With slip rings, each ring stays connected to either P or Q through-out the cycle. This produces an AC output.
A split ring swaps the connection to P and Q twice every cycle, i.e. reversing the direction of the current every half cycle.
Slip rings are used to produce AC, whilst the split ring is used to produce DC.

145

Peak to Peak, Peak and RMS

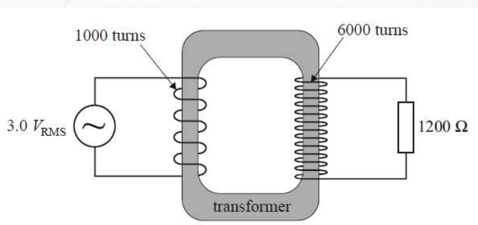


$V_{peak\ to\ peak} = 2\ V_{peak}$

and $V_{peak} = \sqrt{2}\ V_{RMS}$.

146

Transformers



Calculate the RMS voltage across the resistor.

84%, (7)

147

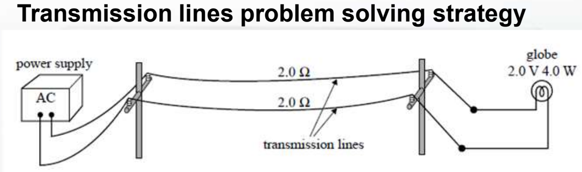
Section 10 Example 4
2013 Question 15a, 1 mark, 77%

From $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

The ratio of the number of turns is 1:6
∴ the ratio of the voltages will be the same
∴ 3.0 : 18.0
∴ **18.0 V (ANS)**

148

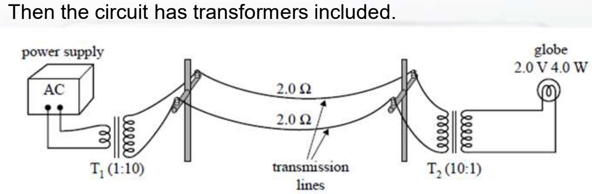
Transmission lines problem solving strategy



You are either provided with the supply voltage and asked to find the output voltage or in this case you are supplied with the output voltage and expected to work back to find the supply voltage. Typically, you find the current in the wires, and to use this to determine the voltage drop across the transmission lines and the power loss in the lines.

149

Then the circuit has transformers included.

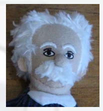


The step-up transformer is always at the supply end. Stepping up the voltage, reduces the current in the transmission lines for the same power being supplied. The decrease in current leads to less power loss in the transmission lines, which leads to more power at the output. The step-down transformer at the output, brings the voltage down to manageable levels.

150

Einstein, Newton and Pascal are hanging out one afternoon.

Einstein is bored, so he suggests,
"Let's play hide-and-seek. I'll be it!" The others agree, so Einstein begins counting. One…Two… Three…"



Pascal runs off right away to find a place to hide.

But Newton merely takes out a piece of chalk and draws a square.

He finishes and steps into the square just as Einstein shouts, "Ready or not – here I come!"

Einstein looks up and immediately spots Newton standing right in front of him.

He says, "I found you, Newton!"

Newton replies,

"No, you found one Newton per square metre, you found Pascal!"

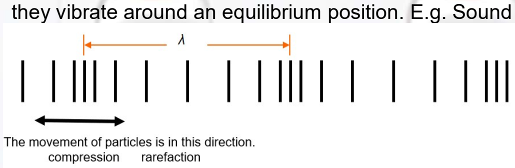
151

How can waves explain the behaviour of light?

152

Longitudinal waves

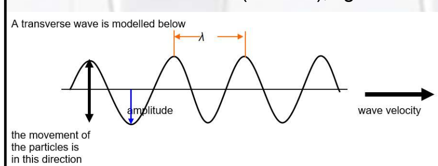
In longitudinal waves the vibration of the waves is in the same direction as the line of travel, the particles do not move forward, they vibrate around an equilibrium position. E.g. Sound waves.



153

Transverse waves

When waves vibrate up and down in a direction perpendicular to the direction of motion of the wave. e.g. water waves, where the motion of the water particles is at right angles (up and down) to the direction of the wave (forward), light.

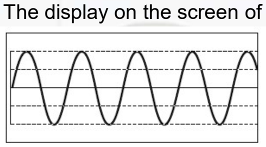


Wave equation

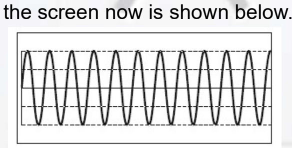
$v = f\lambda$

154

A loudspeaker connected to a signal generator is placed near a microphone. The microphone is connected to an oscilloscope. The display on the screen of the oscilloscope is shown below.



The student varies the settings on the signal generator, but the oscilloscope controls are unaltered. The display on the screen now is shown below.



155

The sound entering the microphone (compared with the earlier situation) is best described as

A. of smaller intensity.
B. of greater wavelength.
C. having a greater frequency.
D. travelling at a greater speed.

55%, (6)

156

Section 11 Example 1

2013 Question 9, 2 marks, 88%

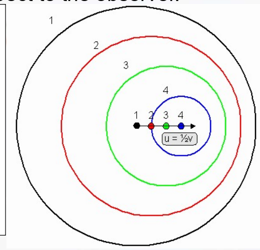
The period has decreased therefore the frequency has increased. The height of the wave remained constant therefore it was not louder.

∴ **C (ANS)**

157

The Doppler effect is when the source of the sound wave is moving with respect to the observer.

As the source moves away from the observer there is an apparent increase in the wavelength and a decrease in the frequency.



As the source moves towards the observer, there is an apparent shortening of the wavelength and hence an increase in the frequency.

Since the medium the wave is travelling in doesn't change, the speed of the wave remains constant. The wavefronts remain circular, but the centre of the circle moves.

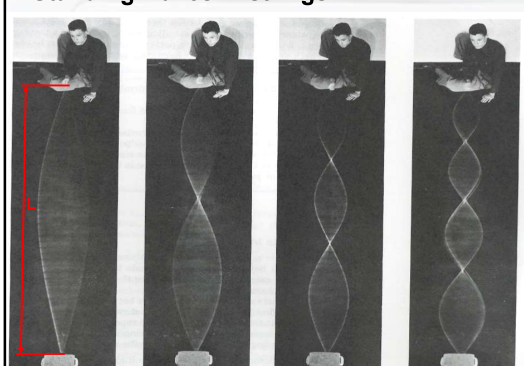
158

Standing waves

If we have two identical waves travelling in the opposite directions in one medium, we get a standing or stationary wave. The superposition principle is used to obtain the waveform.

159

Standing waves in strings

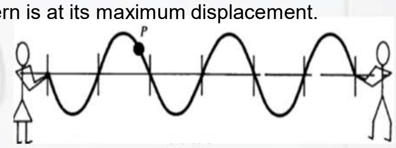


$L = \frac{\lambda}{2}$ $L = \lambda$ $L = \frac{3\lambda}{2}$ $L = 2\lambda$

160

A length of light spring is used to demonstrate waves by setting up a standing wave pattern on the spring. At the instant shown below the pattern is at its maximum displacement.

Which of the statements (**A - F**) best describes the motion of the point P, at the instant shown.



A. It is moving to the right.
B. It is moving to the left.
C. It is moving upwards.
D. It is moving downwards.
E. It is momentarily stationary.
F. It is always stationary.

66%, (5)

161

Section 12 Example 6

1988 Question 36, 1 mark

Since it is a standing wave at its maximum displacement, everywhere on the spring is momentarily stationary.

∴**E (ANS)**

162

Pressure variation in pipes (Open at both ends)

First harmonic (fundamental frequency)

$\lambda_1 = 2L$

$f_1 = \frac{v}{2L}$

Second harmonic (first overtone)

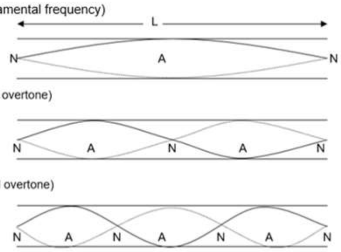
$\lambda_2 = \frac{2L}{2} = L$

$f_2 = \frac{2v}{2L} = 2f_1$

third harmonic (second overtone)

$\lambda_3 = \frac{2L}{3}$

$f_3 = \frac{3v}{2L} = 3f_1$



163

Pressure variation in pipes (Closed at one end)

First harmonic (fundamental frequency)

$\lambda_1 = 4L$

$f_1 = \frac{v}{4L}$

third harmonic (first overtone)

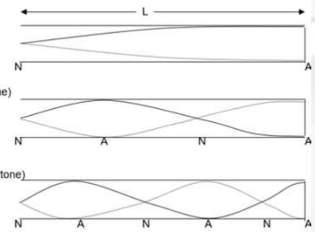
$\lambda_2 = \frac{4L}{3}$

$f_2 = \frac{3v}{4L} = 3f_1$

fifth harmonic (second overtone)

$\lambda_3 = \frac{4L}{5}$

$f_3 = \frac{5v}{4L} = 5f_1$



164

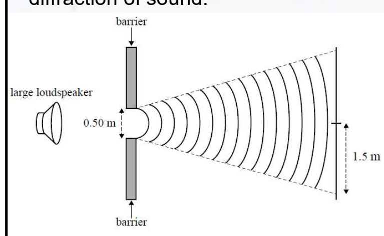
Diffraction

When light (waves) pass through a narrow aperture, a hole, a slit or an obstacle, it spreads out, this is known as diffraction. Diffraction is the bending of the path of the wave from its initial direction.

The amount of diffraction $\propto \frac{\lambda}{d}$

165

A group of students is conducting experiments to study the diffraction of sound.



The frequency is 1200 Hz. The width of the gap between the two barriers is 0.5 m.

At some distance from the gap, the students note that the edge of the diffraction pattern is 1.5 m off the centre line.

166

The students increase the frequency from 1200 Hz to 3000 Hz.

Which one of the following is most likely to be observed?

A.

B.

C.

D.

167

The students increase the frequency from 1200 Hz to 3000 Hz.

Which one of the following is most likely to be observed?

A. The edge of the pattern will still be approximately 1.5 m off the centre line.

B. The edge of the pattern will be closer to the centre line.

C. The edge of the pattern will be further out than 1.5 m.

D. There will now be no edge of the pattern.

72%, (2)

168

Section 12 Example 7

2015 Question 10, 2 marks, 71%

Increasing the frequency will decrease the wavelength.

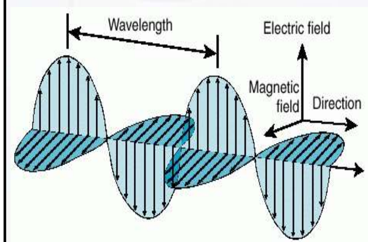
The diffraction varies as $\frac{\lambda}{d}$ where d is the width of the gap and λ is the wavelength. Therefore, the decrease in λ will lead to less spread in the observed pattern.

∴B (ANS)

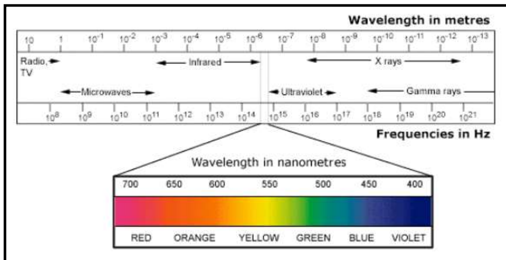
169

Electromagnetic radiation

Maxwell discovered that visible light was an EM radiation in the frequency range of 4.3×10^{14} to 7×10^{14} Hz. He understood that light of any kind is energy-carrying waves of electric and magnetic fields that continually regenerate each other and travel at a single fixed speed, *c*, the speed of light.



170



171

Which of the following **(A - C)** below is greater for red light travelling through a vacuum, than for blue light travelling through a vacuum?

A. Frequency.

B. Speed of propagation.

C. Wavelength.

68%, (7)

172

Section 13 Example 1

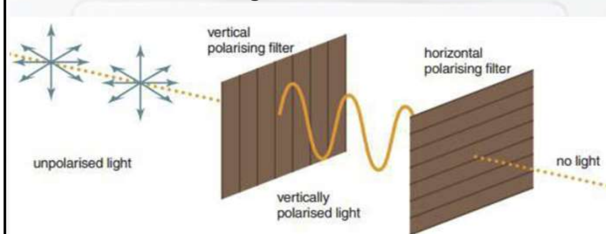
1989 Question 27, 2 marks

Both colours will have the same speed in a vacuum, but both the frequency and wavelength will depend on colour. The wavelength of red light is greater than for blue light.

∴ C (ANS)

173

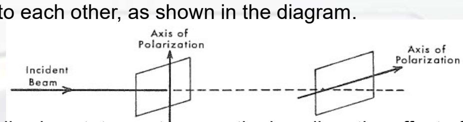
Polarisation of light



Only transverse waves can be polarised.
Optical devices called polarisers only allow light with a specific polarisation to pass through them.
The plane of polarisation is defined as the plane of the electric field.

174

The axes of polarization of two perfect polarizers are perpendicular to each other, as shown in the diagram.



Which of the following statements correctly describes the effect of the polarizers on the beam?

A. The transmitted light will be unpolarized.

B. The light transmitted by the first polarizer will be stopped by the second.

C. The light transmitted by the first polarizer will also be transmitted by the second.

D. Light transmitted through the first polarizer will be de-polarized by the second one.

70%, (8)

175

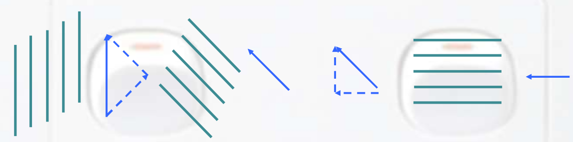
Section 13 Example 2
1977 Question 74, 1 mark, 72%
The components of the electric fields in both vertical and horizontal directions will be blocked.

∴ B (ANS)

176

177

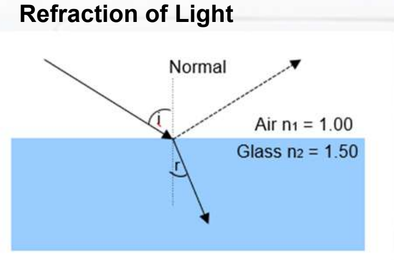
How do three polarising filters work?



You just have to love vectors!

178

Refraction of Light



Snell's Law

$n_1 \sin i = n_2 \sin r$ and $n_1 v_1 = n_2 v_2$

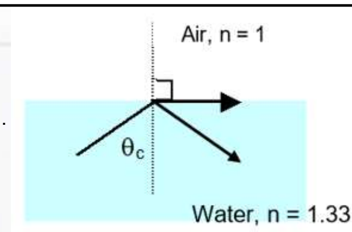
179

Critical angle

Can occur when light goes from a high to a lower refractive material.

$n_1 \sin i_c = n_2 \sin 90$

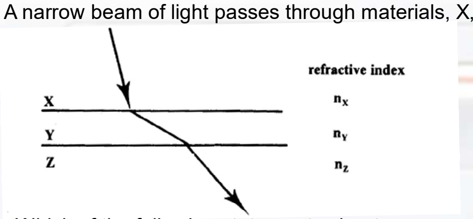
$n_1 \sin i_c = n_2$



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$1.33 \sin\theta_c = 1 \sin 90$$
$$\sin\theta_c = \frac{1}{1.33}$$
$$\theta_c = 48.8$$

180

A narrow beam of light passes through materials, X, Y and Z.



Which of the following statements about the refractive indices is correct?

A. $n_Z > n_Y > n_X$

B. $n_Y > n_X$ and $n_Y > n_Z$

C. $n_X > n_Z > n_Y$

D. $n_Z > n_X > n_Y$

37%, (5)

181

Section 13 Example 3

1982 Question 34, 1 mark, 64%

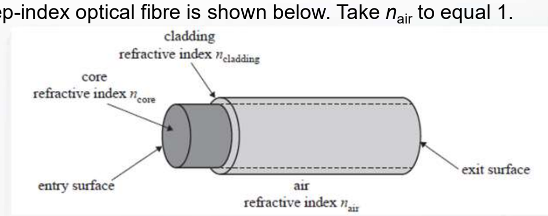
The light bends away from the normal as it goes from X to Y, therefore, $n_X > n_Y$.
The light bends towards the normal as it goes from Y to Z, therefore, $n_Z > n_Y$.
Comparing the angles in X and Y, the light bends away from the normal, therefore, $n_X > n_Z$.

$\therefore n_X > n_Z > n_Y$

$\therefore$ **C (ANS)**

182

A step-index optical fibre is shown below. Take n_{air} to equal 1.



Which of the following combinations gives a critical angle for the core and cladding closest to 83°?

A. $n_{core} = 1.31$, $n_{cladding} = 1.32$

B. $n_{cladding} = 1.71$, $n_{core} = 1.73$

C. $n_{core} = 1.71$, $n_{cladding} = 1.73$

D. $n_{cladding} = 1.31$, $n_{core} = 1.32$

60%, (9)

183

Section 13 Example 6

2016 Question 4, 2 marks, 54%

For a critical angle to exist in the core, $n_{cladding} < n_{core}$

Use $n_1 \sin i = n_2 \sin r$

$\therefore 1.73 \sin i_c = 1.71 \times \sin 90$

$\therefore \sin i_c = \frac{1.71}{1.73}$

$\therefore i_c = 81.3^o$

or

$\therefore 1.32 \sin i_c = 1.31 \times \sin 90$

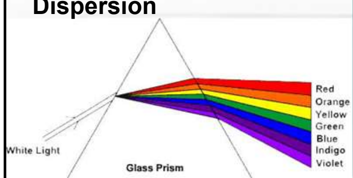
$\therefore \sin i_c = \frac{1.31}{1.32}$

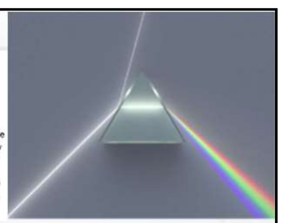
$\therefore i_c = 82.9^o$

$\therefore$ **D (ANS)**

184

Dispersion

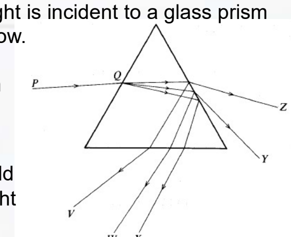




Red light (with its long wavelength) travels fastest ($v = f\lambda$) in glass, so it bends less.

185

A mixed beam of red and blue light is incident to a glass prism along the path PQ as shown below.



The paths of the emerging beam of red light are marked as W and Y on the diagram.

Which of the choices (**A - E**) could represent the path of the blue light emerging from the prism?

A. X

B. W

C. V and Z

D. W and Y

E. V

62%, (4)

186

Section 13 Example 7, 1985
Question 35, 1 mark, 60%

The blue light will bend more than red light on entering the prism. Therefore, when it leaves the prism, it will pass through X.

∴ **A (ANS)**

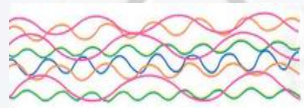
187

Coherent light

A beam of photons having the same frequency, phase, and direction – i.e. a beam of identical photons – is said to be **coherent**. A beam of coherent light spreads and weakens very little.

Incoherent light

Light emitted by a common lamp is incoherent, that is, photons of many frequencies and in many phases of vibration are emitted. A beam of incoherent light spreads out after a short distance, becoming wider and less intense with increased distance.



188

Monochromatic light

A beam formed with a single frequency waves.

Laser

A laser produces a beam of coherent light. Electrons are stimulated to rise to a higher energy level. To return to their original level they release the energy difference as light of a single frequency in a single direction.

189

Synchrotron Radiation

Electrons that are accelerated through a circular arc by magnetic fields. As the particle accelerates it releases energy in the form of electromagnetic radiation

LED's

When an LED is provided with a voltage, electrons are able to jump the band-gap width. The light emitted is from the transition of electrons back from the conduction band to the valence band. The band gap energy determines the energy and hence, the colour of the light emitted.

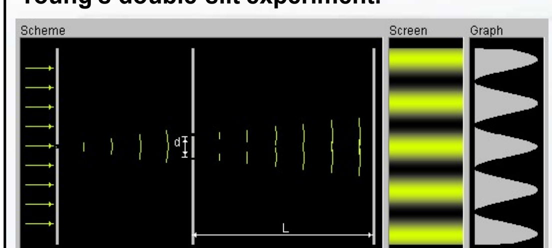
190

Incandescent light

Incandescence is the term used to describe light produced as a result of high temperatures. This causes the atoms of the filament to gain kinetic energy and some of this energy is absorbed by the atom's electrons. The electrons rise to a higher energy level, as they return to their original energy level they release the energy difference as light.

191

Young's double-slit experiment.



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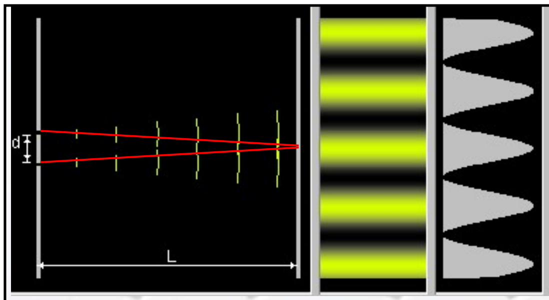

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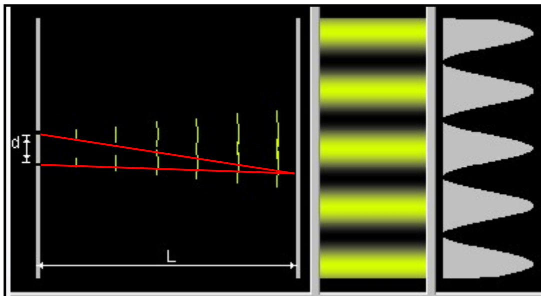

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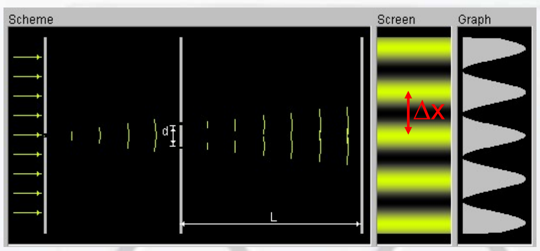
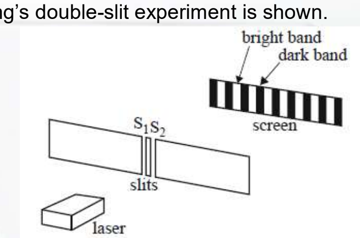


$$\Delta x \approx \frac{n\lambda L}{d}$$

195

The apparatus for a Young's double-slit experiment is shown.



A student reads on a website that 'Young's experiment supports the particle model of light'.

Explain, with reasons, whether the statement is correct or incorrect.

62%, (4)

196

Section 14 Example 1

2013 Question 22d, 3 marks, 60%

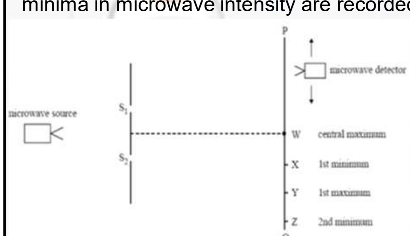
The statement is incorrect.

Young's double slit experiment with light demonstrated interference, which was a wave effect. Young's experiment showed that the light from both slits interfered with each other and produced a pattern of light and dark lines. The interference was both constructive and destructive from the superposition of waves.

The particle model predicted that two bands would appear on the screen behind the slits as sharp shadows, which are not observed.

197

A student is studying Young's double slit experiment using microwaves (λ = 3.0 cm) instead of light. A microwave detector is moved along the line PQ, and the maxima and minima in microwave intensity are recorded.



What is the path difference $S_1Z - S_2Z$ in cm?

39%, (6)

198

Section 14 Example 6
2008 Question 3, 2 marks, 45%

Position Z is the second minimum, so the path difference is 1.5 λ.

So: PD = 1.5 λ

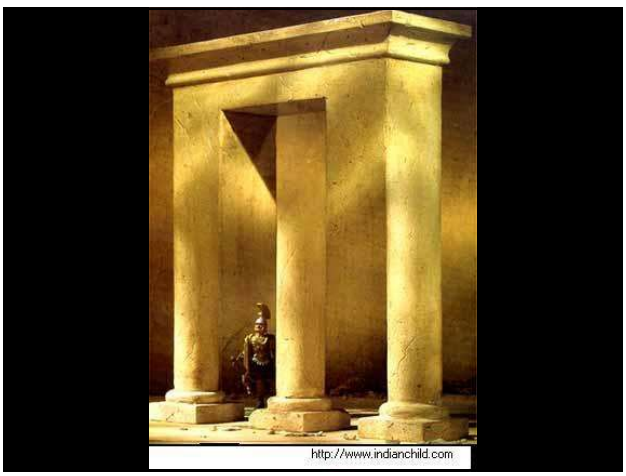
PD = 1.5 × 3.0

∴ **PD = 4.5 cm (ANS)**

199

Awareness Test

200



201

XI + I = X

202

X = I + IX

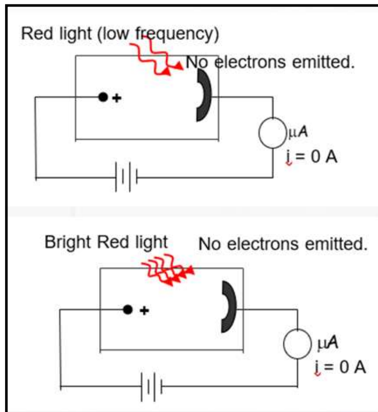
203

How are light and matter similar?

204

- **analyse the photoelectric effect with reference to:**
  - **– evidence for the particle-like nature of light**
  - **– experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency**
  - **– kinetic energy of emitted photoelectrons: $E_{k\,max} = hf - \varphi$, using energy units of joule and electron-volt**
  - **– effects of intensity of incident irradiation on the emission of photoelectrons**

205



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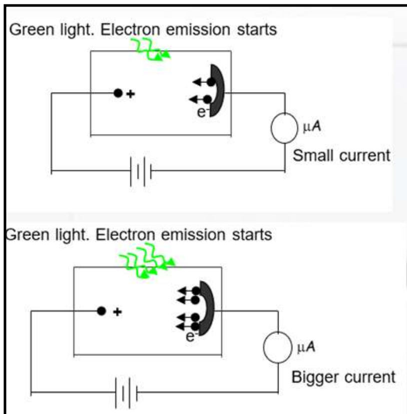

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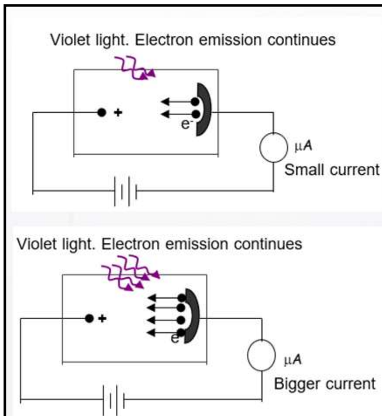
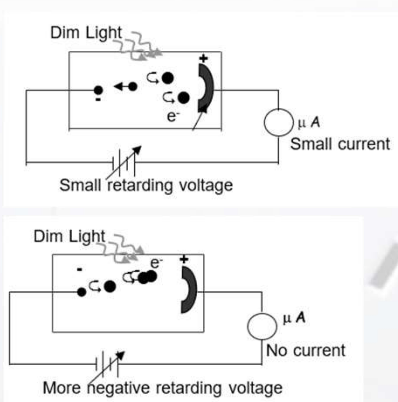


208



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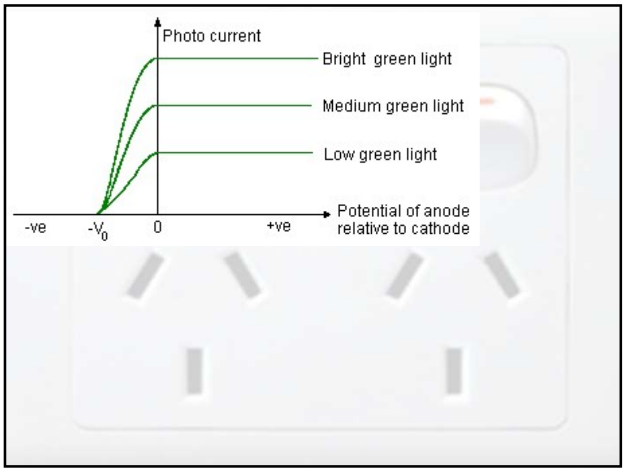

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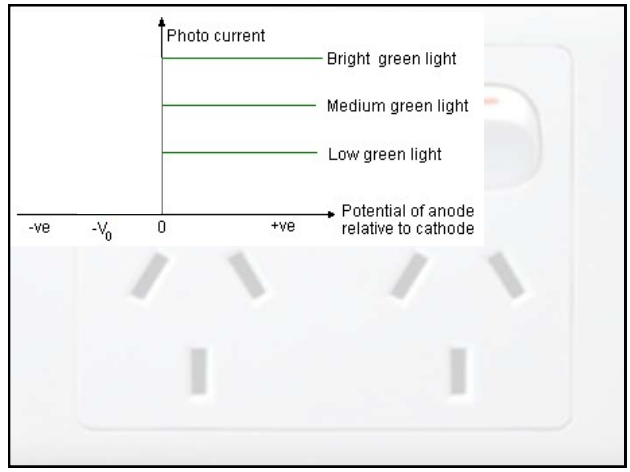

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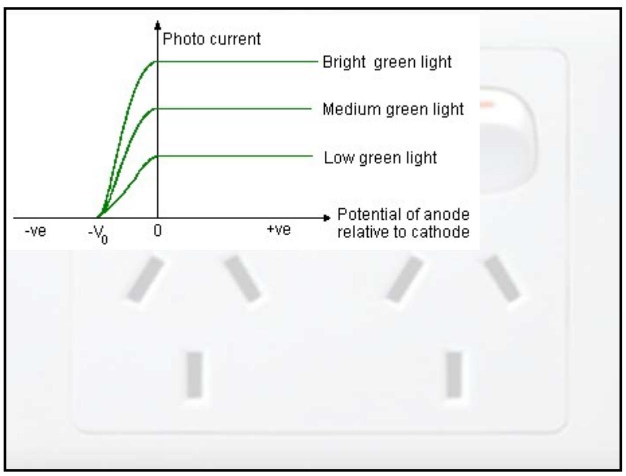

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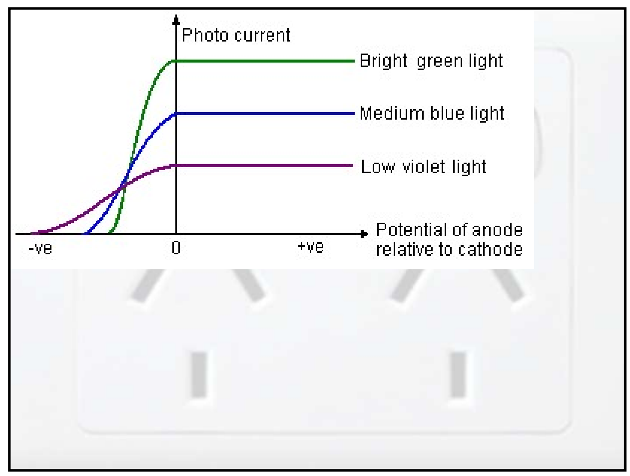

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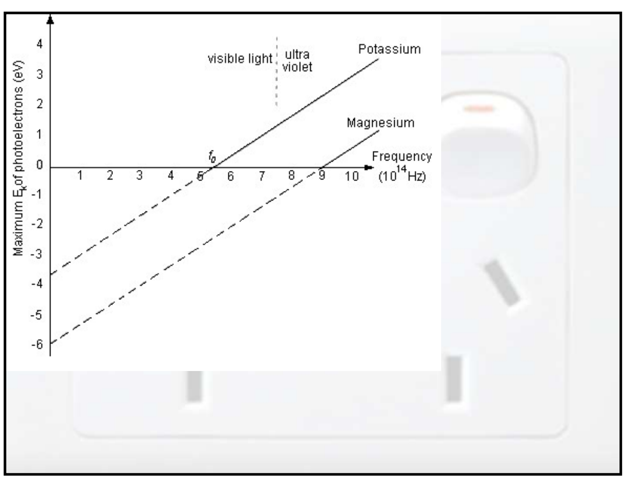

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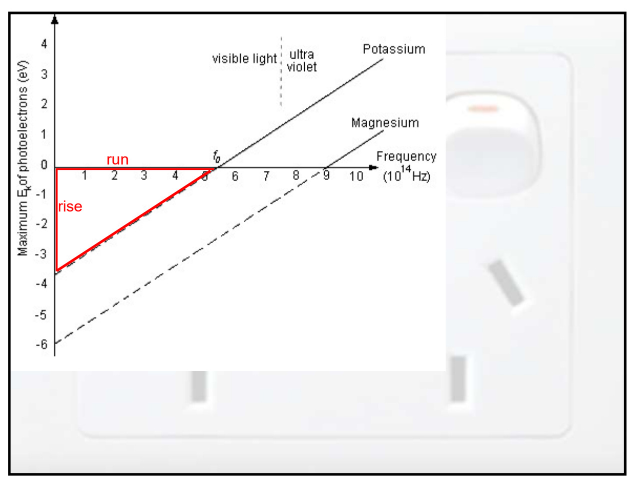


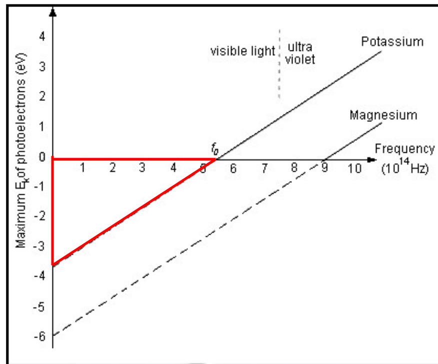
216

The gradient, $h = \frac{\text{rise}}{\text{run}}$

$\therefore h = \frac{\Phi}{f_0}$

$\therefore \phi = hf_0$

217



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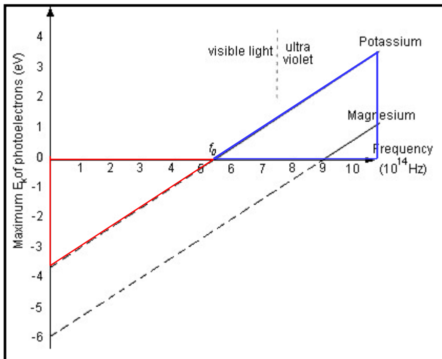

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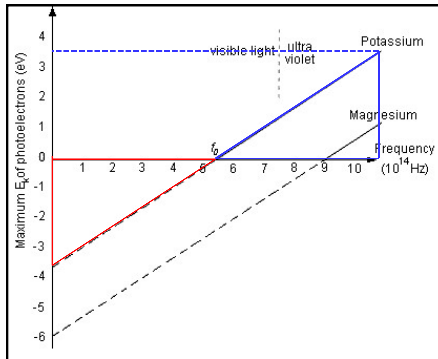

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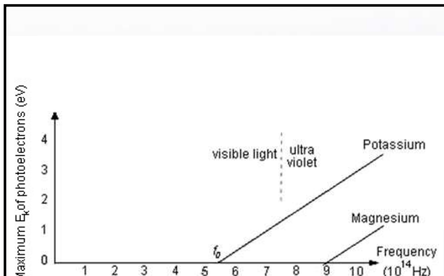

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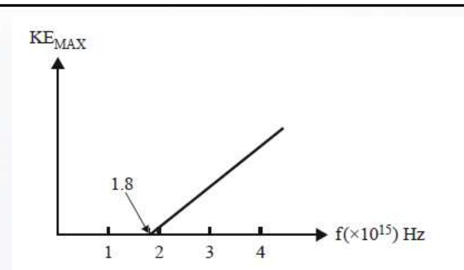


Calculate the work function of the metal in joules.

65%, (7)

222

Section 15 Example 4

2014 Question 20a, 2 marks, 75%

Use $\phi = hf_0$

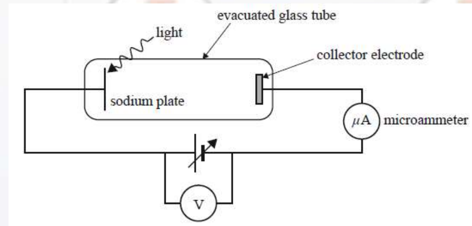
$\therefore \phi = 6.63 \times 10^{-34} \times 1.8 \times 10^{15}$

$\therefore \phi = 11.934 \times 10^{-19}$

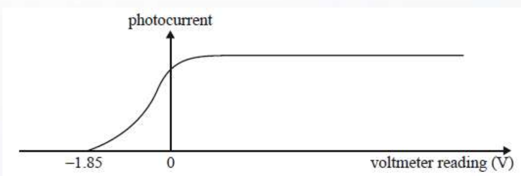
$\therefore$ **$\phi = 1.2 \times 10^{-18}$ J (ANS)**

223

Students are investigating the photoelectric effect by shining monochromatic light with a frequency of 1.00×10^{15} Hz onto a sodium plate.



224



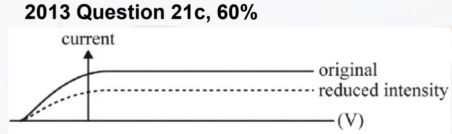
The intensity of the light is now reduced. Sketch the new graph on the diagram above.

60%, (5)

225

Section 15 Example 10

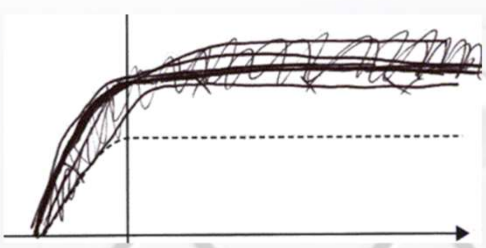
2013 Question 21c, 60%



With the intensity of the light reduced, there will be less photoelectrons released from the metal, so the current will be reduced (vertical – intercept).

As the same light is used, the max KE of the ejected photoelectrons will remain the same, therefore the cut-off voltage will remain the same (horizontal – intercept).

226



227

Einstein's explanation of the photoelectric effect reopened the question about the nature of light. Explain briefly how the results of the photoelectric effect experiment supported a competing model to the one supported by Young's double-slit experiment.

39%, (6)

228

Section 15 Example 2

2009 Question 2, 3 marks, 60%

The photoelectric effect supports the particle model of light. The following findings were not able to be explained using a wave model:

Minimum frequency, i.e. energy, required to emit an electron (threshold frequency).

Energy of emitted photoelectrons is dependent on the frequency of the incident light.

Below the threshold frequency, increasing the intensity of the incident light did not produce photoelectrons.

More intense light was explained
as more particles with the same energy,
whereas the wave model, (from Young's
Double slit experiment) explained more
intense light as a wave of greater amplitude.

229

2009 Question 2 continued

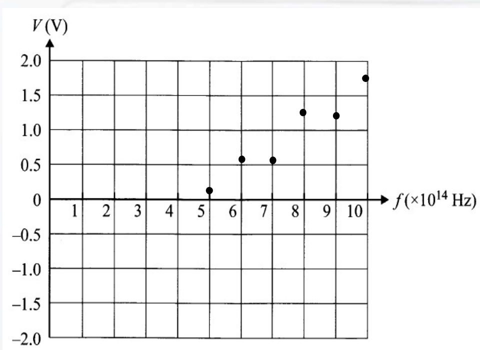
The PE experiment showed that when light was shone on a metal surface, photoelectrons were ejected.

The wave model predicts that more intense light should produce electrons with greater energy. The particle model predicts more intense light, should produce more photoelectrons with the same energy.

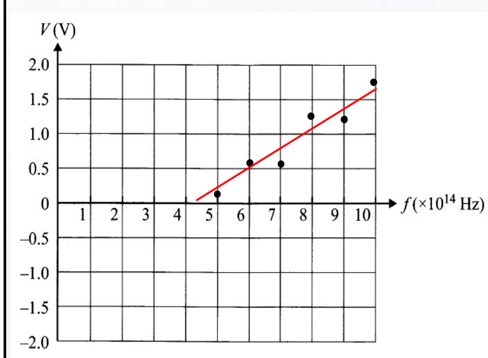
Einstein was able to explain the PE effect using Planck's photon model, which assumes a particle model of light.

230

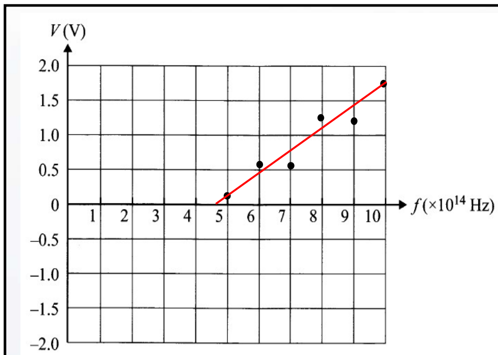
Line of **'best'** fit.



231



232



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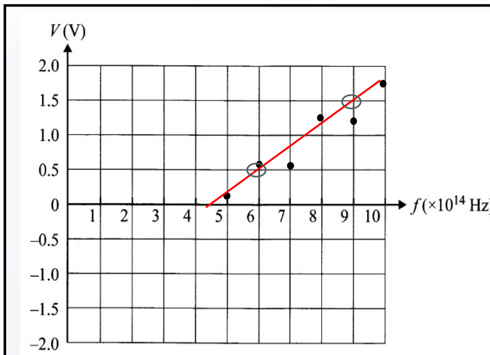
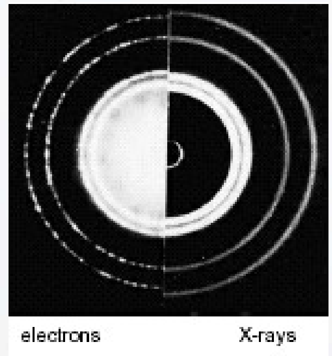


234

Wave properties of matter

235

Diffraction patterns



236

The amount of diffraction is governed by the ratio $\frac{\lambda}{w}$

Since $\lambda = \frac{h}{p} = \frac{h}{mv}$

237

	M > 0	M = 0
Momentum		
Energy		
Wavelength		

238

In a cathode ray tube (CRT), electrons of mass 9.10×10^{-31} kg are accelerated to a velocity of 2.0×10^{7} m s^{-1}.

Calculate the de Broglie wavelength of the electrons.

You must show your working.

71%, (6)

239

Section 16 Example 1

2005 Question 6, 3 marks, 71%

The momentum of the electron

$m \times v = 9.1 \times 10^{-31} \times 2.0 \times 10^{7}$

$= 1.82 \times 10^{-23}$

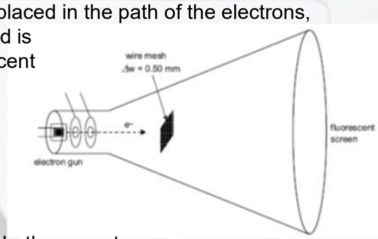
Using $p = \frac{h}{\lambda}$

$\therefore \lambda = \frac{6.63 \times 10^{-34}}{1.82 \times 10^{-23}}$

$= 3.64 \times 10^{-11}$ m (ANS)

240

A fine wire mesh in which the gap between the wires is w = 0.50 mm has been placed in the path of the electrons, and the pattern produced is observed on the fluorescent screen.



Explain, with reasons, whether or not the students would observe an electron diffraction pattern on the fluorescent screen due to the presence of the mesh.

53% , (5)

241

Section 16 Example 2

2005 Question 7, 3 marks, 71%

No.

For diffraction, the gap width must be the same order of magnitude as the wavelength.

From the diagram the mesh spacing is 5×10^{-4} m. This is much greater than the wavelength of the electron

242

A beam of electrons is produced in an electron gun.

The de Broglie wavelength of each electron is 0.36 nm.

An experiment is undertaken to compare the diffraction of these electrons and X-rays. With a similar gap spacing, the diffraction patterns are found to be nearly identical.

Calculate the energy (in eV) of the X-rays.
Show each step of your working.

41%, (7)

243

Section 16 Example 6

2016 Question 20b, 3 marks, 47%

Since the two patterns are nearly identical, they must both have the same wavelength.

For an X-ray, $E = \frac{hc}{\lambda}$

$$\therefore E = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{0.36 \times 10^{-9}}$$

$\therefore E = 34.5 \times 10^{2}$

$\therefore$ **E = 3.5 × 10³ eV (ANS)**

244

Students study diffraction of electrons by a crystal lattice. The apparatus is shown in Figure A. In this apparatus electrons of mass 9.1×10^{-31} kg are accelerated to a speed of 1.5×10^{7} m s^{-1}.

The electrons pass through the crystal, and the diffraction pattern is observed on a fluorescent screen. The pattern the students observe is shown in Figure B.

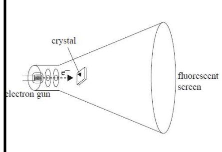


Figure A

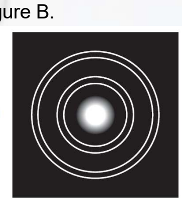
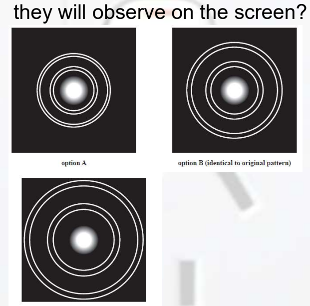


Figure B

245

The students now increase the accelerating voltage and hence the speed of the electrons.

Which one of the options below now best shows the pattern they will observe on the screen? Explain your answer.



37%, (6)

246

Section 16 Example 8

2010 Question 8, 2 marks, 52%

Increasing the accelerating voltage will increase the speed of the electrons. This will increase their momentum.

From $\lambda = \frac{h}{mv}$

increasing the momentum will decrease the deBroglie wavelength of the electrons.

The amount of diffraction (bending) is given by $\frac{\lambda}{w}$

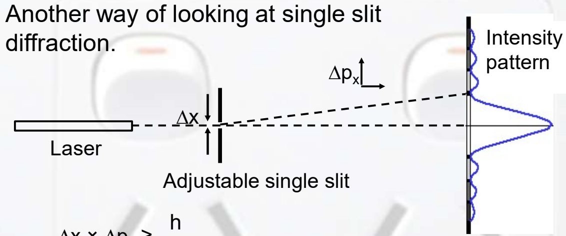
so, the smaller wavelength means smaller spacing between diffraction lines.

∴ **A (ANS)**

247

Heisenberg's uncertainty principle

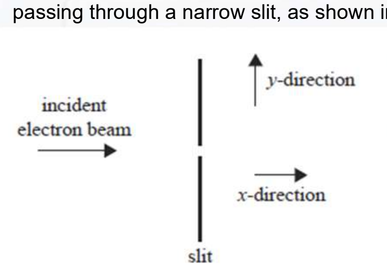
Another way of looking at single slit diffraction.



$$\Delta x \times \Delta p_x \geq \frac{h}{4\pi}$$

248

A diffraction pattern is produced by a stream of electrons passing through a narrow slit, as shown in the diagram below.



249

This electron diffraction pattern can be used to illustrate Heisenberg's uncertainty principle. This is because knowing the uncertainty in the

A. electron's speed is large leads to the uncertainty in its kinetic energy being small.

B. slit width is small leads to a large uncertainty in the electron's momentum in the *y*-direction.

C. electron's momentum in the *y*-direction is small leads to a large uncertainty in the slit's width.

D. electron's angle of approach to the slit leads to a large uncertainty in the electron's momentum in the *y*-direction

58%, (5)

250

Section 16 Example 9

2017 Question 16, 1 mark, 66%

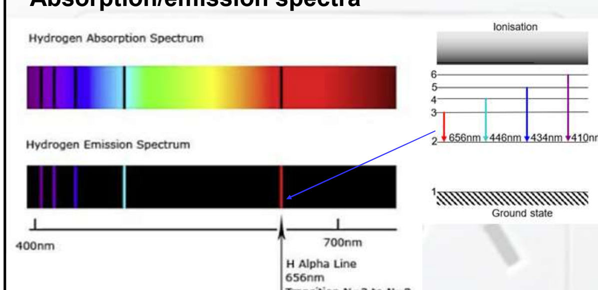
Heisenberg's uncertainty principle states the more we know about the position of the electron, then the more uncertainty we have with knowing its momentum.

For an electron going through a very narrow slit, as it passes through the slit, we know its position (in the y-direction) quite precisely. This means that its momentum in the y-direction has a large uncertainty. This results in the spread of the electrons which is evidenced by a spread in the diffraction pattern.

∴ **B (ANS)**

251

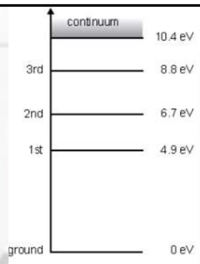
Absorption/emission spectra



252

The figure shows the energy levels of a mercury atom. The atom is initially in the **2nd** excited state.

Which one of the following photon energies could be absorbed by this atom and hence excite it into the **3rd excited** state?



A. 8.8 eV
B. 4.9 eV
C. 2.1 eV
D. 1.8 eV

65%, (2)

253

Section 17 Example 2

2004 Question 6, 2 marks, 65%

Difference between 3rd and 2nd.

∴ 8.8 – 6.7 = 2.1 eV

∴ **C (ANS)**

254

The visible spectrum of the hydrogen atom is observed to emit photons of energy 2.6 eV.

Calculate the wavelength of this emission spectral line.

58%, (6)

255

Section 17 Example 3

2016 Question 21a, 2 marks, 61%

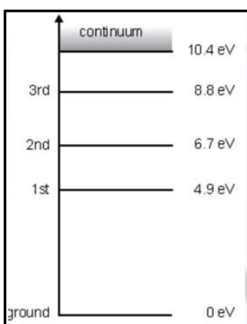
For a photon, $E = \frac{hc}{\lambda}$

$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{2.6}$

$\therefore \lambda = 4.78 \times 10^{-7}$

∴ **λ = 478 nm (ANS)**

256



Which **one or more** of the following photon energies can be emitted by a mercury atom which is initially in its **2nd excited** state?

A. 8.8 eV
B. 4.9 eV
C. 2.1 eV
D. 1.8 eV

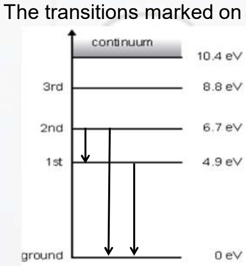
66%, (5)

257

Section 17 Example 5

2004 Question 5, 2 marks, 65%

The transitions marked on the graph are possible.



This gives rise to photons with energies of: 1.8, 6.7 and 4.9 eV

∴ **B, D (ANS)**

258

A simplified diagram of the energy levels for a mercury atom is shown below.

Explain why a mercury atom, while in the first excited state, is able to absorb a 1.8 eV photon, but cannot emit a photon of this energy.

28%, (4)

259

Section 17 Example 6

2014 Question 22a, 2 marks, 40%

If the atom is in the first excited state it has an energy value of 4.9 eV. It can absorb a 1.8 eV photon as this will raise it to the 6.7 eV energy level.

If the atom was in its first excited state, at 4.9 eV, the only photon that it can emit will be one of 4.9 eV. There is no energy level 1.8 eV lower than the first excited state.

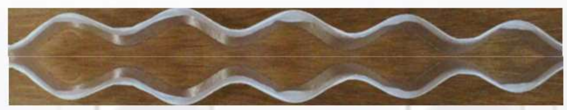
Therefore, it can absorb a 1.8 eV photon, but not emit one.

260

Electron standing wave states

This is a representation of the probability of the electrons position

261



262

263

264

De Broglie suggested that the quantised energy states of atoms could be explained in terms of electrons forming standing waves.

Describe how the concept of standing waves can help explain the quantised energy states of an atom.

You should include a diagram.

64%, (3)

265

Section 17 Example 7

2017 NHT Question 21, 4 marks

De Bröglie suggested that electrons have wave properties such as wavelength, and that the orbits (energy levels) that could exist were those where the wavelength of the electron set up a stable standing wave. This is consistent with the quantisation of energy levels, because standing waves have quantised wavelengths.

De Bröglie said that, in a similar way, the wavelength of the electrons orbiting the nucleus must 'fit' into the circumference of the orbit exactly. This will only happen with particular wavelengths and, therefore, energies and explains why energy levels are quantised.

266

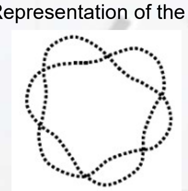
2017 NHT Question 21, 4 marks (continued)

Electrons with wavelengths that do not set up standing waves destructively interfere with themselves and cancel out.

The standing wave is formed when the circumference of the orbit is a whole number of wavelengths, from $2\pi r = n\lambda$

The energy of the electron is linked to the wavelength, $\lambda = \frac{h}{\sqrt{2mKE}}$, so if only certain wavelengths exist, then only certain energies values are permissible.

Representation of the n = 3 level.



267

Practical Investigation

268

EPI examination questions process summary

The first question is most likely to be recall of a definition.

The second step is usually an explanation regarding the methodology of the investigation. This is typically followed by an incomplete data set, that requires some further calculation.

The next step is to plot the data.

Your graph is typically scored as follows:

Correct labelling of axes.

Appropriate scale on axes, (**MUST** be > 50% of the grid).

Accurate plotting of all points.

Drawing of appropriately sized uncertainties.

Reasonable drawing of appropriate line of best fit.

269

Once the graph is plotted, you will be required to interpret it. This is usually either identifying the significance of either the gradient or the intercepts. The area under the graph is also a possibility.

The final question will be an application type question based on a quantity derived from the graph.

There are some easy marks in these questions, paying some attention to detail, the calculations and plotting the graphs will typically gain at least half of the marks for this question.

Make sure that you allow sufficient time for this.

270

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.

271

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 how 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.

272

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.

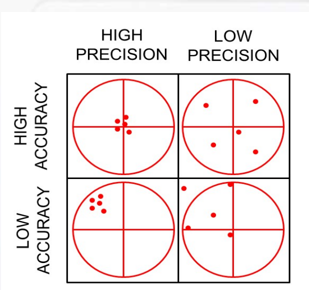
273

Replication of procedures: repeatability and reproducibility

Repeatability refers to the closeness of agreement between independent results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus and/or same laboratory).

Reproducibility refers to the closeness of agreement between independent results obtained with the same method on identical test material but under different conditions (different operators, different apparatus and/or different laboratories).

274



275

Random error

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 error

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.

276

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 $\pm\frac{1}{2}$ the smallest division.

277

VCAA physics exams and exam reports

The 2002 - 2022 papers are available on the VCAA website.

https://www.vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/physics.aspx

The 2018 – 2013 NHT papers can be found here

https://www.vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/nht-past-exams/Pages/nht-past-exams.aspx

You need to scroll down the page to find the Physics exams.

278

What have you learnt today?

279

280

281

282

283

284

I’d rather be a human doing

than a human being

285

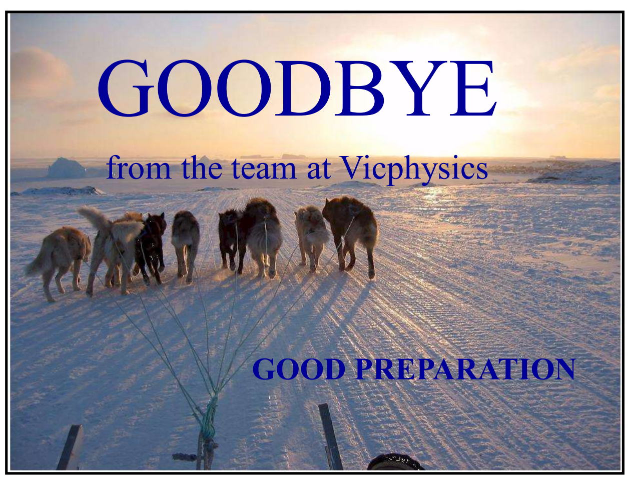
Remember,

a goal without a plan is just a wish.

286

If you have any questions arising from today's presentation:
either speak to one of the presenters or ask your teacher.

287



288