PHYSICS UNITS 3&4

Edrolo

2020 Practice Exam

(including fully-worked answers for every question!)

ABOUT THIS RESOURCE

Our VCE Physics Practice Exam is written by our experienced textbook authors and VCE teachers.

- The exam consists of questions worth 130 marks, in exactly the same format as the VCE exam.
- The questions have been designed and written to simulate the experience of sitting a VCAA-style exam.
- Included is a full answer section with exemplar answers and checklists to guide students on how to produce a high-scoring answer.
- All questions are tailored to the study design updates for 2020.

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The questions and answers in this practice exam have been rigorously designed to help your students understand exactly how to succeed in their upcoming exam, and are modelled on the questions and answers in the new range of Edrolo textbooks, already used and loved by thousands of Victorian students and teachers. Each Edrolo textbook has hundreds of scaffolded exam-style questions, each with full exemplar responses (like you'll find in these pages), plus online video solutions and checklists, all explaining how to get full marks.

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DATE: ____________________

STUDENT NAME: ____

TEACHER NAME: ____

PHYSICS

Practice written examination

Duration: 15 minutes reading time, 2 hrs 30 minutes writing time

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of marks
A	20	20
B	21	110
		Total 130

Reminders for students:

Avoid rounding your calculations until you provide your final answer.

For all questions worth more than one mark, working must be shown.

Write the formula you intend to use and then write the equation with the correct substituted values. In general, marks will be awarded for showing correct substitutions.

Remember to provide your answer in the correct units indicated by the answer box.

For worded responses, ensure your answer addresses the question directly.

SECTION A – Multiple-choice questions

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.

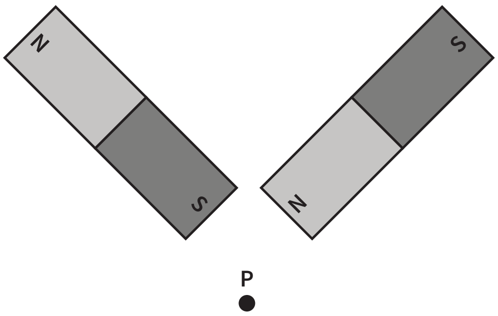
No marks will be given if more than one answer is completed for any question.

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}.

Question 1

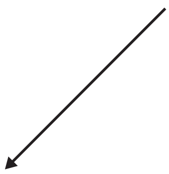
Two identical magnets are arranged perpendicular to each other as shown.

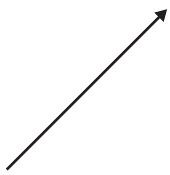


Which one of the following arrows best represents the direction of the resultant magnetic field at point P?

A

B

C 

D 

Question 2

Stevie and Achol measure the wavelength of a particular signal from a loudspeaker on separate occasions.

Stevie takes the following readings: 2.30 m, 3.10 m, 2.60 m, and 2.90 m (average 2.73 m).

Achol takes the following readings: 1.50 m, 2.70 m, 2.50 m, and 3.90 m (average 2.65 m).

The true value of the wavelength is 2.60 m.

Which one of the following statements best describes these sets of measurements?

A Both sets of measurements are equally precise.

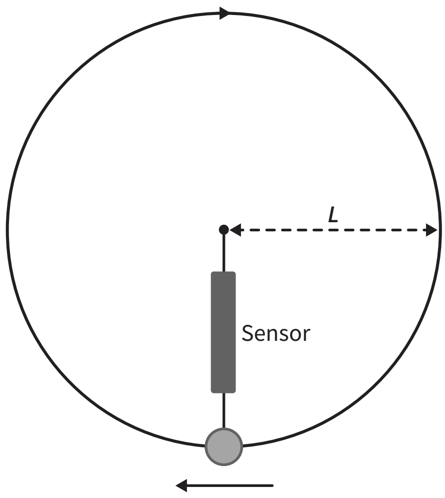
B Stevie's measurements are more accurate than Achol's results.

C Both sets of measurements are equally accurate.

D Achol's measurements are less precise than Stevie's results.

Question 3

Students are investigating the forces involved in vertical circular motion. Their apparatus consists of a ball with a known mass attached to a string that incorporates a sensor for measuring the tension force in the string, as shown.



Using the same ball and keeping the period fixed at 0.2 seconds, the students vary the length of the string, *L*, and record the maximum tension force when the ball is at the lowest position.

Which one of the following is the best description of the dependent variable in this experiment?

A The mass of the ball

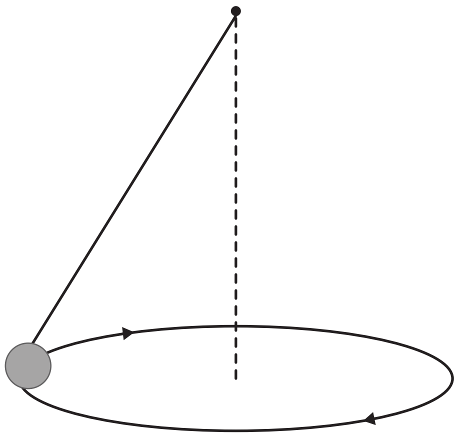
B The tension force in the string

C The length of the string

D The period of each rotation

Question 4

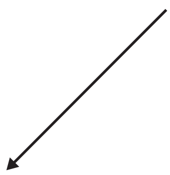
A ball is attached to a string and travelling in a horizontal circle as shown.

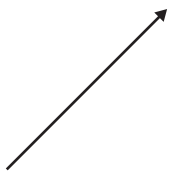


Which one of the following arrows best represents the direction of the resultant force acting on the ball in the position shown?

A

B

C 

D 

Question 5

Which one of the following is the **best** description of light?

A An electric wave which is produced by charges

B An electromagnetic wave which is produced by a constant current, which in turn produces a magnetic field

C An electromagnetic wave which is produced by accelerating charges, which in turn produces changing electric fields and changing magnetic fields

D A discrete electron which has been ejected from a material with an energy proportional to its frequency

Question 6

A particle travels 20 metres in a straight line in a science laboratory. The particle's rest energy is one-quarter of its kinetic energy.

The distance travelled by the particle as measured in its reference frame is closest to

A 4.0 metres.

B 5.0 metres.

C 20 metres.

D 80 metres.

Question 7

An unstable subatomic particle at rest decays completely into electromagnetic radiation. The mass of the particle is 3.2×10^{-27} kg.

The energy released in this decay is closest to

A 2.1×10^{-35} J.

B 9.6×10^{-19} J.

C 2.9×10^{-10} J.

D 2.8×10^{-43} J.

Question 8

Which one of the following statements **best** describes the single photon double slit experiment?

A The experiment provides evidence for the wave nature of light because each photon produces an interference pattern.

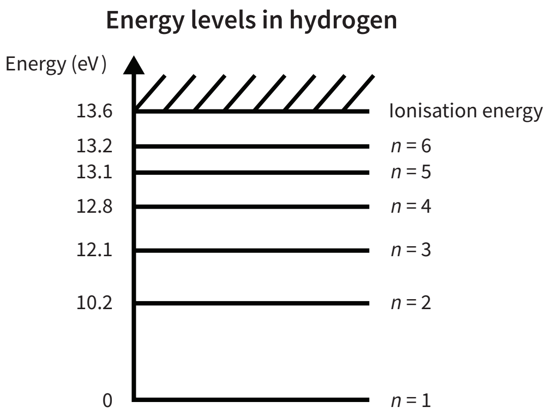
B The experiment provides evidence for the particle nature of light because it demonstrates that photons have momentum.

C The experiment provides evidence for the dual nature of light because photons interfere with each other and each photon produces one bright band.

D The experiment provides evidence for the dual nature of light because individual photons produce discrete spots on the screen but, over time, the collection of spots produces an interference pattern.

Question 9

The energy levels of the hydrogen atom are shown.



Which one of the following is closest to the longest wavelength photon that can be emitted when an electron transitions to a lower energy level from the $n = 4$ state?

A 1.2×10^{-5} m

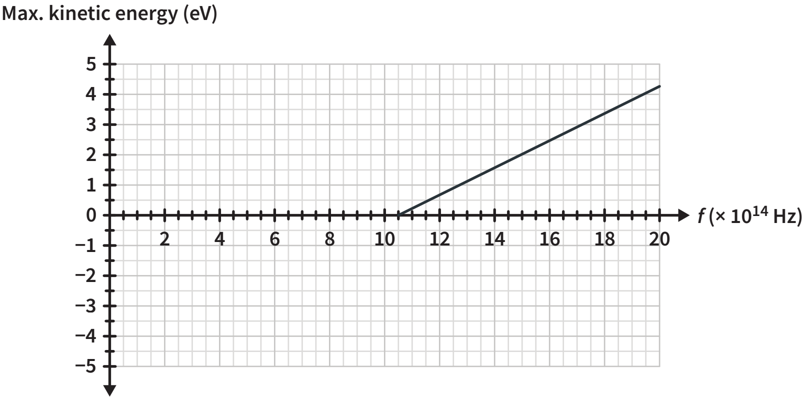
B 1.8×10^{-6} m

C 9.7×10^{-8} m

D 2.8×10^{-25} m

Question 10

Students conducting the photoelectric experiment record the following results for the maximum kinetic energies of photoelectrons at various frequencies.



The work function of various metals are shown.

Metal	Work function
selenium	1.90 eV
sodium	2.75 eV
copper	4.70 eV
gold	5.30 eV

Which metal was used in the students' experiment?

A selenium

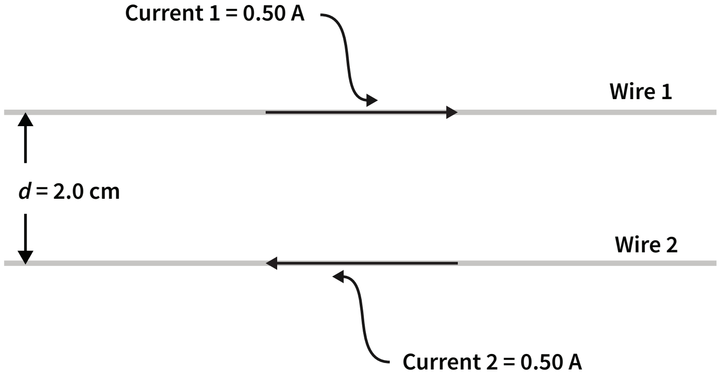
B sodium

C copper

D gold

Use the following information to answer Questions 11 and 12.

Equal current is flowing in opposite directions along two parallel wires that are 2.0 cm apart, as shown. The magnitude of the magnetic field strength at each wire due to the other wire is 3.0×10^{-2} T.



Question 11

Which one of the following best describes the direction of the magnetic force **on Wire 1** due to Wire 2?

A up the page

B down the page

C into the page

D out of the page

Question 12

Which one of the following is closest to the magnitude of the magnetic force on each metre of wire?

A 6.0×10^{-2} N

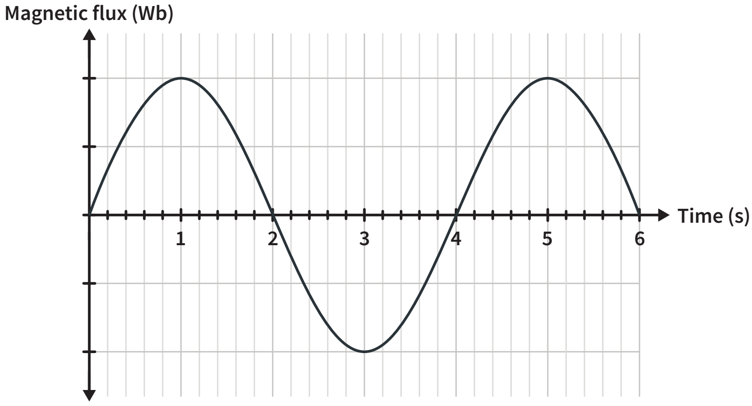
B 3.0×10^{-2} N

C 1.5×10^{-2} N

D 3.0×10^{-4} N

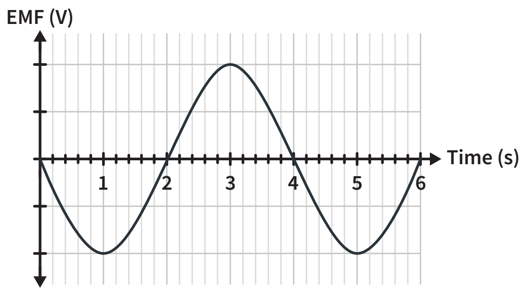
Question 13

The graph shows the variation in magnetic flux versus time for a conducting loop that is rotating inside a uniform magnetic field.

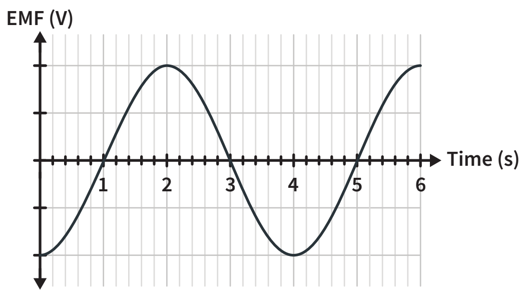


Which one of the following best represents the variation in the induced EMF in the loop during this six-second period?

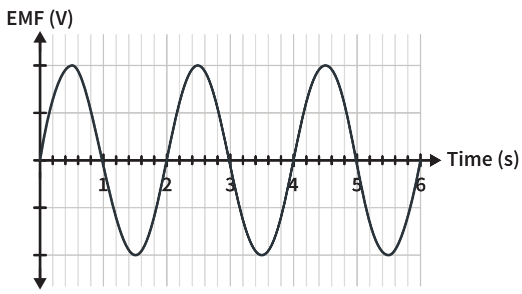
A



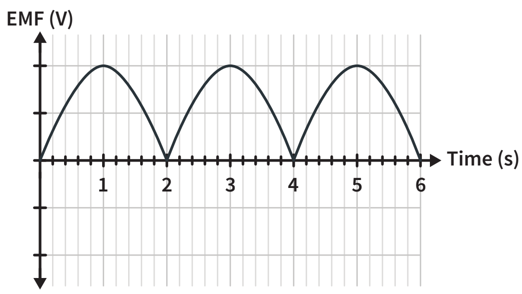
B



C



D



Question 14

Which one of the following statements best describes the conclusions we can draw when photons and electrons produce similar diffraction patterns as they pass through the same crystal lattice?

A They have the same energy, momentum, and wavelength.

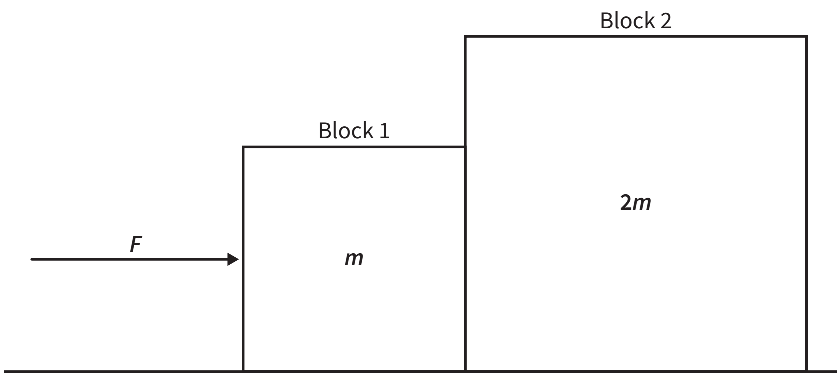
B They have the same energy and momentum but different wavelengths.

C They have different energies and momenta but the same wavelength.

D They have different energies but the same momentum and wavelength.

Question 15

Two blocks are in contact and they are pushed along a horizontal frictionless surface by an external force with magnitude *F* as shown. The mass of Block 1 is *m* and the mass of Block 2 is 2*m*.



Which one of the following statements is true?

A The net force on both blocks is the same.

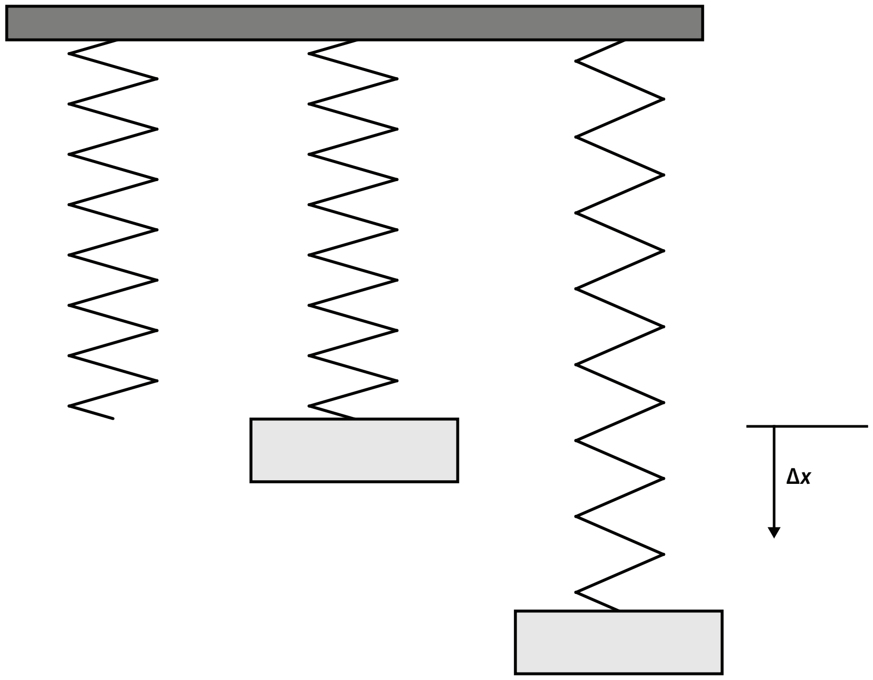
B The net force on Block 1 only is *F*.

C The net force on Block 1 is $\frac{F}{2}$.

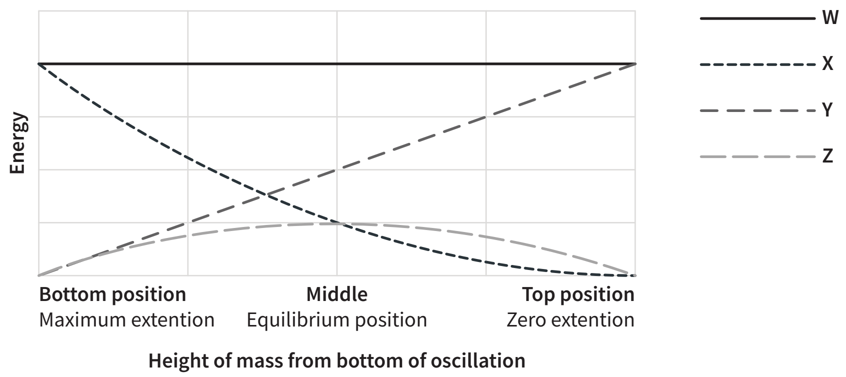
D The net force on Block 1 is $\frac{F}{3}$.

Question 16

A mass is attached to a hanging spring and then released, as shown.



The following graph shows how various types of energy vary for the different positions of the mass.

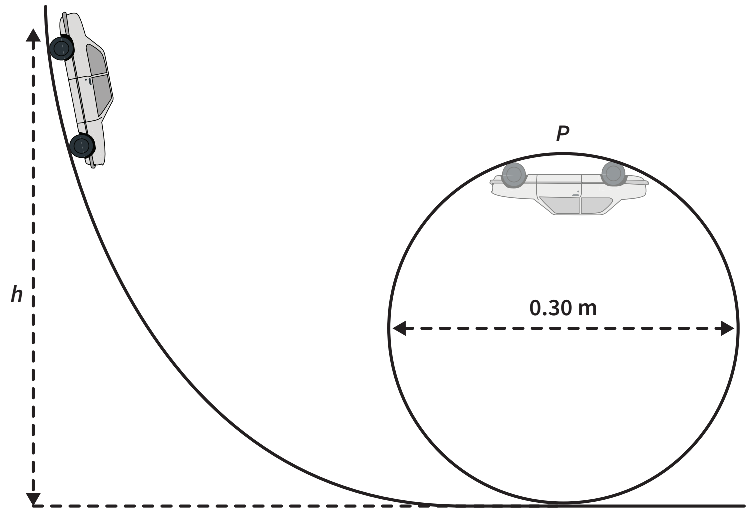


Which of the following could correctly identify the types of energy represented by each curve on the graph?

	Gravitational potential energy	Kinetic energy	Spring potential energy	Total mechanical energy
A	W	X	Y	Z
B	X	Y	Z	W
C	Y	Z	X	W
D	Z	X	Y	W

Question 17

A toy car is released from rest so that it rolls down a ramp and then continues along a vertical circular loop as shown. Point P is the top of the circular loop. The diameter of the circular loop is 0.30 m and the car starts from a height *h* m. Ignore friction in this question.



For which one of the following statements can we be certain that the toy car will complete the entire loop?

A $h > 0.30$ m

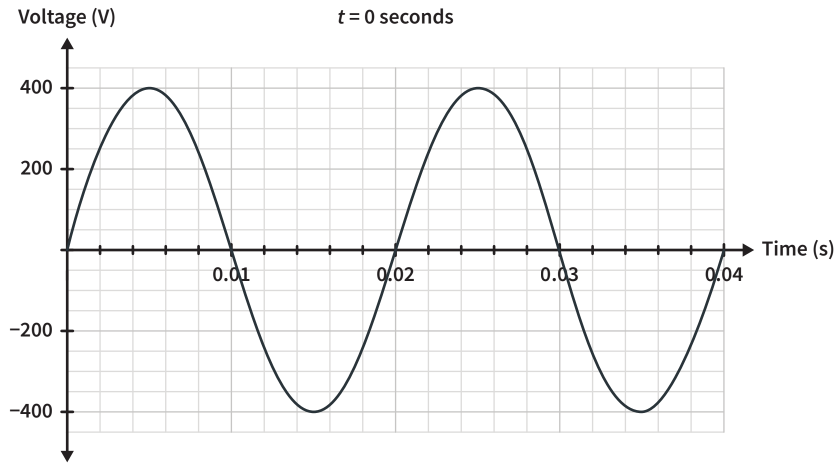
B At point P, the normal force on the toy car from the track is greater than zero.

C At point P, the normal force on the toy car from the track is greater than the gravitational force on the toy car.

D At point P, the kinetic energy of the toy car is greater than its gravitational potential energy.

Question 18

The variation in voltage for an alternating current is shown.



Which one of the following is closest to the value of a DC voltage that would produce the same average power as the varying voltage shown?

A 200 V

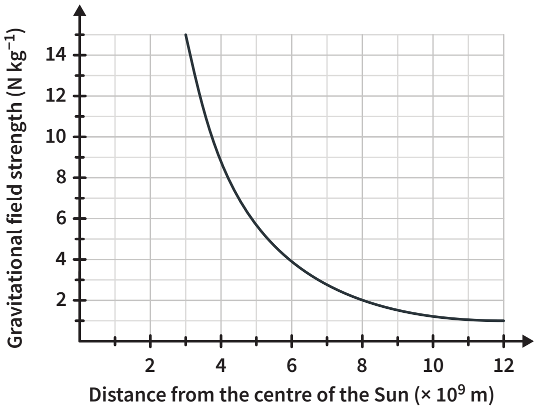
B 283 V

C 400 V

D 566 V

Question 19

The graph shows the variation in gravitational field strength versus distance from the centre of the Sun.



A 200 kg space probe is moving towards the Sun. Assume that the only force acting on the probe is the gravitational force due to the Sun.

Which one of the following is closest to the increase in kinetic energy of the space probe as it moves from a distance of 10×10^9 m to a distance 4×10^9 m from the centre of the Sun?

A 4×10^{12} J

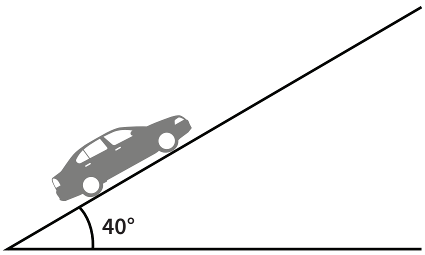
B 2×10^{10} J

C 4000 J

D 20 J

Question 20

A car that has a mass of 1600 kg drives up a hill at an angle of 40° above the horizontal at a constant speed of 2 m s^{-1}.



Which one of the following is closest to the magnitude of the friction force on the wheels by the road? Ignore air resistance.

A 1.0×10^4 N

B 1.2×10^4 N

C 1.6×10^4 N

D 2.0×10^4 N

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

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}.

Question 1 (8 MARKS)

Figure 1a shows a positive stationary point charge, $+q_1$, and three other points (X, Y, and Z) that are evenly spaced apart from each other by a distance d.

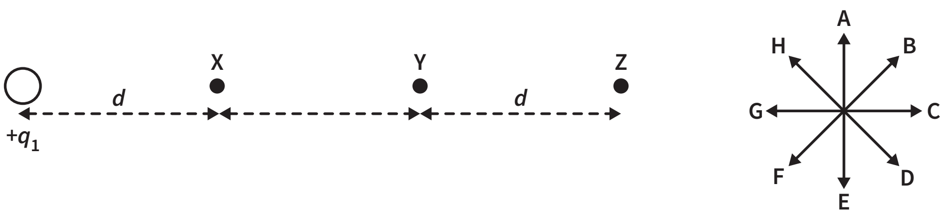


Figure 1a

A **test charge** is placed at point X and it experiences a force of **100 N to the left** (direction G) due to the stationary point charge, $+q_1$.

a Is the **test charge** positive or negative? Give a reason for your answer. 1 MARK

---

b Determine the magnitude and direction (A–H) of the force on the **stationary point charge**, $+q$. 2 MARKS

N	Direction

The test charge is moved from point X to point Y.

c Determine the magnitude of the force on the **test charge** now. Show your working. 2 MARKS

N

A second stationary positive charge, $+q_2$, that is identical to the first ($+q_1 = +q_2$) is placed at Z, as shown in Figure 1b.

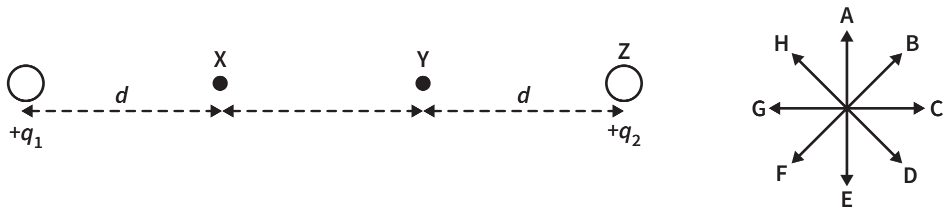


Figure 1b

d Determine the magnitude and direction (A–H) of the resultant force on the **test charge** due to both of the stationary positive charges when it is at point Y. 3 MARKS

N

Direction

Question 2 (6 MARKS)

An electric field accelerates an electron between two plates. The electron exits into a region of uniform magnetic field at right angles to its path, directed into the page, as shown in Figure 2.

Data

mass of electron	9.1×10^{-31} kg
charge on electron	-1.6×10^{-19} C
accelerating voltage	200 V
distance between plates	50 cm
strength of magnetic field	5.0×10^{-5} T

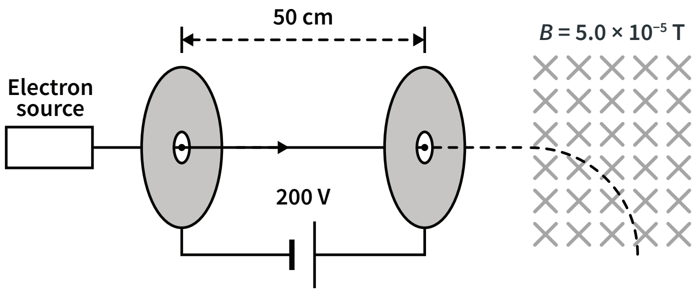


Figure 2

a Calculate the magnitude of the force acting on the electron when it is between the two plates. Show your working. 3 MARKS

N

b Show that the speed of the electron as it exits the electric field, to two significant figures, is 8.4×10^{6} m s^{-1}. 1 MARK

c Calculate the radius of the path of this electron **in the magnetic field**. Show your working. 2 MARKS

m

Question 3 (5 MARKS)

Figure 3 shows a schematic diagram of a DC motor. The motor is initially stationary.

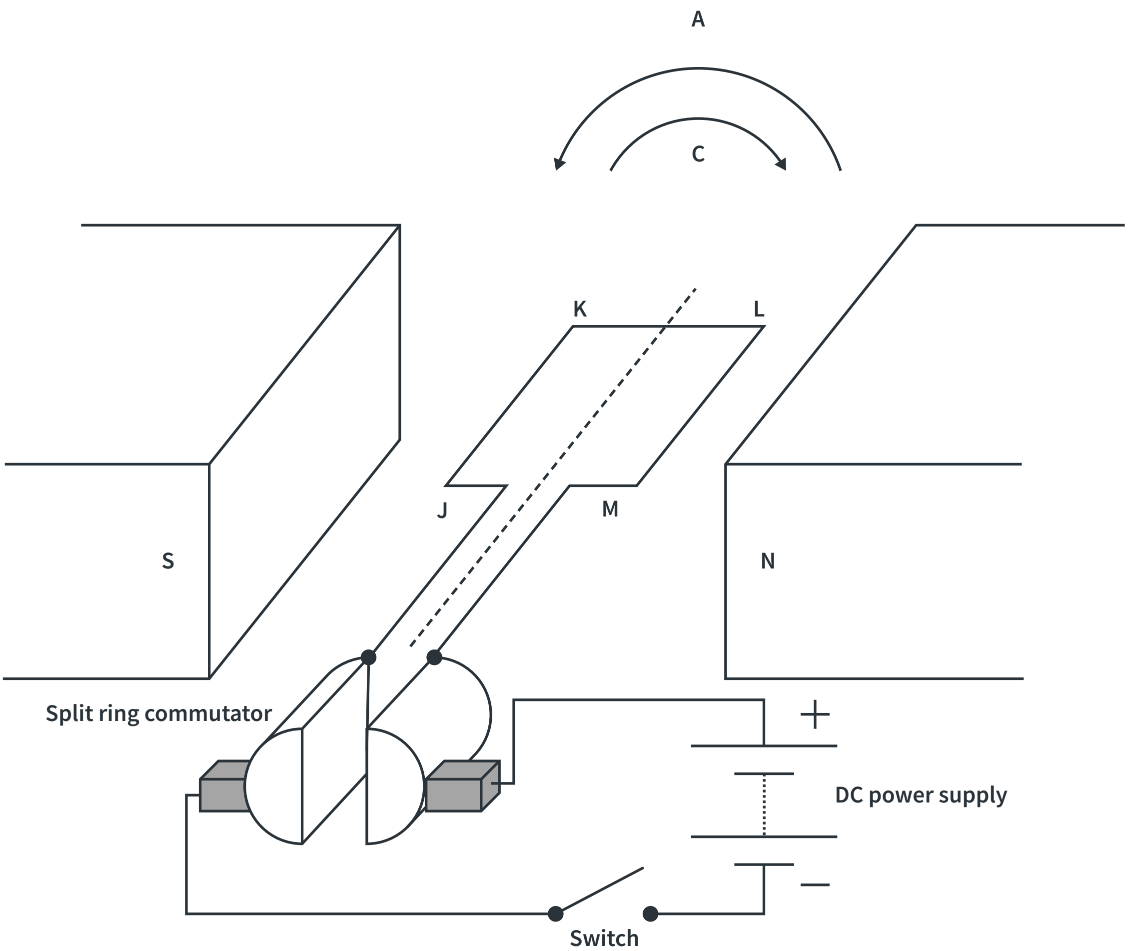


Figure 3

a In which direction, A (anticlockwise) or C (clockwise), will the motor rotate when the switch is closed? 1 MARK

Direction

b Justify your answer to **part a**. 2 MARKS

c Describe what would happen to the operation of the motor if the split ring commutator was replaced with slip rings. 2 MARKS

Question 4 (6 MARKS)

A 2000 kg artificial satellite is in a circular orbit with a radius of 7.40×10^6 m around Earth.

Data

mass of satellite	2000 kg
radius of satellite's orbit	7.40×10^6 m
mass of Earth	5.98×10^{24} kg
radius of Earth	6.37×10^6 m
gravitational constant	6.67×10^{-11} N m^2 kg^{-2}

a Calculate the gravitational field strength due to the Earth at the position of the satellite. Show your working. 2 MARKS

N kg^{-1}

b Calculate the orbital speed of the satellite in metres per second. Show your working. 2 MARKS

m s^{-1}

c The satellite is moved into a lower stable orbit to gather new data. Will this increase, decrease, or have no effect on the period of the satellite's orbit? Justify your answer. 2 MARKS

Question 5 (7 MARKS)

Figure 4 shows an alternator consisting of a rectangular coil with sides of 0.40 m × 0.25 m, and 500 turns rotating in a uniform magnetic field. The magnetic flux through the coil in the position shown is 2.0×10^{-4} Wb.

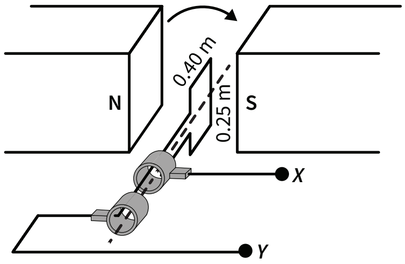


Figure 4

a Determine the magnitude of the magnetic field between the two magnets. Show your working. 2 MARKS

____

____

____

T

b The coil rotates a quarter of a revolution in 8.0 ms from the starting position shown in Figure 4. Calculate the magnitude of the average induced emf in the coil in this time. Show your working. 2 MARKS

____

____

____

V

The speed of rotation is changed. The potential difference between points X and Y for this new speed is shown in Figure 5.

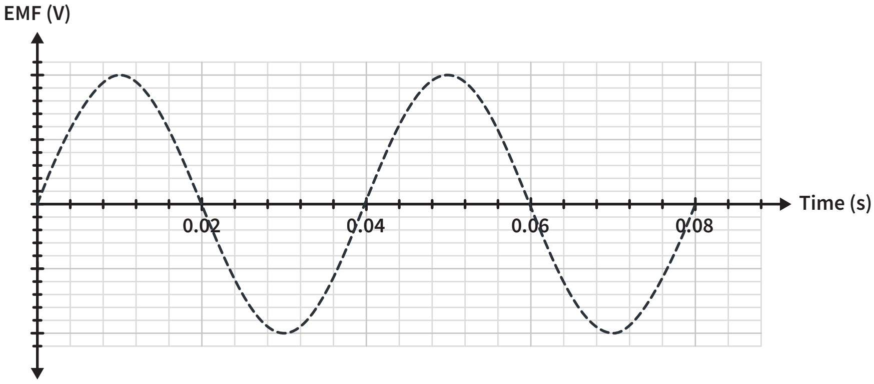


Figure 5

c On Figure 5, sketch the potential difference between points X and Y if the slip rings were replaced by a split ring commutator **and** the rotation speed was halved. 3 MARKS

Question 6 (3 MARKS)

Figure 6a shows a square conducting loop that is attached to a pivot so that it swings into and out of the magnetic field produced by a permanent magnet. Figure 6b shows the conducting loop as viewed from the north pole of the magnet, with the loop passing in front of the south pole.

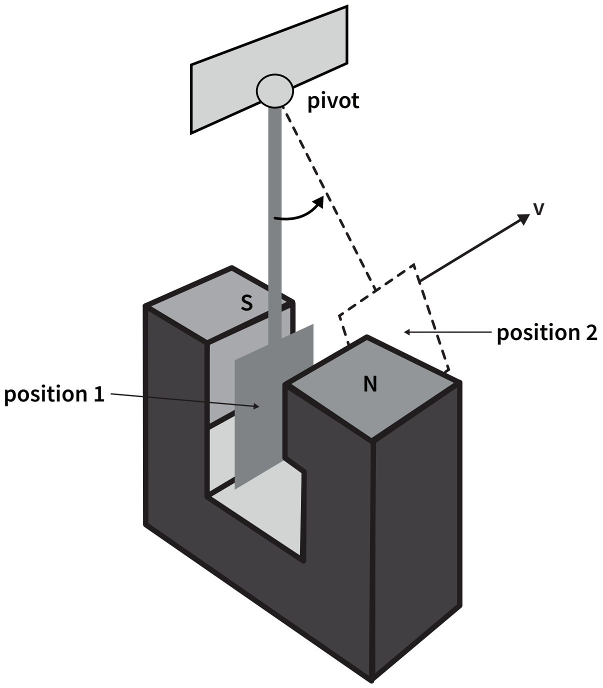


Figure 6a

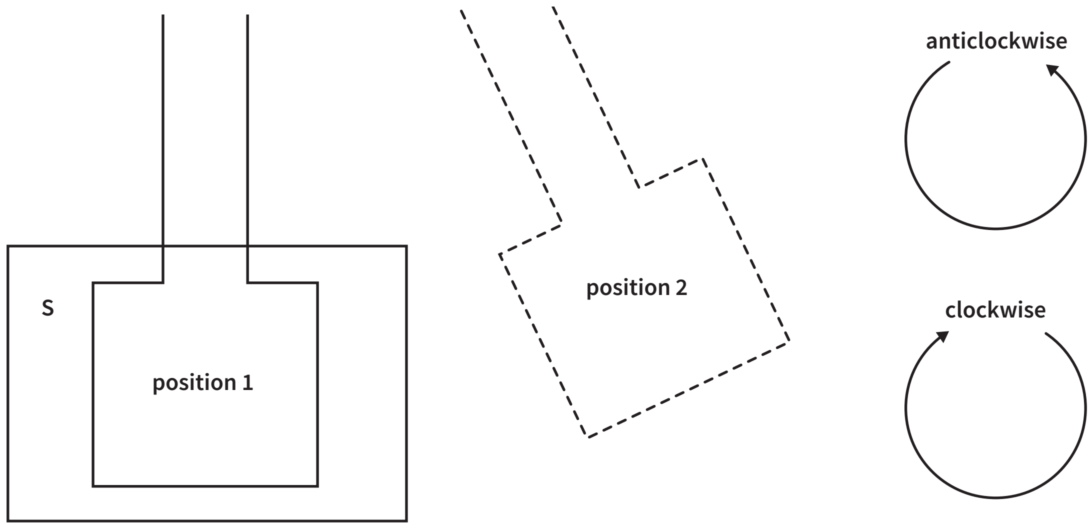


Figure 6b

Determine the direction (clockwise or anticlockwise) of the induced current in the loop as viewed from the north pole of the magnet as it moves from position 1 (inside the field) to position 2 (outside the field). Justify your answer.

Question 7 (3 MARKS)

Figure 7 shows two train carriages moving towards each other. Carriage X has a mass of 4.5 tonnes and is travelling at 5.0 m s^{-1} to the right. Carriage Y has a mass of 3.5 tonnes and is travelling at a 7.0 m s^{-1} to the left. The two carriages lock together when they collide.

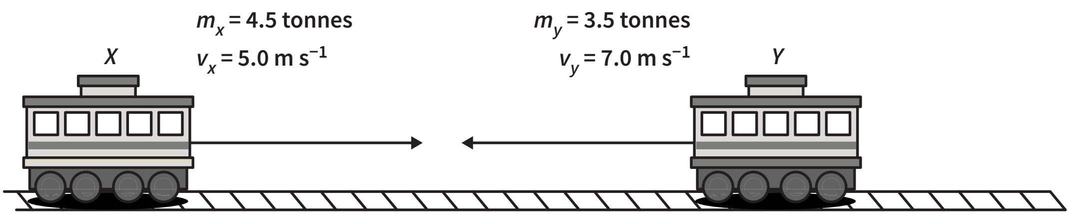


Figure 7

Determine the magnitude and the direction of the velocity of the two carriages after locking together. Ignore friction.

m s^{-1}	Direction

Question 8 (5 MARKS)

Figure 8 shows a 200 g toy car that is launched from a compressed spring at point Q along a track. The section of the track at point P is circular with a radius of 0.10 m. The spring can be assumed to be ideal with $k = 235\ \text{N m}^{-1}$. Ignore resistance forces.

Figure 8

a Show that the minimum speed of the toy car at point P that will make it lose contact with the track is $0.99\ \text{m s}^{-1}$ to two decimal places. 2 MARKS

b Determine the minimum compression of the spring when launching the toy car so that the car leaves the track at point P. Give your answer to the nearest centimetre. Show your working. 3 MARKS

cm

Question 9 (3 MARKS)

Students are conducting an experiment in which a block, m_1, of mass 0.20 kg is pulled across a smooth surface by a string that is attached over a frictionless pulley to another block, m_2, of mass 0.30 kg. The second mass is free to fall vertically. This is shown in Figure 9.

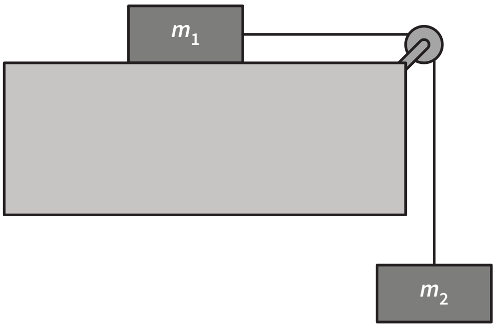


Figure 9

Calculate the magnitude of the tension in the string. Show your working.

N

Question 10 (6 MARKS)

A stunt motorbike rider performs a stunt in which she leaves a ramp at an angle of 60° above the horizontal with a speed of 16 m s^{-1} and aims to land on top of a wide building that is a horizontal distance of 10.0 m from the ramp. The rooftop of the building is 8.0 m above the top of the ramp, as shown in Figure 10. Ignore air resistance.

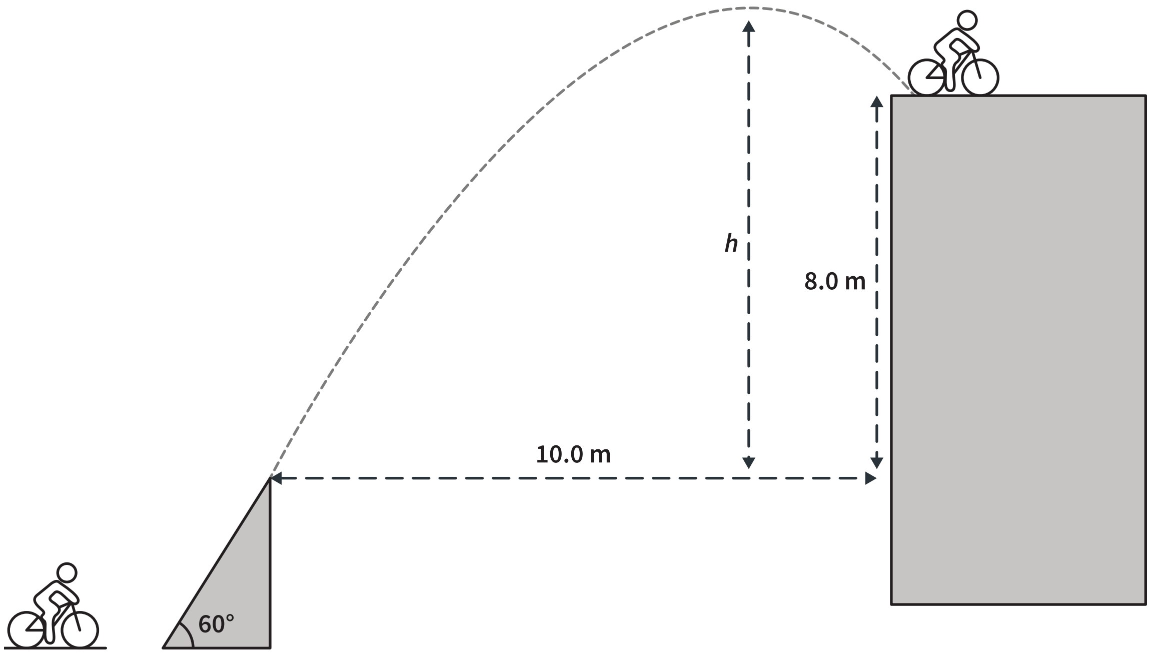


Figure 10

a Show that the stunt rider makes it to the rooftop. 3 MARKS

b Calculate the magnitude of the velocity of the motorbike just prior to landing on the rooftop. Show your working. 3 MARKS

m s^{-1}

Question 11 (6 MARKS)

Figure 11a shows a steel ball of mass 4.1 kg swinging in a circle at the end of a string of length 0.80 m. The maximum tension that the string can withstand before it breaks is 51 N. Ignore air resistance.

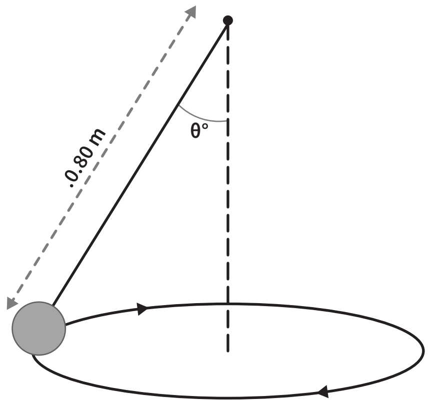


Figure 11a

a Figure 11b shows the circular path of the ball **when viewed from above.** The string breaks at the moment shown. **On Figure 11b,** draw an arrow to show the direction the ball would travel immediately after the string breaks. 1 MARK

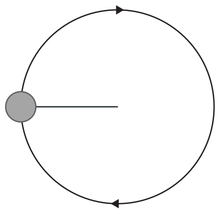


Figure 11b

b Show that the angle that the string makes **with the vertical** (θ° in Figure 11a) when the string is just about to break is 38° (to two significant figures). 2 MARKS

c Calculate the speed of the steel ball when the string is just about to break. Give your answer correct to two significant figures. Show your working. 3 MARKS

m s^{-1}

Question 12 (3 MARKS)

Students are investigating a spring which is known to have the force-extension relationship shown in Figure 12.

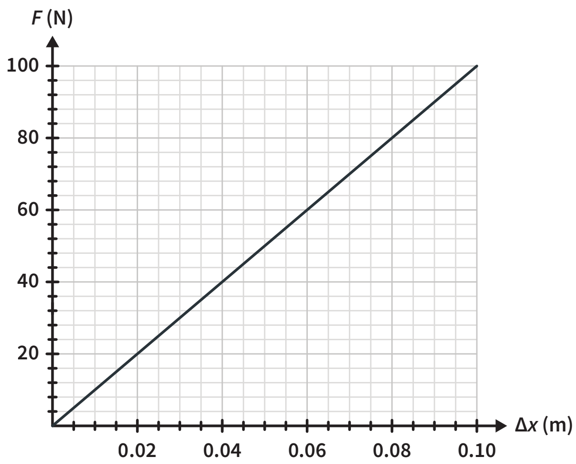


Figure 12

The students aim to verify this relationship. They attach weights of known mass to the spring while it is hanging vertically. They release the weights from the unstretched position and measure the maximum extension of the spring. This setup is shown in Figure 13.

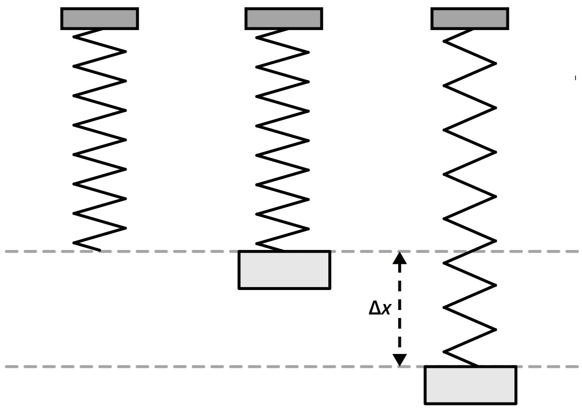


Figure 13

The students obtain the results shown in Table 1.

Table 1

Force due to gravity (N)	Extension (m)
20	0.04
40	0.08
60	0.12

They conclude that the graph in Figure 12 must be wrong because the extension that they have recorded for each weight is double the extension for the same force on the graph.

Explain the mistake the students have made.

Question 13 (3 MARKS)

A new particle is discovered travelling at 0.9682*c*. Take $\gamma = 4.0$ for this speed. Scientists measure the particle to travel 6.8×10^{-4} m in a straight line before decaying.

Calculate the lifetime of the particle as measured in the particle's frame of reference.

s

Question 14 (4 MARKS)

Students construct a model to show the transmission of electricity in transmission lines.
They use a 5.0 V_{RMS} AC power supply and light globe that requires 4.0 V across it to operate correctly.
They connect the power supply to the globe via transmission lines at two ideal transformers.
The current in the transmission lines is measured to be 0.20 A. The apparatus is shown in Figure 14.

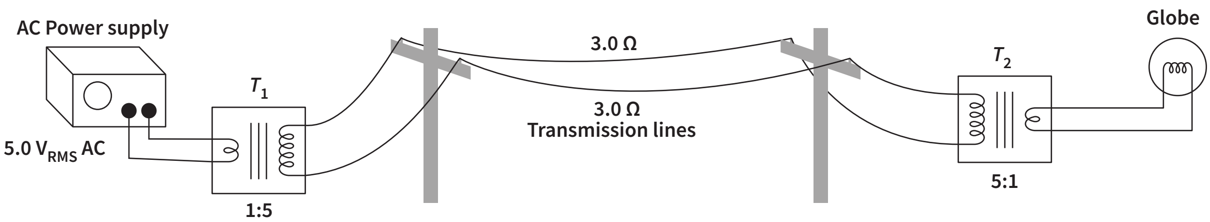


Figure 14

Determine the voltage across the light globe. Show your working.

V

Question 15 (9 MARKS)

Figure 15 shows the displacement-distance graph at $t = 0$ seconds for a 6-metre length of string which has a transverse wave travelling along it. A point halfway along the string is marked and labelled X. The wave speed on the string is 8 m s^{-1}.

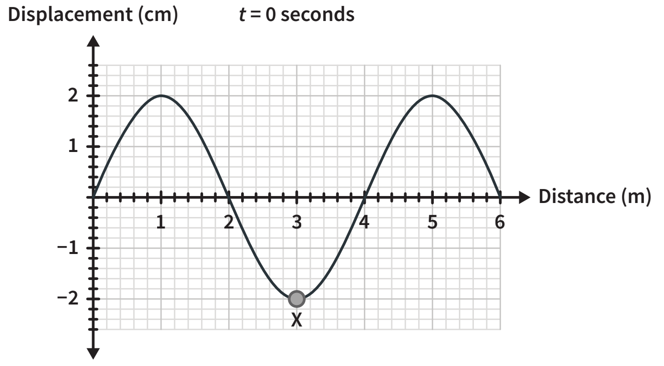


Figure 15

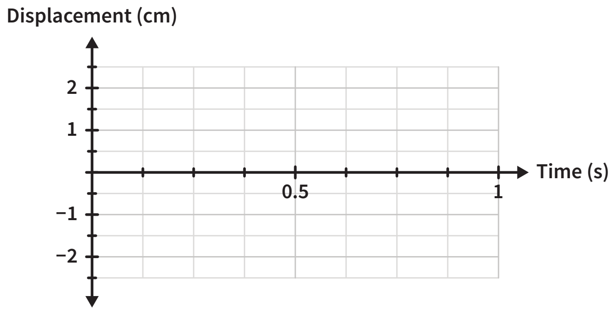
a Determine the frequency of this wave. Show your working. 2 MARKS

____

____

Hz

b On the set of axes provided, draw a displacement-time graph for point X between $t = 0$ s and $t = 1$ s. 3 MARKS



Students fix this string **at one end** to try to make it resonate. Assume that the wave speed is still 8 m s^{-1}.

c Explain how a string can be made to resonate. 2 MARKS

____

____

____

d Will the travelling wave shown in Figure 15 form a standing wave when the string has **one fixed end**? Give a reason for your answer. 2 MARKS

____

____

____

Question 16 (11 MARKS)

Students are investigating the interference of sound from two loudspeakers that are producing the same frequency in phase. The two loudspeakers are separated by a fixed distance of 2.0 metres.

The students use a sound level meter to identify regions of maximum sound intensity (loud regions) and regions of minimum sound intensity (quiet regions). They measure the spacing, Δx, between adjacent maxima at various perpendicular distances, L, from the two speakers.

Take the speed of sound in air to be 340 m s^{-1}.

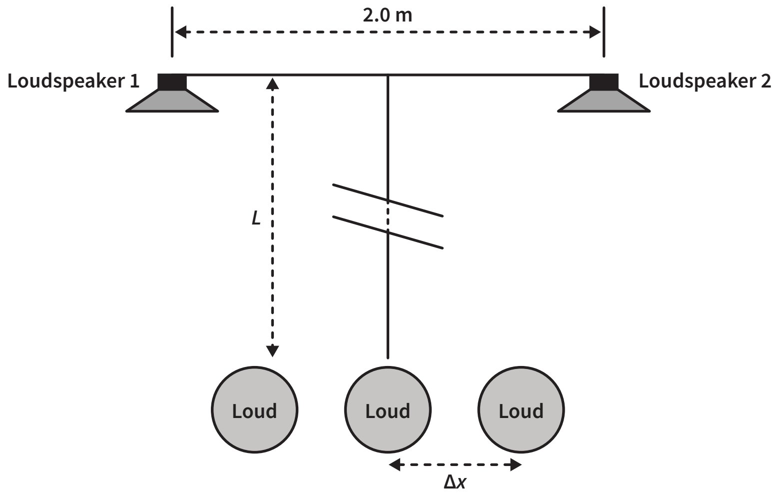


Figure 16

a Identify the independent variable, the dependent variable and a controlled variable involved in this experiment. 3 MARKS

Independent variable ____

Dependent variable ____

Controlled variable ____

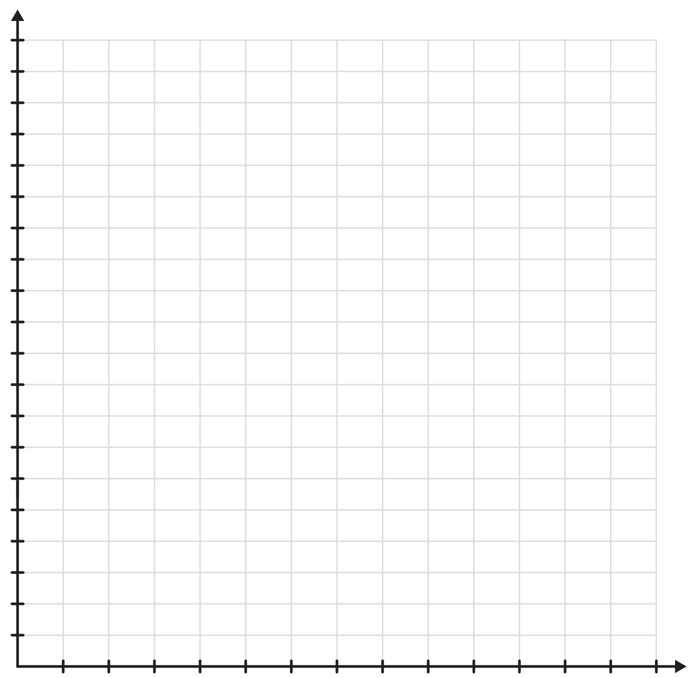
b The students know the value of L with great accuracy but they estimate the experimental uncertainty for the measurements between adjacent maxima to be ±0.5 metres. The students have recorded the data collected in the table below. 5 MARKS

Perpendicular distance L (m)	**Spacing Δx (m)**
10.0	3.5
15.0	6.2
20.0	8.0
25.0	9.4

The relationship between Δx and L is given by the formula $\Delta x = \frac{\lambda L}{d}$.

On the axes provided below:

- Plot a graph of Δx versus L using the data in the table
- Include the correct uncertainty bars for the Δx values
- Label each of the axes correctly
- Draw a line of best fit



c Use the line of best fit to determine the wavelength of the sound produced by the loudspeakers. Show your working. 3 MARKS

____

____

____

m

Question 17 (3 MARKS)

Students set up a loudspeaker inside a box with a 0.2-metre wide opening, as shown in Figure 17. They use two signals in turn, one of 300 Hz and one of 4000 Hz. The sound intensity level at point P, directly in front of the opening, is the same for both frequencies.

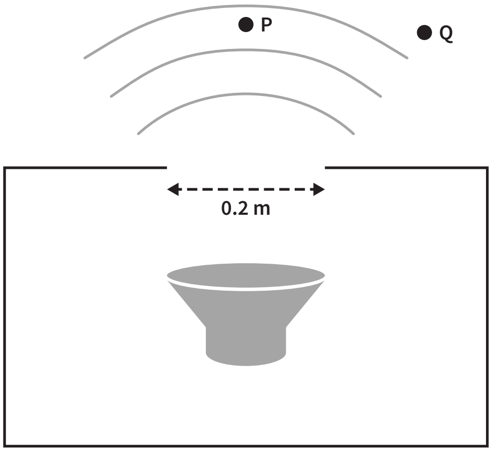


Figure 17

Compare the intensity of the two frequencies when measured at point Q. Justify your answer.

Question 18 (11 MARKS)

Students are studying the photoelectric effect using the apparatus shown in Figure 18.

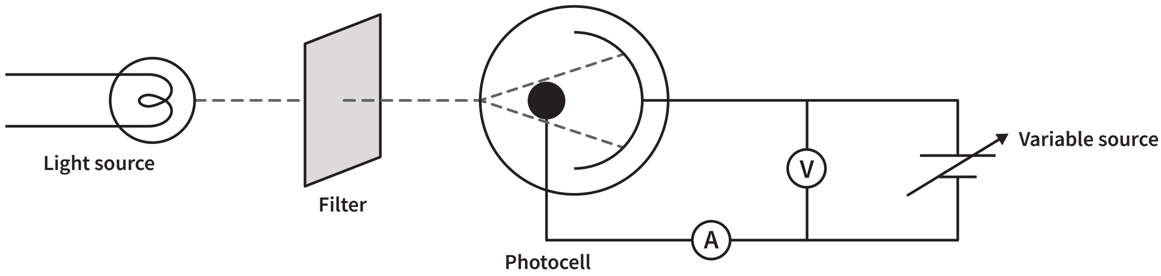


Figure 18

Initially, the students use an unknown metal plate in the apparatus. Figure 19 shows the results the students obtained for the maximum kinetic energy of the emitted photoelectrons versus the frequency of the incoming light.

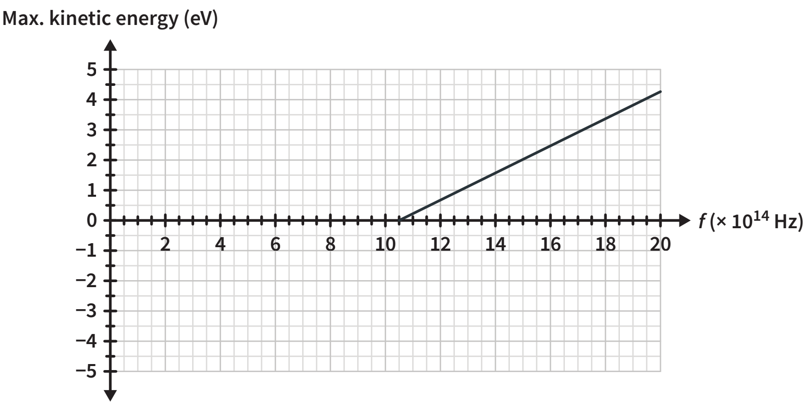


Figure 19

a Identify the point on the graph in Figure 19 that the wave model of light fails to predict. Explain why the wave model fails to predict this observation. 3 MARKS

b Using only the data from Figure 19, determine the value the students would obtain for Planck's constant, *h*. 2 MARKS

eV s

The graph of photoelectric current versus potential difference across the photocell for a particular frequency of light shining on the metal is shown in Figure 20.

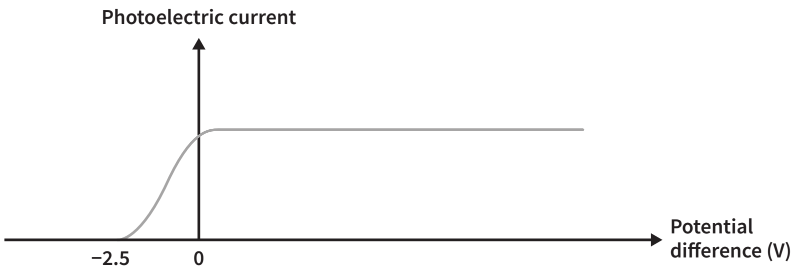


Figure 20

c Use Figure 20 and Figure 19 to determine the frequency of light that was used when the graph in Figure 20 was produced. 2 MARKS

Hz

d On the graph of photoelectric current versus potential difference shown in Figure 20, sketch the graph expected if the light is changed to a **higher frequency** with a **lower intensity** than the original light. Specific values are not required. 2 MARKS

e The metal plate is replaced with a different metal that has a **smaller work function**. The experiment is repeated with this modification.

On the graph of maximum electron kinetic energy versus frequency shown in Figure 19, draw the new graph that the students should expect to obtain. Specific values are not required. 2 MARKS

Question 19 (3 MARKS)

The apparatus for Young's double slit experiment is shown in Figure 21. The laser produces light of a single wavelength.

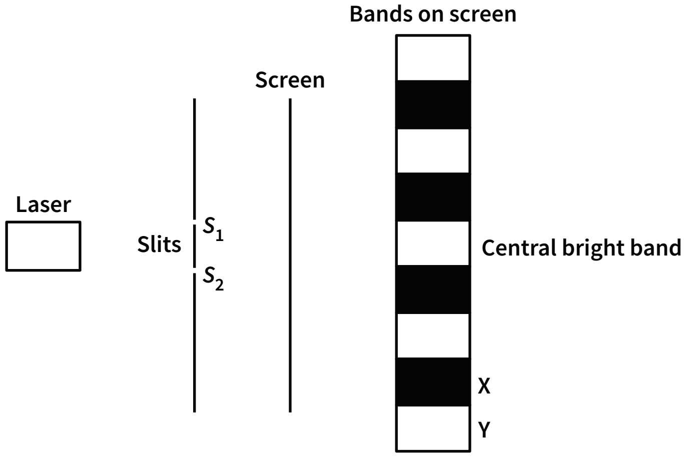


Figure 21 not to scale

The distance from S_1 to the second dark band from the centre, X, is 900 nm further than the distance from S_2 to X.

Calculate the path difference (in metres) from the slits to the second bright band from the centre, Y.

m

Question 20 (3 MARKS)

The left-hand side of Figure 22 shows the diffraction pattern produced when electrons with kinetic energies of 500 eV pass through a crystal lattice. The right-hand side of Figure 22 shows a very similar diffraction pattern produced by X-rays as they pass through the same crystal.

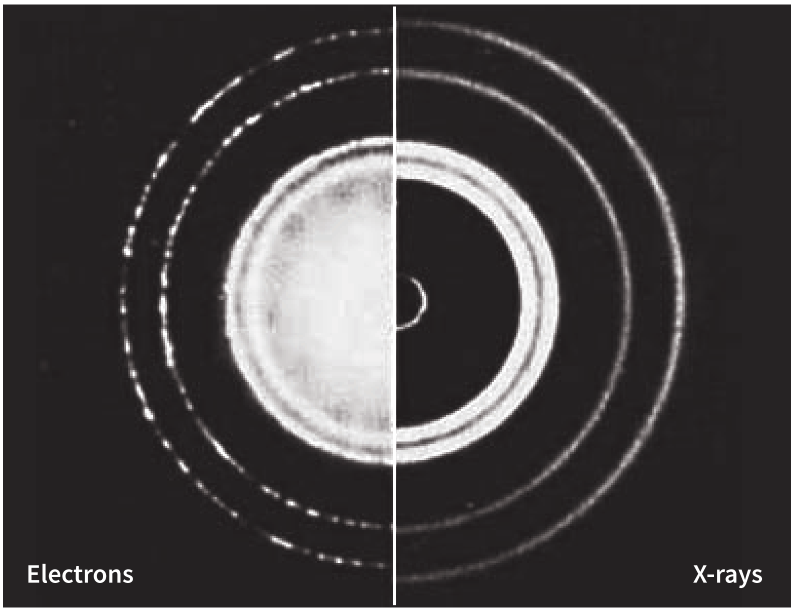


Figure 22

Estimate the energy, in eV, of a photon of these X-rays. Show your working.

____

____

____

____

____

eV

Question 21 (2 MARKS)

Describe how the quantisation of a hydrogen atom's energy levels can be explained by the wave nature of electrons.

____

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End of question book

How to check your answers

SECTION A ANSWERS

For each question, the correct multiple choice response is provided and, where helpful, an additional explanation is provided to help students understand if they chose an incorrect answer.

SECTION B ANSWERS

Answers for calculation-based questions

For each calculation-based question, a full mark solution with mark allocations is provided. Where helpful, additional explanations are provided to help students understand the thought process behind each step.

- Exemplar responses with checklists for worded responses to help students work towards a full mark answer.
- Full mark answers with checklists for questions that require drawing or sketching.

Answers for questions requiring a worded response

For each question requiring a worded response, we provide:

- An **exemplar answer** that demonstrates how a student could respond to get full marks. The depth of the answer is derived from the wording of the question, the number of marks, and an analysis of examiners' reports from previous VCAA examinations. The answers are written in full sentences to model strong literacy and aid learning, although students may distill their responses into briefer phrases or dot points and still receive full marks.
- A **checklist** that identifies the function of each section of the response. This should help students to understand the exemplar answer and to compare it with the unique wording of their own response. The number of checklist items **does not** always correspond to the number of marks. There may be more than one checklist item per mark when there are multiple distinct elements required to earn a given mark.

In the example below, the VCAA examiner's report clearly states that there were two elements required to earn the only available mark.

Question 1a.

Marks	0	1	Average
%	56	44	0.5

Students were required to state that the charge is negative and to identify some process for finding this. A reference to a right-hand rule or similar was sufficient.

If students prefer writing answers as brief dot points, the checklist can be used to ensure they have still provided a complete and correct answer. When used with Edrolo's digital platform, students can use the checklist to self-mark short answer questions, and teachers can view this data to track class progress.

Question 1 (3 MARKS)

Two students set up a double slit experiment. Before turning on the laser, Jeffrey claims that a dark spot will occur in the centre of the pattern. Eva disagrees, claiming that the centre is always a bright band.

Evaluate Jeffrey and Eva's opinions. Justify your answer.

Exemplar responses show students what a full mark answer could look like

1 [Eva is correct.[1]] [The path difference is zero in the centre,[2]] [which means constructive interference occurs, and hence a bright band.[3]]

- I have explicitly addressed which student is correct.[1]
- I have used the relevant theory: path difference.[2]
- I have used the relevant theory: constructive interference.[3]

Numbers help students identify which part of the exemplar relates to which checklist item

Checklist items help students identify the function of the parts of the exemplar response so they can evaluate their own response more meaningfully and develop the skills to make their responses more coherent

Answers for questions requiring a drawn response

For each question requiring a drawn response (such as drawing a graph or vector arrows), we provide:

- An **exemplar answer** that demonstrates how a student could respond to get full marks.
- A **checklist** that identifies the key features of the drawn response that must be shown correctly to earn full marks. The number of checklist items does not always correspond to the number of marks.

Bonus questions

Underneath some exemplar answers, there is a box that contains an exam-style question and its corresponding answer. These extra questions are from Edrolo's Year 12 Physics textbook, which contains hundreds of exam-style questions, answers, and checklists. The bonus question aims to provide students with an example of a different type of question they may be asked on the same topic.

WANT MORE?

Here's another question to show the theory from a different perspective.

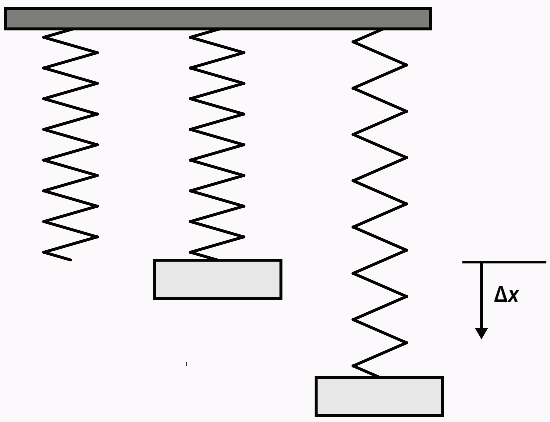
Study design dot point:

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

Related Edrolo Textbook Lesson: 3F – Page 155

Question 6

Ryle and Rushil hang a mass of 0.800 kg on the end of a spring with spring constant 12 N m^{-1}. They initially hold the mass at the unstretched length of the spring and then release it.



a Determine how far the spring stretches until the mass comes to rest, before moving upwards again. (3 MARKS)

b Calculate the maximum speed of the mass. (3 MARKS)

Answer

6 a $GPE_{top} = SPE_{bot}$

$mgh_{top} = \frac{1}{2}k(\Delta x_{bot})^2$ (1 MARK)

Since $h_{top} = \Delta x_{bot}$: $0.800 \times 9.8 \times \Delta x_{bot} = \frac{1}{2} \times 12 \times (\Delta x_{bot})^2$ (1 MARK)

$\Delta x_{bot} = 1.3$ m (1 MARK)

b $SPE_{mid} + KE_{mid} + GPE_{mid} = SPE_{bot}$ (1 MARK)

$\frac{1}{2} \times 12 \times 0.65^2 + \frac{1}{2} \times 0.800 \times v_{mid}^2 + 0.800 \times 9.8 \times 0.65 = \frac{1}{2} \times 12 \times 1.3^2$ (1 MARK)

$v_{mid} = 2.5$ m s^{-1} (1 MARK)

SECTION A – ANSWERS

1 B. The result is the vector sum of the field from the left-hand magnet, which points up and to the left at point P, and the field from the right-hand magnet, which points down and to the left.

2 D. A set of measurements is more accurate than another set if its average is closer to the true value. A set of measurements is more precise than another set if it has a smaller range (all the values in the set are less spread).

3 B. The dependent variable is a variable that the experimenter measures (tension) and which is predicted to be affected by the independent variable (which is the length of the string in this case).

4 A. The resultant (net) force must always point towards the centre of the circle.

5 C

6 A. $KE = (\gamma - 1)E_{rest} \therefore \gamma - 1 = 4 \therefore \gamma = 5; L = \frac{L_0}{\gamma} = \frac{20}{5} = 4.0$ metres

7 C. $\Delta E = mc^2 = 3.2 \times 10^{-27} \times (3.0 \times 10^8)^2 = 2.9 \times 10^{-10}$ J

8 D

9 B. The longest wavelength photon corresponds to the lowest energy photon. From $n = 4$, the smallest change in energy that results in the emission of a photon is a transition from $n = 4$ to $n = 3$.

$\Delta E = \frac{hc}{\lambda} \therefore 12.8 - 12.1 = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^8}{\lambda}$

$\lambda = 1.8 \times 10^{-6}$ m.

10 C. Trace the line of best fit to the intercept on the vertical axis. The magnitude of the intercept indicates the work function, which should be around 4.7 eV.

11 A. By the right-hand coil rule, the direction of the magnetic field at Wire 1 due to Wire 2 is into the page. By the right-hand palm rule (with thumb pointing right and fingers pointing into the page), the force must be up the page.

12 C. $F = nBIL = 1 \times 3.0 \times 10^{-2} \times 0.50 \times 1 = 1.5 \times 10^{-2}$ N

13 B. The EMF is proportional to the rate of change of magnetic flux. When the flux is a maximum or minimum, the EMF should be zero.

14 D

15 D

$F = (m + 2m) \times a \therefore a = \frac{F}{3m}$

For Block 1: $F_{net} = m \times a = m \times \frac{F}{3m} = \frac{F}{3}$

The sum of net forces should add to F. For Block 1, $F_{net} = \frac{F}{3}$.
For Block 2, $F_{net} = 2 \times \frac{F}{3}$.

16 C. GPE must increase with height, SPE must decrease with height (as extension decreases), KE must be zero at the top and bottom and be a maximum in the middle, and the total energy must be constant.

17 B. To complete the entire loop, the car must remain in contact at point P. When two surfaces are in contact, there must be a normal contact force.

18 B. $V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{400}{\sqrt{2}} = 283$ V

19 A. $\Delta KE = -\Delta GPE$ = *area under graph* × *mass*

1 box = $1 \times 1 \times 10^9 = 1 \times 10^9$ J kg^{-1}

There are approximately 21 boxes under the graph between 10×10^9 and 4×10^9 m from the centre of the Sun.

$\Delta KE = 21 \times 1 \times 10^9 \times 200 = 4.2 \times 10^{12} = 4 \times 10^{12}$ J to one significant figure

20 A. $F_{net} = 0$ so $F_{drive} = mg\sin(\theta) = 1600 \times 9.8 \times \sin(40°) = 1.0 \times 10^4$ N

SECTION B – ANSWERS

1 **a** [Negative.[1]][Since the test charge is attracted to $+q$, its charge must have the opposite sign.[2]]

- I have explicitly addressed whether the test charge is positive or negative.[1]
- I have used the relevant theory: the relationship between the signs of charges and the attractive or repulsive nature of forces.[2]

b 100 N (1 MARK)

Direction C (to the right) (1 MARK)

The force on the stationary charge and the force on the test charge are a Newton's third law pair so the magnitudes must be equal and the directions must be opposite.

c The electrostatic force between charged particles follows an inverse square law.

$\frac{F_Y}{F_X} = \frac{r_X^2}{r_Y^2} \therefore \frac{F_Y}{F_X} = \frac{d^2}{(2d)^2} = \frac{1}{4}$ (1 MARK)

$F_Y = 25$ N (1 MARK)

d The test charge is attracted to both $+q_1$ and $+q_2$ so it experiences a force to the left due to $+q_1$ and a force to the right due to $+q_2$.

$F_{net} = F_{+q2} - F_{+q1} = 100 - 25$ (1 MARK)

$F_{net} = 75$ N (1 MARK)

Direction: C (to the right) (1 MARK)

2 **a** $E = \frac{V}{d} = \frac{200}{0.50} = 400 \text{ N C}^{-1}$ (1 MARK)

$F = qE = 1.6 \times 10^{-19} \times 400$ (1 MARK)

$F = 6.4 \times 10^{-17}$ N (1 MARK)

b $\frac{1}{2}mv^2 = qV$

$\frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 1.6 \times 10^{-19} \times 200$ (1 MARK)

Solving for v yields
$v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 200}{9.1 \times 10^{-31}}} = 8.386 \times 10^6 = 8.4 \times 10^6 \text{ m s}^{-1}$ but no marks are awarded for this step since the final value is provided in the question.

c $r = \frac{mv}{qB} = \frac{9.1 \times 10^{-31} \times 8.386 \times 10^6}{1.6 \times 10^{-19} \times 5.0 \times 10^{-5}}$ (1 MARK)

$r = 0.95$ m (1 MARK)

This value is obtained when using the unrounded value for speed calculated in part b. If the value of speed rounded to two significant figures ($v = 8.4 \times 10^6 \text{ m s}^{-1}$) is used, then the answer will be $r = 0.96$ m. This answer is also acceptable.

3 **a** A (anticlockwise) (1 MARK)

b [The magnetic field is directed to the left and the current travels from M to L.[1]][By the right-hand palm rule, this results in an upward force on this side.[2]]

- I have stated the direction of the magnetic field and the direction of the current on one of the sides perpendicular to the magnetic field.[1]
- I have used the relevant theory: right-hand palm rule to determine the direction of force.[2]

c [The motor would no longer function.[1]][The coil would turn one-quarter of a rotation where it would oscillate in the vertical position and eventually stop.[2]]

- I have stated that the motor would not operate correctly anymore.[1]
- I have described the position where the motor stops rotating.[2]

4 **a** $g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(7.40 \times 10^6)^2}$ (1 MARK)

$g = 7.28 \text{ N kg}^{-1}$ (1 MARK)

b $v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{7.4 \times 10^6}}$ (1 MARK)

$v = 7.4 \times 10^3 \text{ m s}^{-1}$ (1 MARK)

OR

$a = \frac{v^2}{r}$ where a is the acceleration due to gravity.

$7.28 = \frac{v^2}{7.40 \times 10^6}$ (1 MARK)

$v = 7.34 \times 10^3 \text{ m s}^{-1}$ (1 MARK)

This method involves consequential marks from **part a**.

c [Orbital period is related to radius by $T = \sqrt{\frac{4\pi^2 r^3}{GM}}$,[1]][so if the orbital radius decreases then the period must also decrease.[2]]

- I have provided the correct relationship between orbital period and radius.[1]
- I have explicitly addressed how the period must change when the radius decreases.[2]

5 **a** $\Phi_B = B_\perp A$

$2.0 \times 10^{-4} = B \times 0.40 \times 0.25$ (1 MARK)

$B = \frac{2.0 \times 10^{-4}}{0.40 \times 0.25} = 2.0 \times 10^{-3}\ T$ (1 MARK)

b $\varepsilon = N\frac{\Delta\Phi_B}{\Delta t}$

$\varepsilon = 500 \times \frac{2.0 \times 10^{-4} - 0}{8.0 \times 10^{-3}}$ (1 MARK)

$\varepsilon = 13$ V (1 MARK)

WANT MORE?

Here's another question to show the theory from a different perspective.

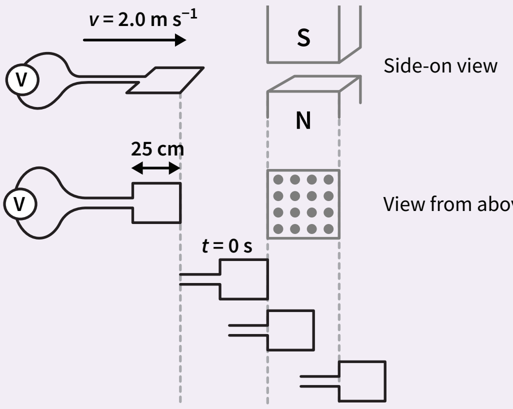
Study design dot point:

- 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

Related Edrolo Textbook Lesson: 7A – Page 245-246

Question 11b

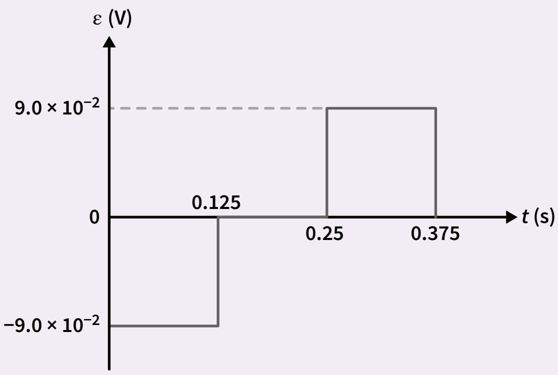
A square coil with 6 turns starts in a region with no magnetic field and then passes at a constant speed of 2.0 m s^{-1} into, through, and out of a uniform magnetic field ($B = 3.0 \times 10^{-2}$ T) between the poles of two bar magnets as indicated by the diagram. Assume that the uniform magnetic field is a square shape with side length of 50 cm, and the loop has a side length of 25 cm.



On a set of axes similar to those provided, sketch a graph of the EMF in the coil against time. Appropriate values should be included on the graph. (3 MARKS)

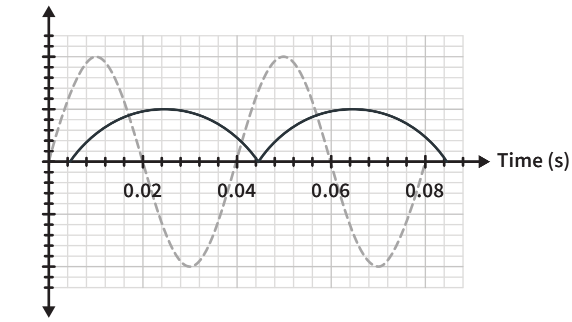
Answer

$\varepsilon = N\frac{\Delta\Phi_B}{\Delta t} = 6 \times \frac{1.875 \times 10^{-3}}{0.125} = 9.0 \times 10^{-2}$ V



- I have drawn a constant EMF when the rate of change of magnetic flux is constant.
- I have drawn zero EMF when the rate of change of magnetic flux is zero.
- I have used the opposite sign for the EMF when the flux is increasing compared to when the flux is decreasing.
- I have included the values of the maximum magnitudes of EMF.
- I have included the time for each stage of the motion.

c



- I have accounted for the effect of the reduced speed on the period: the period is doubled.
- I have accounted for the effect of the reduced speed on the amplitude: the amplitude is halved.
- I have accounted for the effect of replacing the slip rings with the split ring commutator: either the negative or the positive values are inverted.

6 [As the loop moves from position 1 to position 2, the magnetic flux which is directed into the page (in Figure 6b) decreases.[1]] [By Lenz's law, the induced magnetic field must be directed into the page to oppose the change in flux.[2]] [By the right-hand coil rule, the current flows in a clockwise direction.[3]]

- I have stated the direction and the change in flux through the loop.[1]
- I have applied Lenz's law to state the direction of the induced magnetic field.[2]
- I have applied the right-hand coil rule to state the direction of the induced current.[3]

7 Momentum is conserved.

$m_X v_X + m_Y v_Y = (m_X + m_Y) v_{final}$

Take right as the positive direction.

$4.5 \times 10^3 \times 5.0 + 3.5 \times 10^3 \times (-7.0) = (4.5 + 3.5) \times 10^3 \times v_f$ (1 MARK)

$v_f = \frac{4.5 \times 5.0 + 3.5 \times (-7.0)}{4.5 + 3.5} = -0.25$ m s^{-1}

Magnitude: 0.25 m s^{-1} (1 MARK)

Direction: left (1 MARK)

8 a $\frac{mv^2}{r} = mg - F_N$ (1 MARK)

$F_N = 0$ when the toy car loses contact with the track.

$\frac{mv^2}{0.10} = 3 \times 9.8 - 0$ (1 MARK)

Cancelling m on both sides of the equation and solving for v yields $v = \sqrt{9.8 \times 0.10} = 0.99$ m s^{-1} but no marks are awarded for this step since the final value is provided in the question.

b $KE_Q + GPE_Q + SPE_Q = KE_P + GPE_P + SPE_P$

$\frac{1}{2}k\Delta x^2 + 0 + 0 = \frac{1}{2}mv_P^2 + mgh_P + 0$ (1 MARK)

$\frac{1}{2} \times 235 \times \Delta x^2 = \frac{1}{2} \times 0.200 \times 0.99^2 + 0.200 \times 9.8 \times 0.10$ (1 MARK)

$\Delta x = \sqrt{\frac{0.200 \times 0.99^2 + 2 \times 0.200 \times 9.8 \times 0.10}{235}} = 0.05$ m $= 5$ cm (1 MARK)

9 Consider the connected masses as a single system. The only unbalanced force on the system is the force on m_2 due to gravity.

$a = \frac{F_{net}}{m_{total}} = \frac{0.30 \times 9.8}{0.20 + 0.30}$ (1 MARK)

$a = 5.88\ \text{m s}^{-2}$ (1 MARK)

Now consider m_1 only. The only unbalanced force is the tension force.

$F_{net} = m_1 a$

$F_T = 0.20 \times 5.88 = 1.2\ \text{N}$ (1 MARK)

An alternative approach is to use the acceleration to calculate the net force acting on m_2. This approach is slightly more complicated because m_2 has both the tension force and the gravitational force acting on it.

10 a Consider the horizontal direction:

$v_x = u_x = 16 \times \cos(60°) = 8.0\ \text{m s}^{-1}$

$v_x = \frac{s_x}{t}\ \therefore 8.0 = \frac{10.0}{t}\ \therefore t = 1.25\ \text{s}$ (1 MARK)

Consider the vertical direction:

$u_y = 16.0 \times \sin(60°) = 13.86\ \text{m s}^{-1}$

$s_y = u_y t + \frac{1}{2} a_y t^2 = 13.86 \times 1.25 + \frac{1}{2} \times (-9.8) \times 1.25^2$ (1 MARK)

$s_y = 9.7$ m. The rider will make it to the rooftop because she is 9.7 m above the ramp when she reaches the building, which is greater than the height of the rooftop from the top of the ramp (8.0 m). (1 MARK)

An alternative method is to show that the stunt rider falls below a height of 8.0 m at a horizontal distance that is greater than 10.0 m.

b Consider the vertical direction:

$v_y^2 = u_y^2 + 2a_y s_y$

$v_y^2 = 13.86^2 + 2 \times (-9.8) \times 8.0$ (1 MARK)

$v_y^2 = 35.3\ \text{m s}^{-1}$ (1 MARK)

Use vector addition with the horizontal and vertical components to find the magnitude of the velocity:

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{8.0^2 + 35.3} = 10\ \text{m s}^{-1}$ (1 MARK)

OR

Use energy conservation:

$KE_i + GPE_i = KE_f + GPE_f$

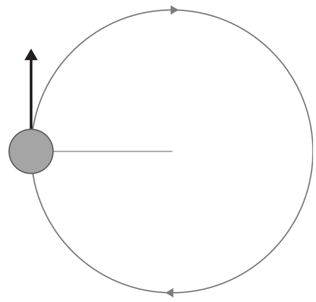
$\frac{1}{2} m v_i^2 + 0 = \frac{1}{2} m v_f^2 + mgh_f$ (1 MARK)

$\frac{1}{2} \times m \times 16.0^2 = \frac{1}{2} \times m \times v_f^2 + m \times 9.8 \times 8.0$ (1 MARK)

Cancel m on both sides of the equation.

$v_f = \sqrt{16.0^2 - 2 \times 9.8 \times 8.0} = 10\ \text{m s}^{-1}$ (1 MARK)

11 a



I have drawn an arrow that is a tangent to the circle, pointing directly up the page.

If the string breaks, there is no longer a centripetal force acting on the ball so it will continue moving in the direction it was moving when the string breaks.

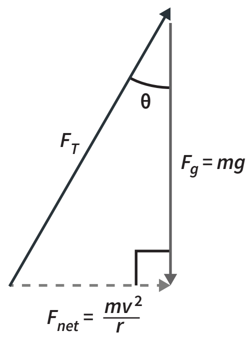
b Consider the forces in the vertical direction:

$F_g = F_T \times \cos(\theta)$

$4.1 \times 9.8 = 51 \times \cos(\theta)$ (1 MARK)

$\theta = \cos^{-1}\left(\frac{4.1 \times 9.8}{51}\right) = 38°$ (1 MARK)

c



For a ball on a string, the speed is related to the radius of the circle and the angle of the string from the vertical by the equation $v = \sqrt{rg \times \tan(\theta)}$ (which is derived by considering the relationship between the centripetal force and the force due to gravity: $\tan(\theta) = \frac{mv^2/r}{mg}$).

Determine the radius of the circle using the angle that the string makes with the vertical.

$r = 0.80 \times \sin(38°) = 0.49\ \text{m}$ (1 MARK)

$v = \sqrt{rg \times \tan(\theta)} = \sqrt{0.49 \times 9.8 \times \tan(38°)}$ (1 MARK)

$v = 1.9\ \text{m s}^{-1}$ (1 MARK)

12 [The students have incorrectly assumed that spring force at the maximum extension has the same magnitude as the force due to gravity $(F_s = F_g)$.[1]][These forces will have the same magnitude only when the weight is not accelerating (including being stationary).[2]] [At the maximum extension in the students' experiment, the weight is accelerating upwards so $F_{net} > 0$ which means $F_s > F_g$ at this point.[3]]

I have explicitly addressed the students' mistake: confusing the spring force with the force due to gravity.[1]

I have identified the specific situation when spring force is equal to the force due to gravity.[2]

I have used the relevant theory to justify why the two forces are not equal: Newton's 2nd law.[3]

WANT MORE?

Here's another question to show the theory from a different perspective.

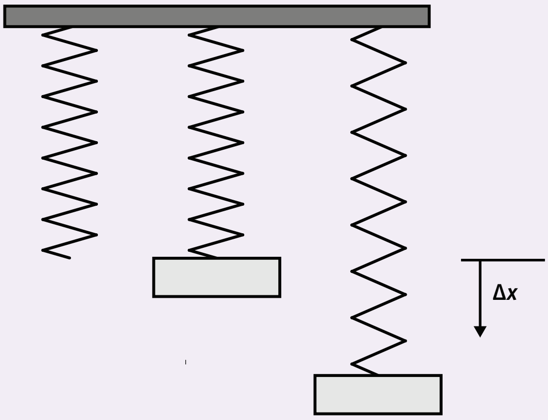
Study design dot point:

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

Related Edrolo Textbook Lesson: 3F – Page 155

Question 6

Ryle and Rushil hang a mass of 0.800 kg on the end of a spring with spring constant 12 N m^{-1}. They initially hold the mass at the unstretched length of the spring and then release it.



a Determine how far the spring stretches until the mass comes to rest, before moving upwards again. (3 MARKS)

b Calculate the maximum speed of the mass. (3 MARKS)

Answer

6 a $GPE_{top} = SPE_{bot}$

$mgh_{top} = \frac{1}{2}k(\Delta x_{bot})^2$ (1 MARK)

Since $h_{top} = \Delta x_{bot}$: $0.800 \times 9.8 \times \Delta x_{bot} = \frac{1}{2} \times 12 \times (\Delta x_{bot})^2$ (1 MARK)

$\Delta x_{bot} = 1.3$ m (1 MARK)

b $SPE_{mid} + KE_{mid} + GPE_{mid} = SPE_{bot}$ (1 MARK)

$\frac{1}{2} \times 12 \times 0.65^2 + \frac{1}{2} \times 0.800 \times v_{mid}^2 + 0.800 \times 9.8 \times 0.65 = \frac{1}{2} \times 12 \times 1.3^2$ (1 MARK)

$v_{mid} = 2.5$ m s^{-1} (1 MARK)

13 The scientists' frame measures the proper length. Convert from the distance measurement in the scientist's frame to the distance measurement in the particle's frame:

$L = \frac{L_0}{\gamma} = \frac{6.8 \times 10^{-4}}{4.0}$ (1 MARK)

$L = 1.7 \times 10^{-4}$ m (1 MARK)

Relate the time to the distance and the speed in the particle's frame:

$t_0 = \frac{L}{v} = \frac{1.7 \times 10^{-4}}{0.9682 \times 3.0 \times 10^8} = 5.9 \times 10^{-13}$ s (1 MARK)

OR

Relate the time to the distance and the speed in the scientists' frame:

$t = \frac{L_0}{v} = \frac{6.8 \times 10^{-4}}{0.9682 \times 3.0 \times 10^8} = 2.34 \times 10^{-12}$ s (1 MARK)

This time in the scientists' frame is the dilated time. Convert from the time measurement in the scientist's frame to the time measurement in the particle's frame:

$t = t_0 \gamma$

$2.34 \times 10^{-12} = t_0 \times 4.0$ (1 MARK)

$t_0 = 5.9 \times 10^{-13}$ s (1 MARK)

WANT MORE?

Here's another question to show the theory from a different perspective.

Study design dot point:

- model mathematically time dilation and length contraction at speeds approaching c using the equations:

  $t = t_0 \gamma$ and $L = \frac{L_0}{\gamma}$ where $\gamma = \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

Related Edrolo Textbook Lesson: 4B – Page 155

Question 16

Two spacecraft are travelling towards each other. Spacecraft 1 has a beacon which flashes once every 5.00 seconds. An observer on spacecraft 2 detects the pulse periodically flashing every 5.72 seconds.

What is the relative speed of the two spacecraft? Give your answer in metres per second. (2 MARKS)

Answer

$t = t_0\gamma \therefore t = t_0 \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \therefore 5.72 = 5.00 \times \frac{1}{\sqrt{1 - \frac{v^2}{(3.0 \times 10^8)^2}}}$ (1 MARK)

$v = 1.5 \times 10^8$ m s^{-1} (1 MARK)

14 For transformer T_1:

$\frac{V_{T_1,out}}{V_{T_1,in}} = \frac{5}{1} \therefore \frac{V_{T_1,out}}{5.0} = \frac{5}{1}$

$V_{T_1,out} = 25$ V (1 MARK)

For the transmission lines:

$V_{loss} = I_{line}R = 0.20 \times (3.0 + 3.0) = 1.2$ V (1 MARK)

For transformer T_2:

$V_{T_2,in} = V_{T_1,out} - V_{loss} = 25 - 1.2 = 23.8$ V (1 MARK)

$V_{T_2,out} = V_{globe}$

$\frac{V_{globe}}{V_{T_2,in}} = \frac{1}{5} \therefore \frac{V_{globe}}{23.8} = \frac{1}{5}$

$V_{globe} = 4.8$ V (1 MARK)

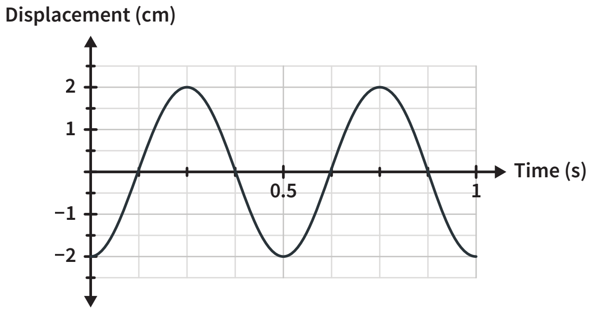
15 a From the provided graph, λ = 4 m.

$v = f\lambda$

$8 = f \times 4$ (1 MARK)

$f = 2$ Hz (1 MARK)

b With λ = 4 m and $v = 8$ m s^{-1} we can determine that the period is 0.5 s. From the provided graph, point X is at the lowest position when $t = 0$ s so the graph must start at the minimum displacement of −2 cm.



I have drawn a sinusoid starting from its minimum value (a negative cosine graph).

I have drawn a sinusoid with a period of 0.5 seconds.

I have drawn a sinusoid with an amplitude of 2 cm.

c [A string can be made to resonate when it is forced to oscillate at one of its natural frequencies of vibration[1]] [so that the superposition of the travelling wave and its reflection forms a standing wave.[2]]

I have described the cause of resonance: forced oscillations matching the natural frequency.[1]

I have described the effect of resonance on a string: superposition of a travelling wave and its reflection resulting in a standing wave.[2]

d [No.[1]] [For a string with one fixed end, a standing wave will form only if the string length, L, is an odd multiple of $\frac{\lambda}{4}$. In this case, $L = 6$ m is not an odd multiple of $\frac{\lambda}{4} = \frac{4}{4} = 1$ m.[2]]

I have explicitly addressed whether a standing wave will form.[1]

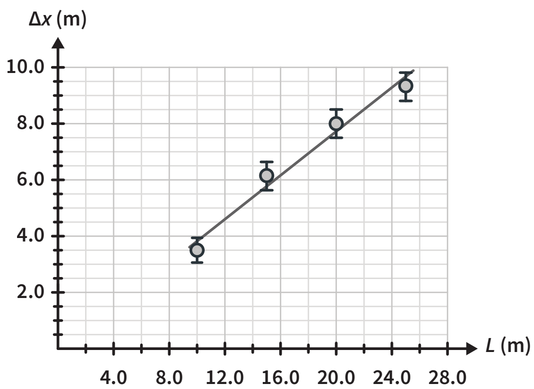
I have used the relevant theory: the relationship between string length and wavelength for strings with one fixed end.[2]

16 a Independent variable: Perpendicular distance from speakers, L (1 MARK)

Dependent variable: Spacing between maxima, Δx (1 MARK)

Controlled variable: The separation of the speakers **OR** the frequency of the sound (1 MARK)

b



I have labelled the horizontal axis with the independent variable, the vertical axis with the dependent variable, and included correct units.

I have included an appropriate and consistent scale on both axes.

I have plotted each data point.

I have drawn correctly sized uncertainty bars.

I have drawn a straight line of best fit which passes through all uncertainty bars.

c Use any two points from the line of best fit that are far apart to calculate the gradient.

$gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{8.5 - 5.5}{22.0 - 14.0} = 0.375$ (1 MARK)

$gradient = \frac{rise}{run} = \frac{\Delta x}{L}$

Δx and L are related by the formula $\Delta x = \frac{\lambda L}{d}$

$\frac{\Delta x}{L} = \frac{\lambda}{d}$ $\therefore gradient = \frac{\lambda}{d}$ (1 MARK)

$0.375 = \frac{\lambda}{2.0}$ $\therefore \lambda = 0.75$ m (1 MARK)

Depending on the line of best fit drawn, gradients between 0.35 and 0.40 are acceptable, which corresponds to an allowable range of wavelengths between 0.70 m and 0.80 m.

17 [The 300 Hz sound will have a greater intensity at point Q.[1]] [To reach Q, the sound has to diffract.[2]] [Diffraction is greater when the ratio $\frac{\lambda}{w}$ is greater. Since the 300 Hz sound has the greater wavelength, it will diffract more.[3]]

I have explicitly addressed which frequency will have the greater intensity at point Q.[1]

I have identified the relevance of diffraction to this situation.[2]

I have applied the theory to this situation: the effect of the different frequencies on the extent of diffraction.[3]

18 a [The wave model fails to predict the existence of a minimum (threshold) frequency of light for ejecting photoelectrons, indicated by the horizontal axis intercept.[1]] [According to the wave model, light is a continuous distribution of energy,[2]] [so an electron should be able to accumulate enough energy over time to be ejected from the metal regardless of the frequency.[3]]

I have explicitly addressed the specific point on the graph that the wave model cannot predict: the threshold frequency.[1]

I have used the relevant theory: the continuous nature of waves.[2]

I have explicitly addressed the incorrect prediction of the wave model.[3]

b Use two points that are far apart on the line of best fit to calculate the gradient:

$h = \frac{rise}{run} = \frac{4.0 - 0}{(19.5 - 10.5) \times 10^{14}}$ (1 MARK)

$h = 4.4 \times 10^{-15}$ eV s (1 MARK)

Depending on the data points used to calculate the gradient, $h = 4.5 \times 10^{-15}$ eV s is also an acceptable answer.

c The magnitude of the horizontal axis intercept of the current versus potential difference graph has the same numerical value as the maximum electron kinetic energy when measured in eV.

$KE_{max} = 2.5$ eV (1 MARK)

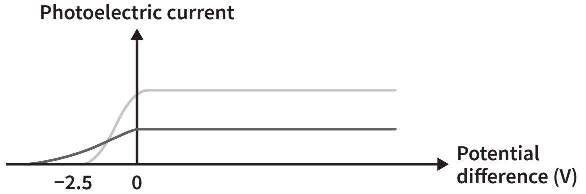
From the max. kinetic energy vs frequency graph, when $KE_{max} = 2.5$ eV, $f = 16 \times 10^{14}$ Hz (1 MARK)

OR

$KE_{max} = h(f - f_0)$ $\therefore 2.5 = 4.4 \times 10^{-15} \times (f - 10.5 \times 10^{14})$ (1 MARK)

$f = 16 \times 10^{14}$ Hz (1 MARK)

d

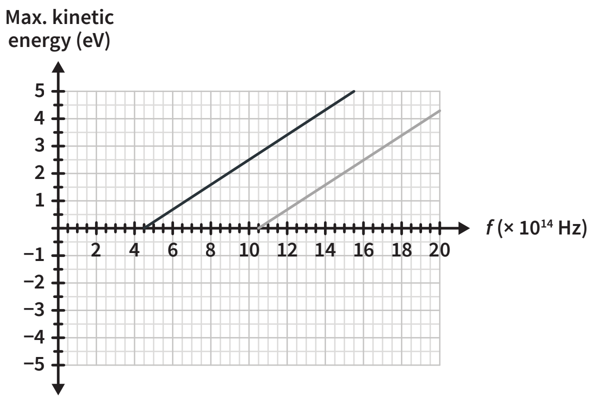


I have drawn a graph with a lower saturation (maximum) current.

I have drawn a graph with a horizontal intercept that is further to the left (more negative).

A higher frequency means that each electron absorbs a photon with more energy so the photoelectrons have more kinetic energy, which means the magnitude of the cut-off potential is greater. A lower intensity means less photons are absorbed so less electrons are ejected, which means the current is reduced.

e



I have drawn a straight line that is parallel to the original (the gradient is the same).

I have drawn a straight line that is shifted upwards/to the left compared with the original.

A smaller work function means that electrons escape with more energy. The gradient corresponds to Planck's constant, which should be the same regardless of the work function.

19 Since X is a dark band, $S_1X - S_2X = \left(n - \frac{1}{2}\right)\lambda$ where n is the number of the dark band counted from the centre ($n = 1, 2, 3, \ldots$).

$9.00 \times 10^{-9} = \left(2 - \frac{1}{2}\right)\lambda$ (1 MARK)

$\lambda = 6.00 \times 10^{-9}$ m (1 MARK)

Since Y is a bright band, $S_1Y - S_2Y = n\lambda$ where n is the number of the bright band counted from the centre ($n = 0, 1, 2, 3, \ldots$).

$S_1Y - S_2Y = 2 \times 6.00 \times 10^{-9} = 1.20 \times 10^{-8}$ m (1 MARK)

20 For the electron:

$KE = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} \text{ J} = 8.0 \times 10^{-17}$ J

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

$8.0 \times 10^{-17} = \frac{p^2}{2 \times 9.1 \times 10^{-31}}$

$p = \sqrt{8.0 \times 10^{-17} \times 2 \times 9.1 \times 10^{-31}} = 1.21 \times 10^{-23}$ kg m s^{-1} (1 MARK)

The momenta of the electrons and the X-ray photons must be the same ($p_e = p_X$) (1 MARK)

For the X-ray photon:

$E = pc = 1.21 \times 10^{-23} \times 3.0 \times 10^8 = 3.6 \times 10^{-15}$ J

$E = 2.3 \times 10^4$ eV (1 MARK)

OR

For the electron:

$KE = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} \text{ J} = 8.0 \times 10^{-17}$ J

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

$8.0 \times 10^{-17} = \frac{p^2}{2 \times 9.1 \times 10^{-31}}$

$p = \sqrt{8.0 \times 10^{-17} \times 2 \times 9.1 \times 10^{-31}} = 1.21 \times 10^{-23}$ kg m s^{-1} (1 MARK)

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.21 \times 10^{-23}} = 5.48 \times 10^{-11}$ m

The wavelengths of the electrons and the X-ray photons must be the same ($\lambda_e = \lambda_X$) (1 MARK)

For the X-ray photon:

$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^8}{5.48 \times 10^{-11}} = 2.3 \times 10^4$ eV (1 MARK)

21 [A stable orbit only exists if the electron can form a standing wave, which occurs if the de Broglie wavelength of the electron fits the orbit an integer number of times ($2\pi r = n\lambda, n = 1, 2, 3, \ldots$).[1]] [Electron energies are quantised because they are the energies corresponding to these wavelengths.[2]]

I have used the relevant theory: electrons forming standing waves depending on the de Broglie wavelength.[1]

I have related the discrete allowable wavelengths to the quantisation of energy levels.[2]