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PROCESSING LABEL HERE

Write your **student number** in the boxes above. **Letter**

Physics

Question and Answer Book

VCE Examination – Wednesday 12 November 2025

- Reading time is **15 minutes**: 9.00 am to 9.15 am
- Writing time is **2 hours 30 minutes**: 9.15 am to 11.45 am

Approved materials

- One scientific calculator
- Pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape)

Materials supplied

- Question and Answer Book of 48 pages
- Formula Sheet
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

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

Contents

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

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Section A – Multiple-choice questions

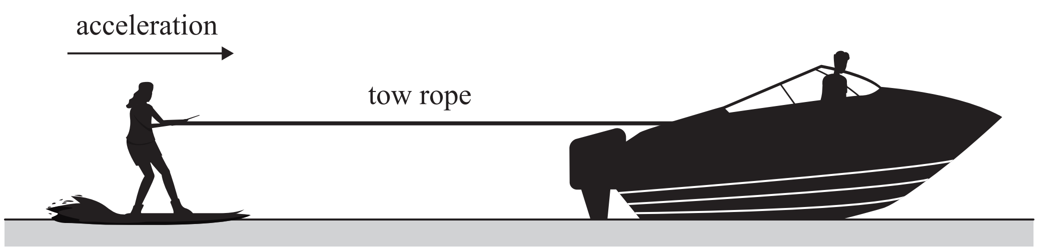
Instructions

- Answer **all** questions in pencil on your Multiple-Choice Answer Sheet.
- 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.

Question 1

Jacinta is water skiing on one ski, as shown in the diagram below.

She is towed in a straight line by a horizontal rope behind a boat along a stretch of flat water. At a particular instant Jacinta is accelerating at 4.0 m s^{-2}. The total resistance on Jacinta and the ski at that instant is 500 N. The combined mass of Jacinta and the ski is 65 kg.



Source: Adapted from <Brothers klia/Shutterstock.com> and <GreenSkyStudio/Shutterstock.com>

Which one of the following is closest to the magnitude of the tension force in the rope?

A. 240 N

B. 260 N

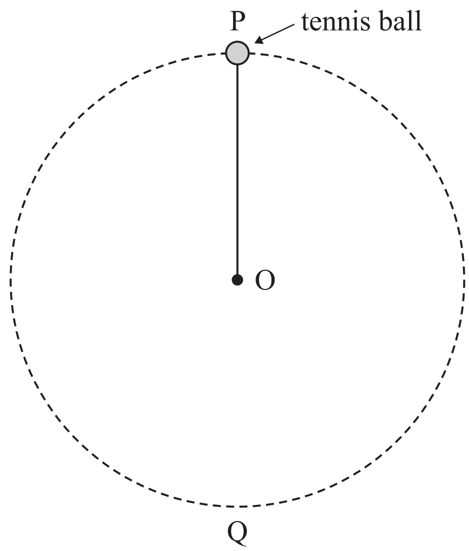
C. 500 N

D. 760 N

Question 2

Anders swings a tennis ball on a string in a vertical circle, as shown in the diagram below.

Assume that his hand is stationary at the centre of the circle, O, that the string remains fully extended throughout the motion and that the tennis ball is moving at a constant speed at both points P and Q.



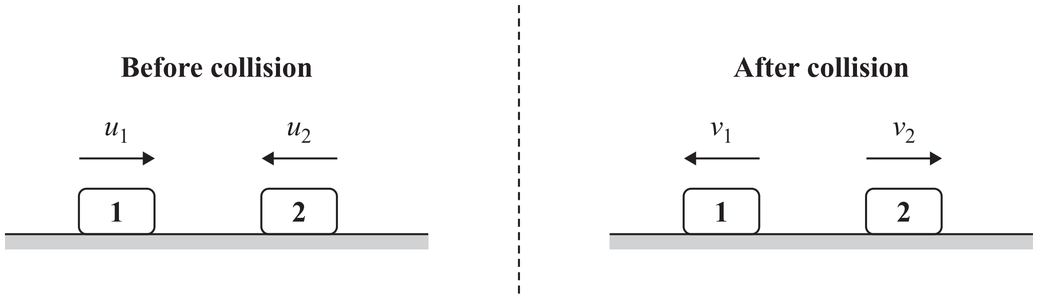
Which one of the following best shows the direction of the acceleration of the tennis ball at the highest point, P, and at the lowest point, Q?

	At point P	At point Q
A.	↓	↓
B.	↑	↑
C.	↓	↑
D.	↑	↓

Question 3

During a practice session of ice hockey, two identical pucks on the ice collide, as shown in the diagram below. The entire collision takes place along a straight line, and friction between the pucks and ice can be ignored.

Initially, Puck 1 has speed u_1, and Puck 2 has speed u_2. After the collision, their speeds are v_1 and v_2, respectively. The mass of each puck is m.



Which one of the following is closest to the speed of Puck 2, v_2, after the collision?

A. $\dfrac{u_2 - u_1}{v_1}$

B. $\dfrac{v_1}{u_2 - u_1}$

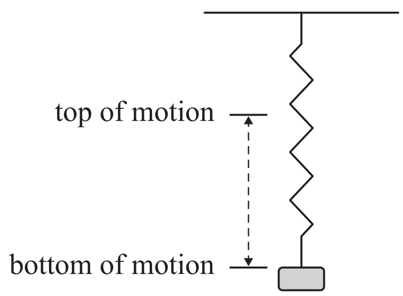
C. $u_1 - u_2 + v_1$

D. $u_1 + u_2 - v_1$

Question 4

A mass at the end of an ideal spring is oscillating freely up and down between two positions, as shown in the diagram below.

While oscillating, the spring is always longer than its natural length.

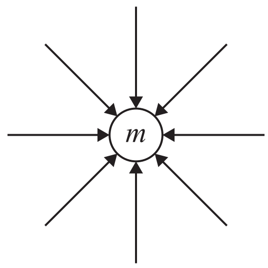
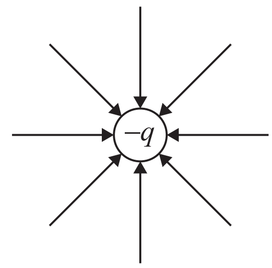
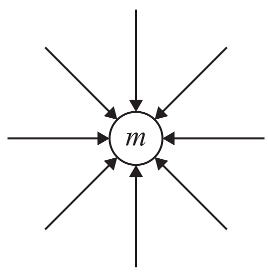
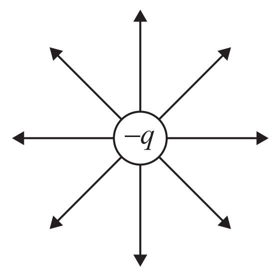
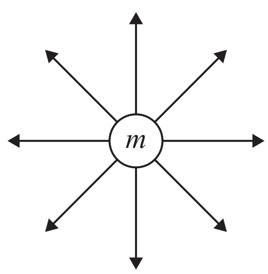
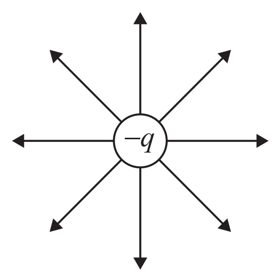
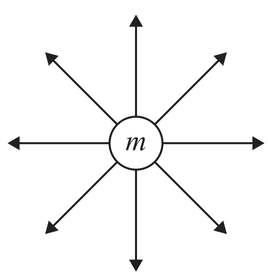
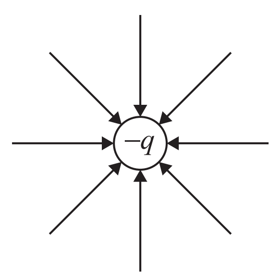


Ignoring air resistance, which one of the following best describes the energy changes in the system of the oscillating mass and the spring as the mass travels from the bottom of the motion back up to the top?

	Gravitational potential energy	Elastic potential energy	Total energy of the system
A.	increases	decreases	remains constant
B.	increases	decreases	decreases
C.	decreases	increases	increases
D.	decreases	increases	remains constant

Question 5

Which one of the following diagrams best represents the direction of the gravitational field around a point mass, *m*, and the electric field around a negative point charge, –*q*?

	Point mass	Point charge
A.		
B.		
C.		
D.		

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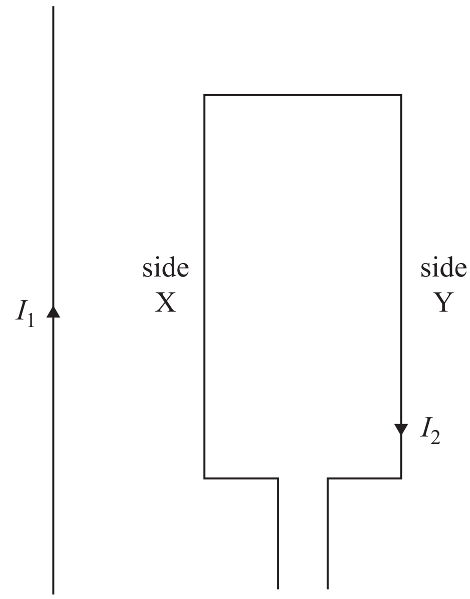
Question 6

A long straight wire carrying a current of I_1 lies in the same plane as a rectangular loop of wire that carries a current of I_2, as shown in the diagram below.



Which one of the following best gives the direction of the force on the two sides of the loop, Side X and Side Y, due to the current in the long straight wire, I_1?

	Side X	Side Y
A.	to the left	to the left
B.	to the left	to the right
C.	to the right	to the left
D.	to the right	to the right

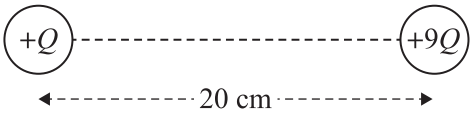
Question 7

Which one of the following options correctly describes a static field and a non-uniform field?

	Static field	Non-uniform field
A.	direction of field varies over time	field varies across the region
B.	strength of field is constant over time	field varies across the region
C.	strength of field is constant over time	field is unchanged across the region
D.	direction of field is constant over time	field is unchanged across the region

Question 8

Two point charges, $+Q$ and $+9Q$, are placed 20 cm apart, as shown in the diagram below.



On the straight line between the charges, the electric field is

A. non-zero everywhere.

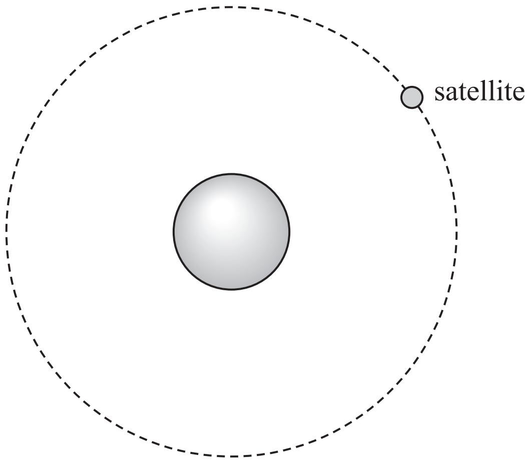
B. zero at a point 2.2 cm from the point charge $+Q$.

C. zero at a point 5.0 cm from the point charge $+Q$.

D. zero at a point 6.7 cm from the point charge $+Q$.

Question 9

A satellite, in uniform circular motion, orbits a planet at a fixed altitude with a constant speed.



Which one of the following correctly identifies the magnitude of the work done by the force(s) acting on the satellite in one orbit and gives the correct reasoning?

	Magnitude of work done	Reasoning
A.	zero	The net force on the satellite is zero.
B.	zero	The gravitational force acts at 90° to the direction of motion of the satellite.
C.	greater than zero	The work done equals the kinetic energy of the satellite.
D.	greater than zero	The work done equals the gravitational force multiplied by the length of the orbital path of the satellite.

Question 10

In Victoria, high voltage alternating current (HVAC) systems are used in overhead lines to transmit electrical energy over long distances.

The electrical generator at the power station generates electricity at 20 kV RMS. This is then converted to 500 kV RMS for transmission, using a transformer.

The transformer output is 100 MW of electrical power.

Assuming that the transformer is ideal, which one of the following is closest to the RMS current in the 20 kV RMS electrical generator?

A. 2.5 A

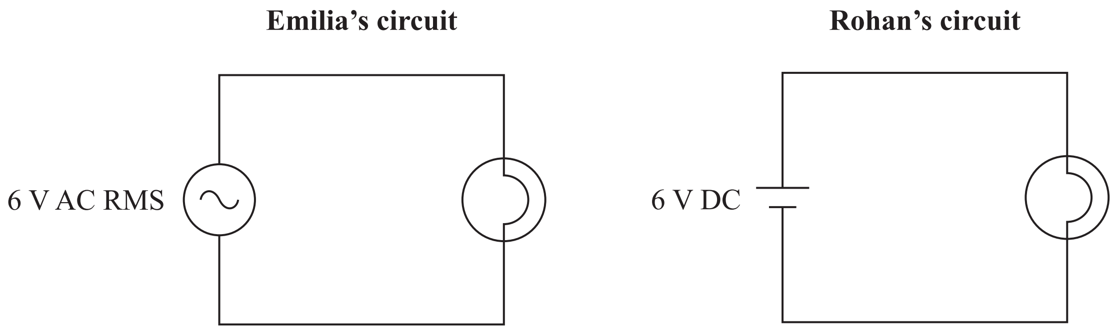
B. 5.0 A

C. 2.5 kA

D. 5.0 kA

Question 11

Emilia and Rohan each connect identical light globes to a power supply. Emilia uses a 6 V AC RMS power supply while Rohan uses a constant 6 V DC power supply, as shown in the diagram below.



Assuming the resistance of the connecting wires is negligible, which one of the following is correct?

A. The average current through the light globe is the same in each circuit.

B. The average power transferred to the light globe is the same in each circuit.

C. The average potential difference across the light globe is the same in each circuit.

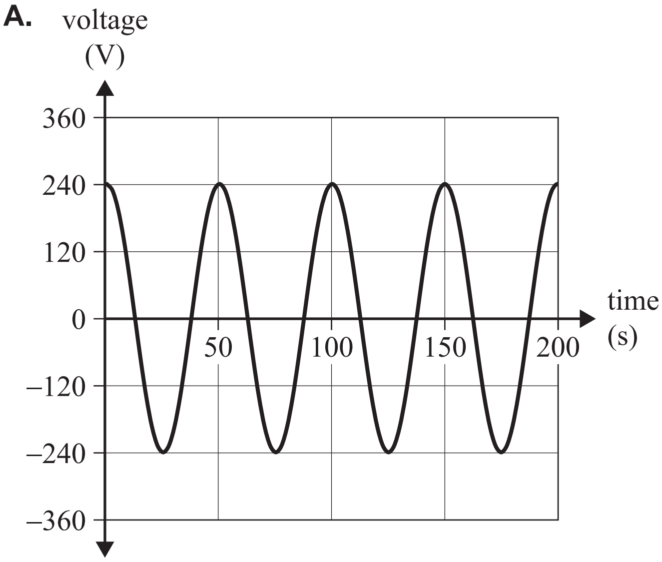
D. The maximum potential difference across the light globe is the same in each circuit.

Question 12

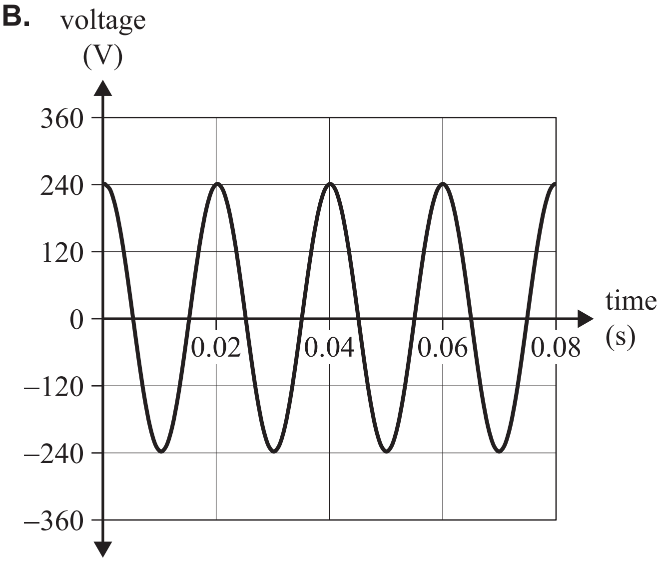
The AC adaptor on a charging cable for a laptop is designed for an input of 240 V RMS at 50 Hz.

Which one of the following traces of the input voltage is best suited to the AC adaptor?

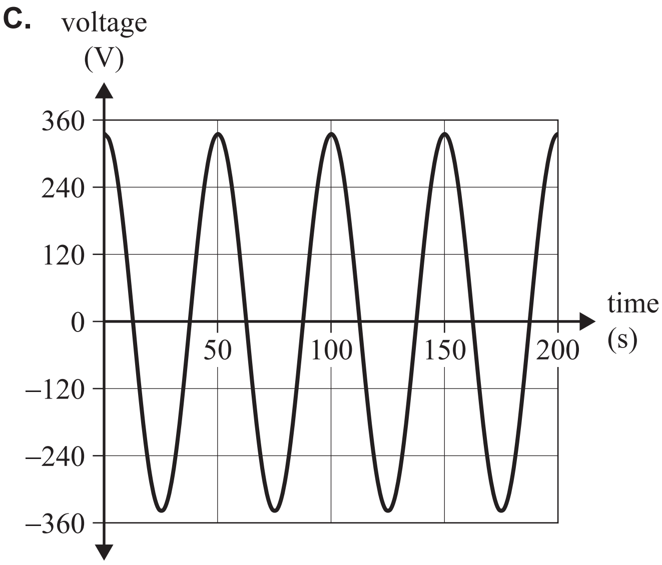
A.



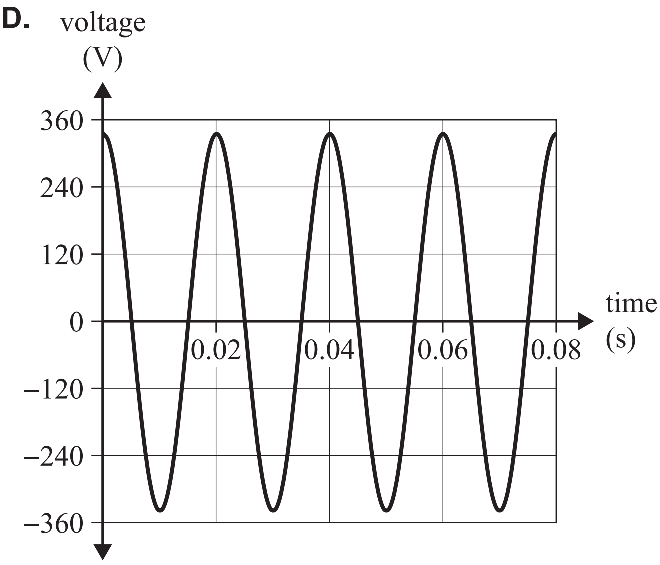
B.



C.

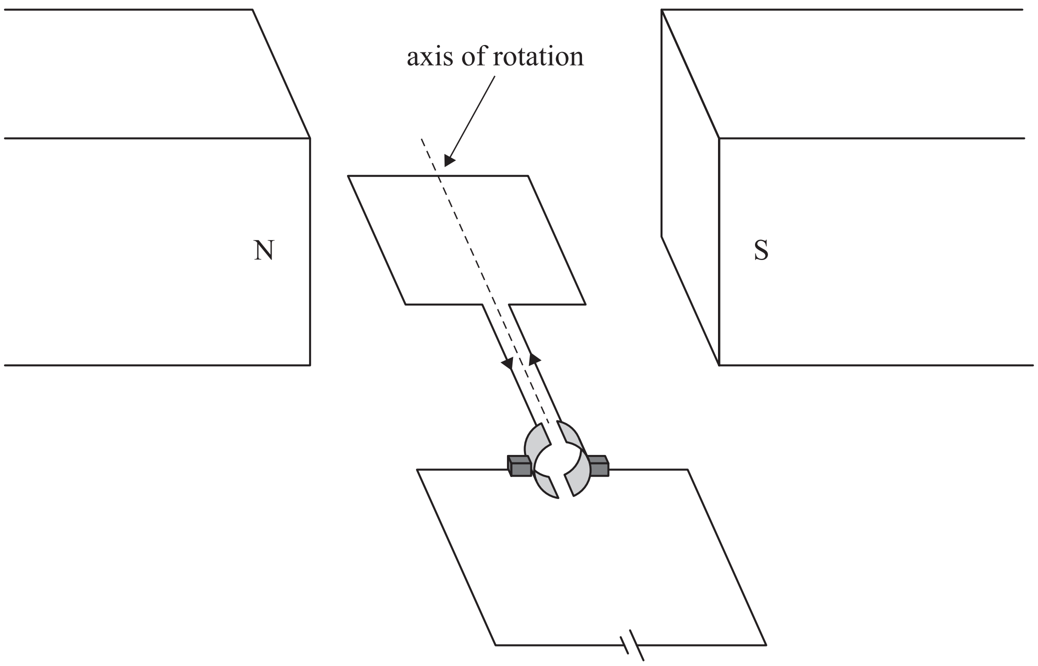


D.



Question 13

Students build a simple electric motor as shown below.



Which one of the following modifications would **not** increase the torque of the motor?

A. increasing the battery voltage

B. increasing the strength of the magnetic field

C. increasing the resistance of the single-turn coil

D. replacing the single-turn coil with a multiple-turn coil

Question 14

Ignoring the motion of Earth, which one of the following travellers is **not** in an inertial frame of reference?

A person

A. seated on a train while the train is stationary at a platform.

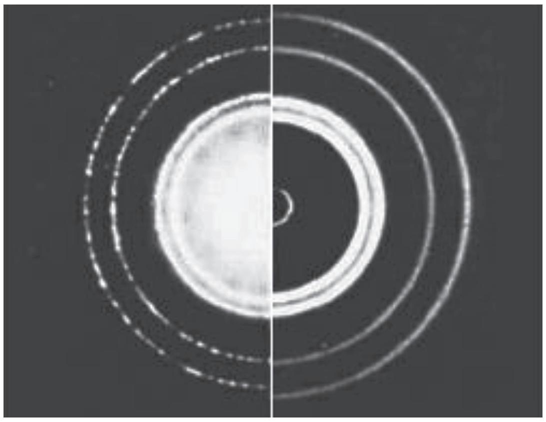
B. seated on a train while the train is travelling at constant velocity.

C. walking at constant velocity along the corridor of a train that is stationary at a platform.

D. standing in the corridor of a train that is travelling around a bend at constant speed.

Question 15

Janet and Boris pass electrons and X-rays through the same crystal sample and observe that the diffraction patterns produced have a similar spacing, as shown below.



This is because the electrons and X-rays used have similar

A. speeds.

B. masses.

C. energies.

D. wavelengths.

Question 16

Protons with a Lorentz factor, γ, equal to 2.10 are injected into a 100 m long beamline in a particle physics laboratory.

In the reference frame of the protons, which one of the following is closest to the length of the beamline?

A. 17.4 m

B. 47.6 m

C. 100 m

D. 210 m

Question 17

Which one of the following phenomena can **only** be explained using the concept of quantisation?

A. absorption spectra of atoms

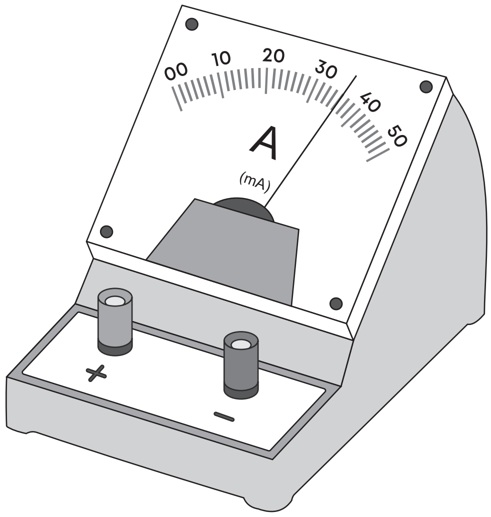
B. diffraction patterns observed with electrons

C. interference patterns observed in Young's double-slit experiment

D. the increase in photocurrent as the intensity of incident light, of a constant frequency, is increased in the photoelectric effect

Question 18

Lia is taking measurements using an analogue ammeter (an ammeter with a scale and pointer), as shown in the diagram below.



Source: <huntingSHARK/Shutterstock.com>

Four possible sources of measurement error are listed below.

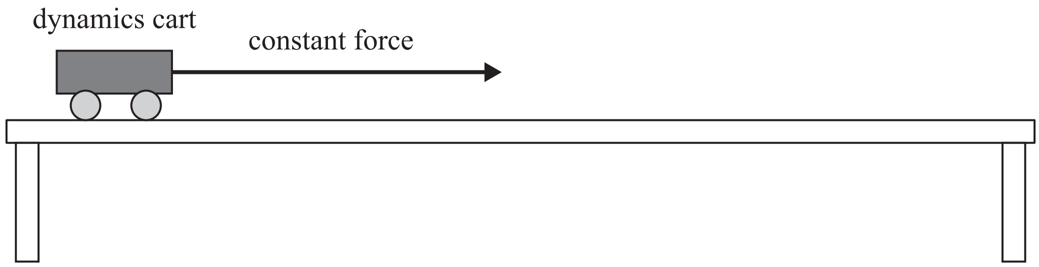
1. The ammeter is not properly zeroed.
2. The reading is made from different angles, which give slightly different scale readings for the same pointer position.
3. The reading on the ammeter is always 5% too high.
4. Internal friction may cause the pointer to sometimes not quite reach the correct position.

Which one of the following correctly identifies the types of measurement error?

	Systematic error	Random error
A.	1 and 3	2 and 4
B.	1 and 4	2 and 3
C.	2 and 4	1 and 3
D.	2 and 3	1 and 4

Question 19

Students place a dynamics cart on the laboratory bench. They apply a constant force to the right on the cart and measure the acceleration of the cart. Their experimental set-up is shown in the diagram below.



The students expect a graph of acceleration versus force to be similar to that in Diagram 1. When they plot their data they obtain the graph in Diagram 2.

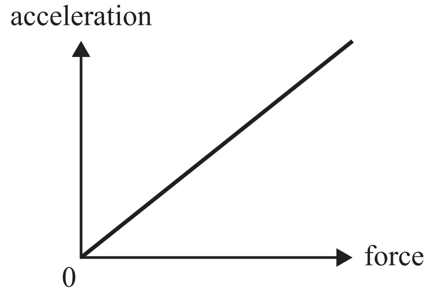


Diagram 1

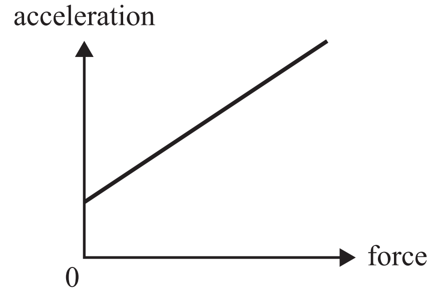


Diagram 2

Which one of the following could explain this?

A. Friction and air resistance act on the cart.

B. The laboratory bench is not exactly level but slopes down to the left.

C. The laboratory bench is not exactly level but slopes down to the right.

D. They were not able to keep the force completely constant. It varied during the measurements.

Question 20

Harriet and Tom were investigating how the speed, v, of a falling object varied with the distance, s, it had fallen.

They dropped a small steel ball, initially at rest, from the third floor of their school building. The speed of the ball was measured at six positions as it fell.

Air resistance can be ignored.

Which one of the following graphs of their data would be expected to result in a straight line through the origin?

A. v versus s

B. v versus $\sqrt{s}$

C. v^2 versus $\sqrt{s}$

D. $\sqrt{v}$ versus s

End of Section A

Section B

Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- 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.

Question 1 (6 marks)

A cat, sitting on a high ledge, gently taps a small bouncy ball off the ledge so that the ball drops vertically to the floor 1.80 m below, as shown in Figure 1.

The ball lands on the ground directly below. Air resistance can be ignored.

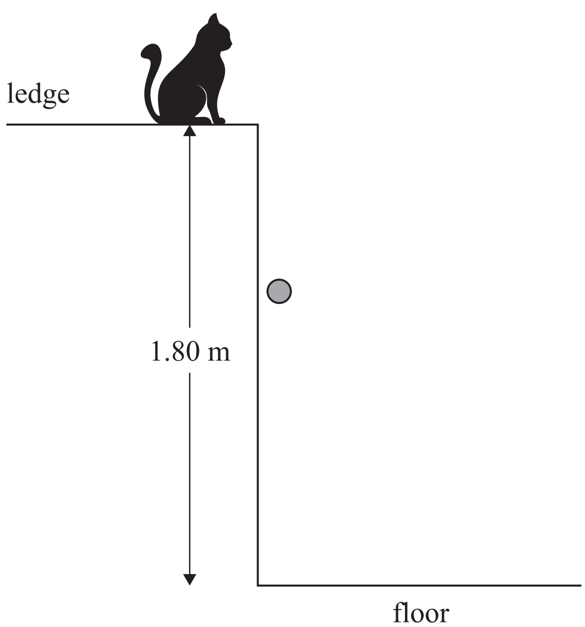


Figure 1

a. Show that the ball takes 0.606 s to fall from the ledge to the floor. 1 mark

b. Calculate the speed of the ball immediately before it hits the floor. 2 marks

m s^{-1}

c. After it hits the floor, the ball rebounds vertically upwards. Explain, in terms of energy transformations, why the ball is unlikely to rebound to the original height of 1.80 m. 1 mark

d. On a second occasion, the cat taps the ball harder, and the ball leaves the ledge horizontally with a velocity of 0.75 m s^{-1}.

How does the time taken for the ball to hit the ground compare with the value in **part a**? (Circle your answer.)

Time will be less. Time will be the same. Time will be greater.

Justify your answer. No calculations are required. 2 marks

Question 2 (6 marks)

The effectiveness of airbags in protecting a driver's head is demonstrated in a crash test. The car comes to a sudden stop when it hits a solid barrier, causing an airbag to inflate. The head of the crash-test dummy hits the airbag. The dummy's head, of mass 5.0 kg, comes to rest a very short time after it first hits the airbag. The initial speed of the dummy's head is 12 m s^{-1}.

This situation can be modelled as a horizontal collision between the dummy's head and the airbag.

Figure 2 shows the position of the crash-test dummy's head, relative to the airbag and steering wheel.

Figure 2

Source: Adapted from <https://ctmirror.org/2022/09/29/airbags-like-being-in-the-ring-with-george-forman/>; photo © www.iihs.org

a. Calculate the magnitude of the impulse that the dummy's head exerts on the airbag during the collision. 1 mark

N s

b. Justify the inclusion of airbags in cars by comparing the average force on the dummy's head in the airbag collision to that in a collision at the same speed with just the steering wheel.

No calculations are required. 2 marks

c. Figure 3 is a simplified graph of the force on the dummy's head by the airbag, F, versus displacement, s.

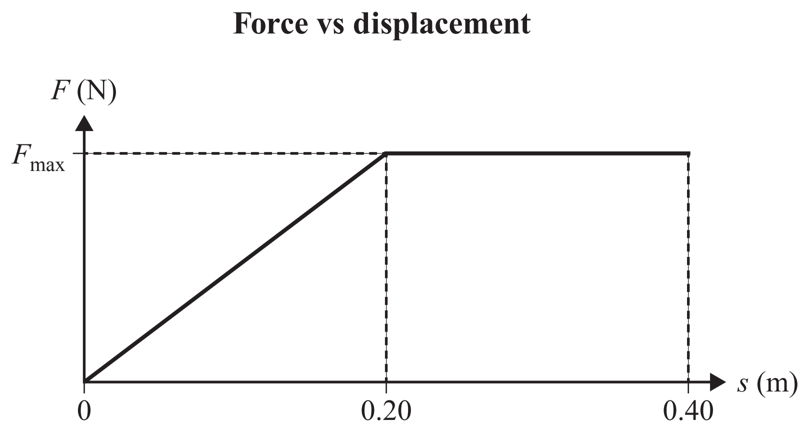


Figure 3

The dummy's head comes to rest after a displacement of 0.40 m.

Determine the maximum force, F_{max}, acting on the dummy's head. Show your working. 3 marks

N

Question 3 (6 marks)

A snowboarder with a total mass (including snowboard) of 72.0 kg slides down a snow slope at a constant speed, as shown in Figure 4. The angle of the slope is 15.0°.

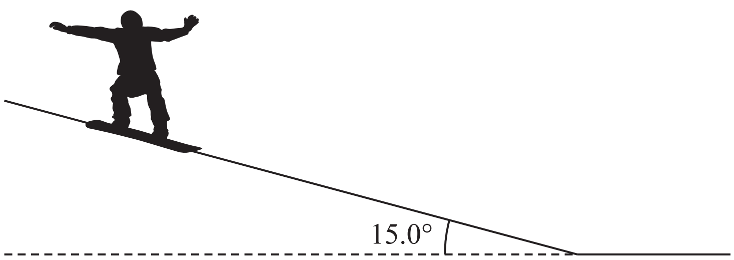


Figure 4

Source: Adapted from <Real Sports Photos/Shutterstock.com>

This situation can be modelled as a 72.0 kg object sliding down an inclined plane, as shown in Figure 5.

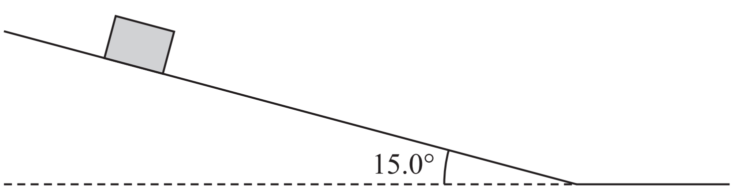


Figure 5

a. On Figure 5, draw arrows to represent the direction of each individual force acting on the snowboarder. Label each force clearly. 3 marks

b. Show that the magnitude of the total of all the resistive forces opposite to the direction of the motion of the snowboarder is 183 N. 1 mark

c. The snowboarder does not exert any effort to increase, decrease or maintain constant speed but just slides down the slope from position A to B to C, as shown in Figure 6.

At the bottom of the slope, position B, the snowboarder continues to slide along a horizontal section, coming to rest at position C. Assume that the total resistive force remains constant from position A to position C.

The speed of the snowboarder at position B is 10.0 m s^{-1}.

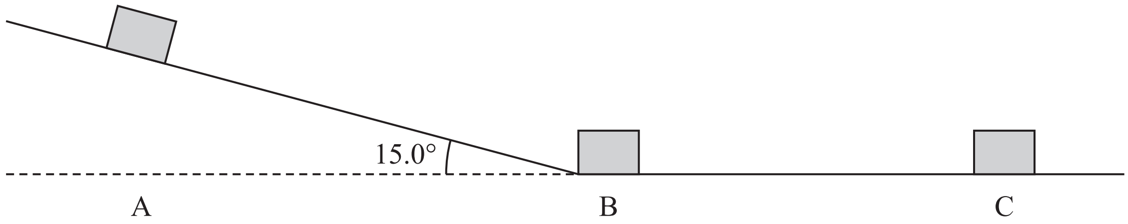


Figure 6

Calculate the distance travelled from position B until the snowboarder comes to rest at position C. 2 marks

m

Question 4 (5 marks)

An engineer, Sam, is designing a new track for a high-speed racing car.

The car makes a circular turn of radius 240 m on a flat track. A top view of this situation is shown in Figure 7. The sideways force between the tyres and the horizontal road surface is measured.

The car and driver have a combined mass of 800 kg and travel at a constant speed of 30 m s^{-1} around the curve.

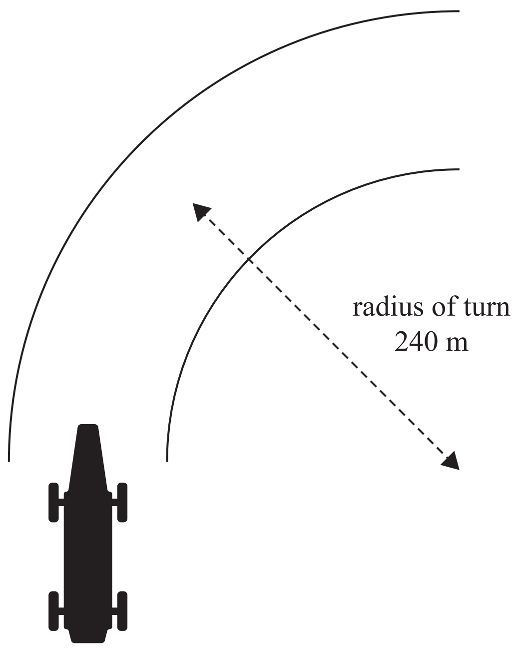


Figure 7

a. Calculate the magnitude of the total sideways force on the tyres from the horizontal road surface. 2 marks

N

b. Sam wishes to preserve the car tyres as much as possible. She calculates a banking angle, θ, of a curved track that would result in no sideways friction force on the tyres as the car travels around the curve. The design of the banked track, viewed from behind the car, is shown in Figure 8.

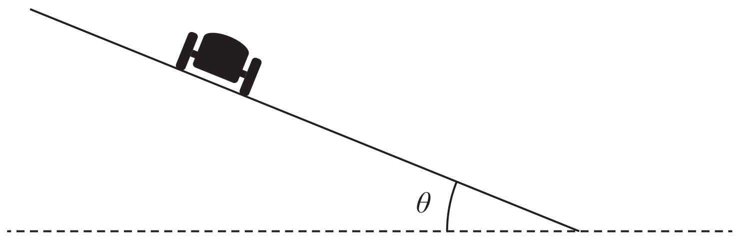


Figure 8

Determine the value of the banking angle, θ. The speed and radius of the turn are unchanged. 3 marks

°

Question 5 (4 marks)

Two identical point charges, each with a charge of 3.00 μC, are fixed in positions A and C, as shown in Figure 9.

Positions B and D are unoccupied.

Together, positions A, B, C and D form a square of side length 5.00 cm.

The direction of north is shown as N in Figure 9.

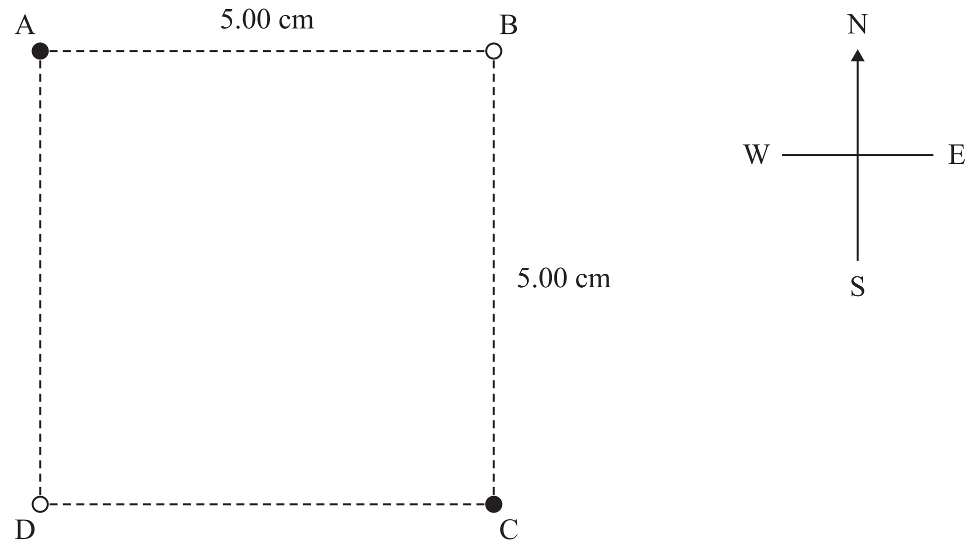


Figure 9

a. Show that the magnitude of the electric field at position D due to the point charge at position A is 1.08×10^7 N C^{-1}. 1 mark

b. Calculate the resulting magnitude of the electric field, and its direction, at position D due to both the point charges at positions A and C. 3 marks

$N\ C^{-1}$

Direction:

Question 6 (4 marks)

Electrons are emitted by a hot filament connected to a 12 V battery. These electrons are accelerated between two metal plates, P and Q, which are 50 mm apart. The plates are connected to a battery and the potential difference between them is 250 V.

The experimental set-up is shown in Figure 10. The entire apparatus is enclosed in a vacuum.

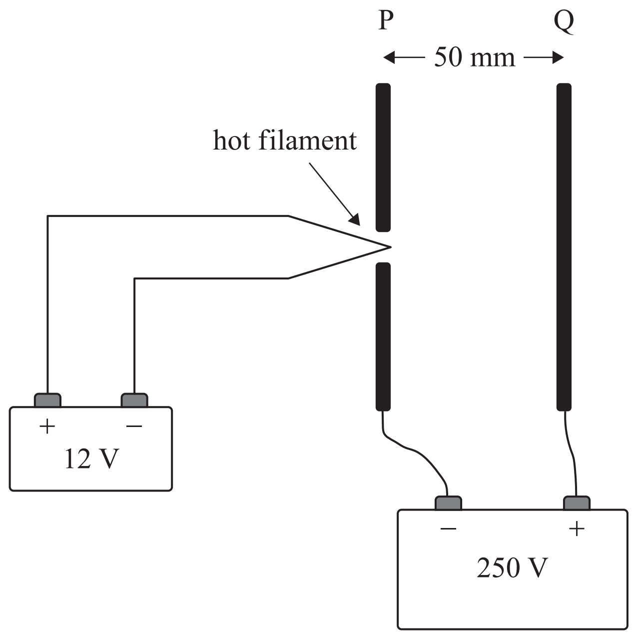


Figure 10

While it is moving between plates P and Q, the electron has an electric force, F_e, acting on it and gains kinetic energy, E_k.

a. Calculate the magnitude of the electric force, F_e, acting on the electron while it is moving between plates P and Q. 2 marks

N

b. The distance between the two charged plates is now doubled to 100 mm.

Explain any changes to the kinetic energy, E_k, of the electron while it is moving from plate P to plate Q. 2 marks

Question 7 (3 marks)

An electron travelling with a speed of 7.80×10^7 m s^{-1} enters a uniform magnetic field, B, as shown in Figure 11. The magnetic force acting on the electron causes it to travel in a circular arc.

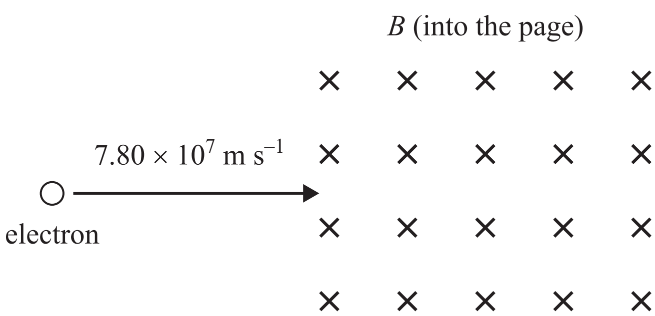


Figure 11

a. Determine the direction of the magnetic force acting on the electron as it enters the uniform magnetic field. 1 mark

b. The strength of the magnetic field, B, is 2.50×10^{-4} T.

Calculate the radius of the electron's path. Give your answer to three significant figures.

Ignore relativistic effects. 2 marks

m

Question 8 (6 marks)

An observation satellite of mass 2.60×10^3 kg, shown in Figure 12, is placed in a circular orbit at an altitude of 1.25×10^3 km above Earth's surface.

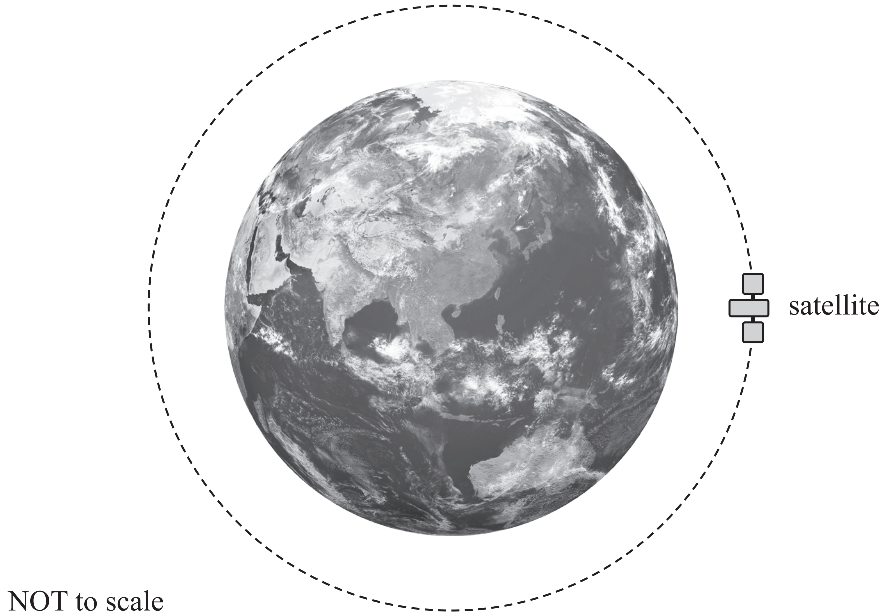


Figure 12

Source: Adapted from <Alex Staroseltsev/Shutterstock.com>

a. Show that the satellite's orbital period is 6.62×10^3 s. 2 marks

b. Calculate the gravitational force that acts on the satellite due to Earth. 2 marks

N

c. With reference to Newton's laws of motion, explain why the satellite is accelerating towards Earth. 2 marks

Question 9 (2 marks)

Tom is calculating the work done on a 500 kg spacecraft to move it from Earth's surface to an altitude of 250 km. His working is as follows.

$$\begin{aligned} W &= mg\Delta h \\ &= 500 \times 9.81 \times 250\,000 \\ &= 1.23 \times 10^{9}\ \text{J} \end{aligned}$$

Ignoring air resistance, identify the assumption Tom made in using this formula, and state its effect on the value of *W*.

Question 10 (5 marks)

A bar magnet is dropped vertically through a solenoid connected to a sensitive ammeter, as shown schematically in Figure 13.

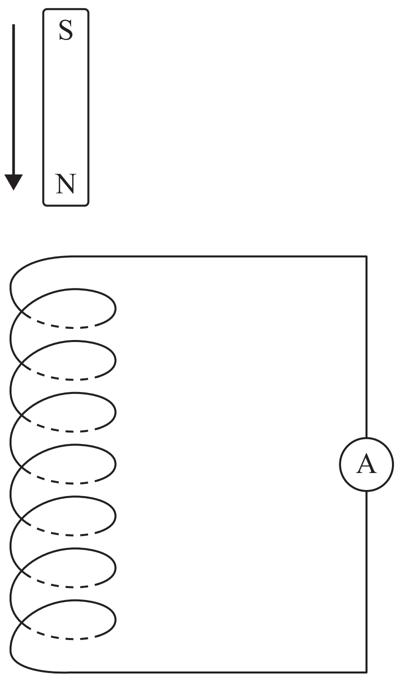


Figure 13

a. As the magnet falls through the solenoid, a **current** is observed.

Explain this observation. 2 marks

b. The ammeter is replaced with an oscilloscope. The measurement of induced EMF versus time, shown in Figure 14, is recorded as the magnet falls. Note there is a large negative induced EMF spike at A, and an even larger positive induced EMF spike at B.

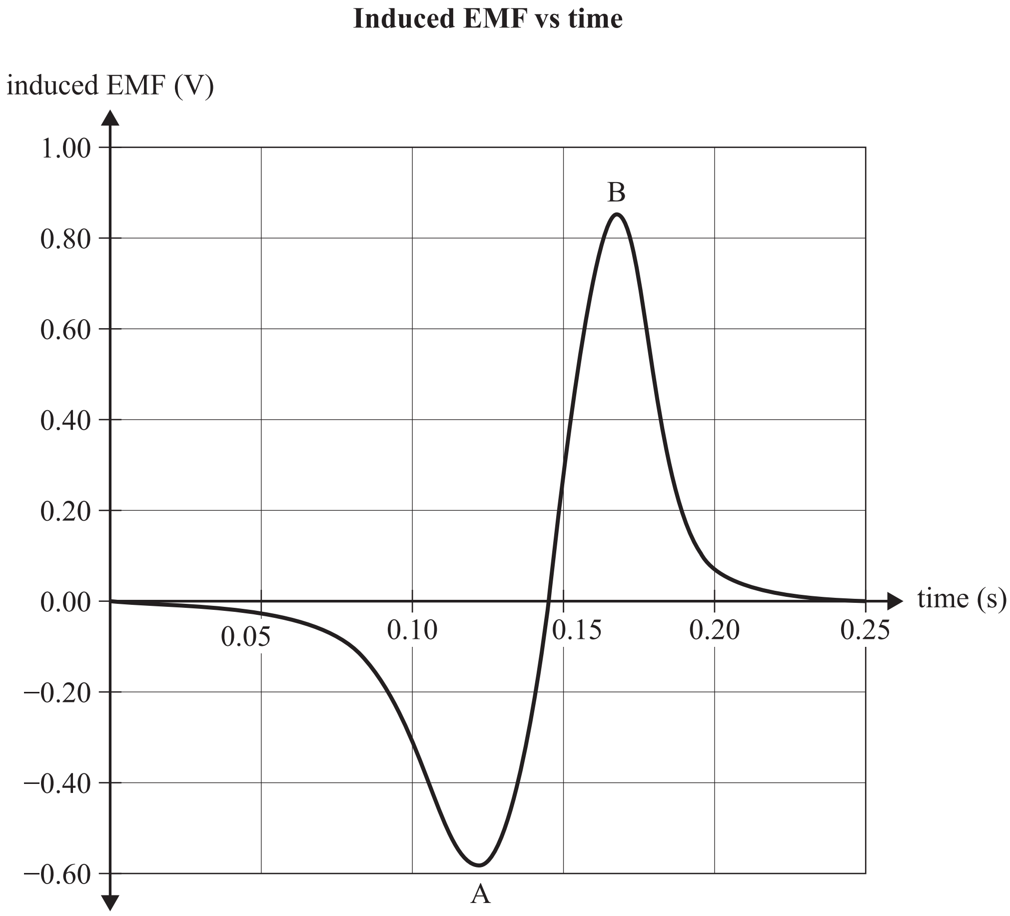


Figure 14

The magnitude of the maximum induced EMF of the spike at B is **both** opposite in sign to, **and** larger than, the maximum induced EMF of the spike at A. Explain. 3 marks

Question 11 (7 marks)

Janine is a poultry farmer.

She is interested in using renewable energy to supply the power to a shed containing heat lamps for chicken incubators.

She uses a wind turbine that supplies an AC voltage of 230 V RMS and can deliver up to 5.00 kW of electrical power.

The best location for the wind turbine is 900 m away from the shed. The total resistance of the wires connecting the turbine to the shed is 6.0 Ω. The system is represented schematically in Figure 15.

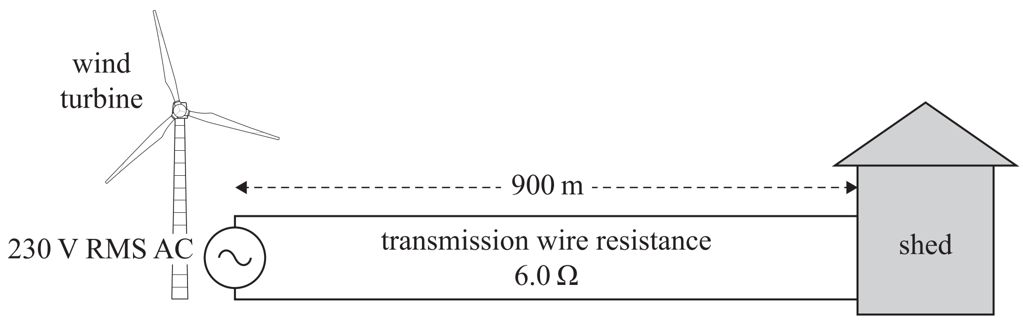


Figure 15

Source: Adapted from <vectorisland/Shutterstock.com>

a. Each heat lamp is designed to dissipate 70 W of power and is intended to be operated with a minimum voltage of 210 V RMS. Show that the current through a heat lamp under these conditions is 0.33 A RMS. 1 mark

b. Janine connects a number of heat lamps, in parallel, in the shed. When the wind turbine is operating, the potential difference across the shed is 210 V RMS. How many heat lamps have been installed? Show your working. 3 marks

c. Janine's friend, Zana, suggests including transformers, T_1 and T_2, as shown in Figure 16, to increase the number of heat lamps that can be powered by the wind turbine.

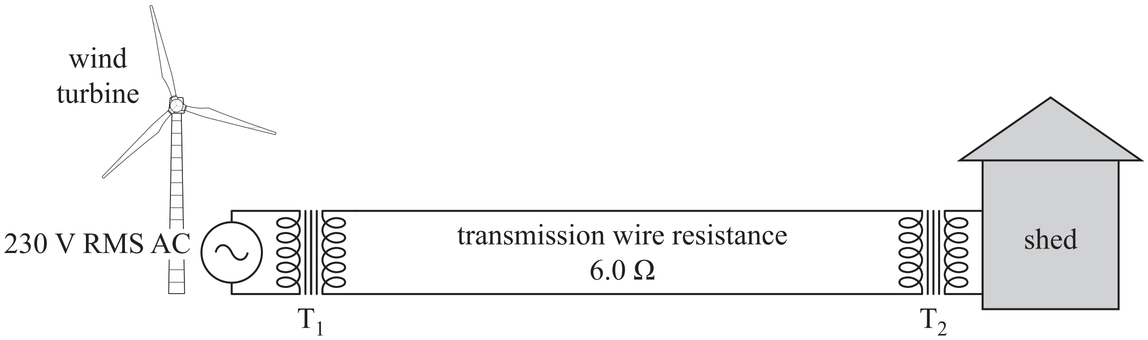


Figure 16

Source: Adapted from <vectorisland/Shutterstock.com>

i. Identify the specific type of transformer, step-up or step-down, that should be used for T_1 and T_2 respectively. 1 mark

T_1:

T_2:

ii. Justify your choices for step-up or step-down transformers. 2 marks

Question 12 (7 marks)

Denzil is using a demonstration hand-cranked generator.

A schematic diagram of the generator is shown in Figure 17. The generator contains a rectangular coil with side lengths of 5.0 cm and 2.5 cm, consisting of 20 turns of insulated copper wire. The coil is rotated between two bar magnets that provide a field strength of 0.60 T between the magnets.

Denzil rotates the coil at a frequency of 50 Hz.

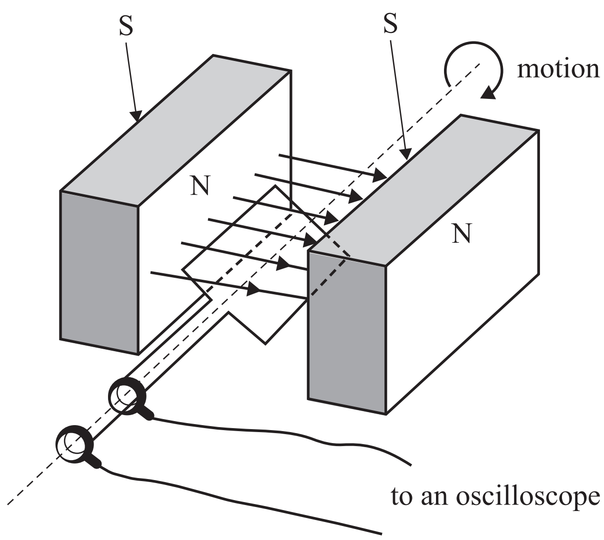


Figure 17

a. State why the flux through the coil changes as the coil rotates. 1 mark

b. Show that the change in flux as the coil rotates from a horizontal to a vertical position is 7.5×10^{-4} Wb. 1 mark

c. Calculate the average EMF induced as the coil is rotated through a quarter turn from a horizontal to a vertical position. 3 marks

V

d. State a change to the set-up in Figure 17 that could produce a DC output from the generator. Give a reason for your choice. 2 marks

Question 13 (3 marks)

Diffraction patterns can be produced by directing electrons at a graphite foil.

Electrons are emitted by a hot filament at the cathode, accelerated by the anode and hit the target graphite foil, producing diffraction patterns on a fluorescent screen, as shown in Figure 18.

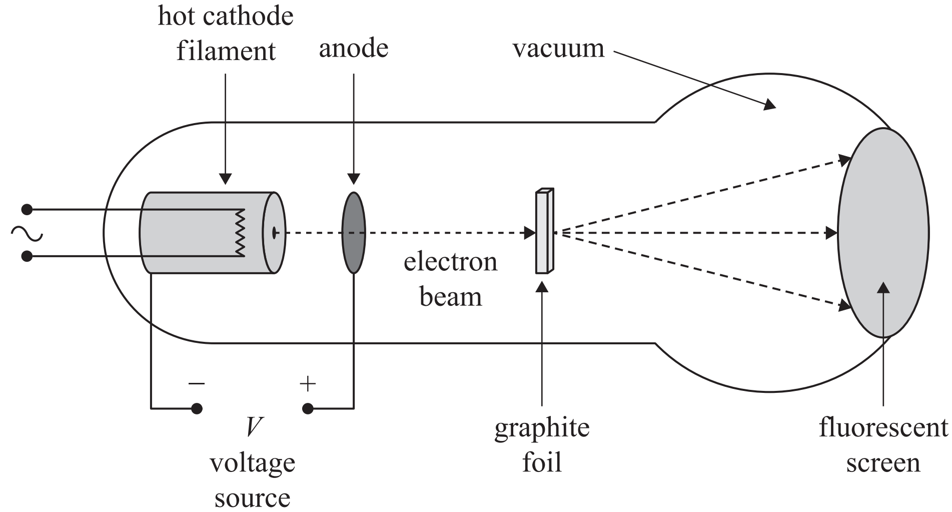


Figure 18

A diffraction pattern is observed using electrons of de Broglie wavelength 1.20×10^{-11} m.

Determine the accelerating voltage, V, applied to the anode, that is needed to produce electrons with this wavelength. Ignore relativistic effects.

kV

Question 14 (3 marks)

Explain how the null result of the Michelson–Morley experiment supports Einstein's special theory of relativity.

Question 15 (4 marks)

In a Young's double-slit experiment, a green light source of wavelength 550 nm is incident on two slits. The resulting interference pattern, on a screen situated 2.00 m behind the slits, includes a group of bright bands that are 2.75 mm apart. The set-up is shown in Figure 19.

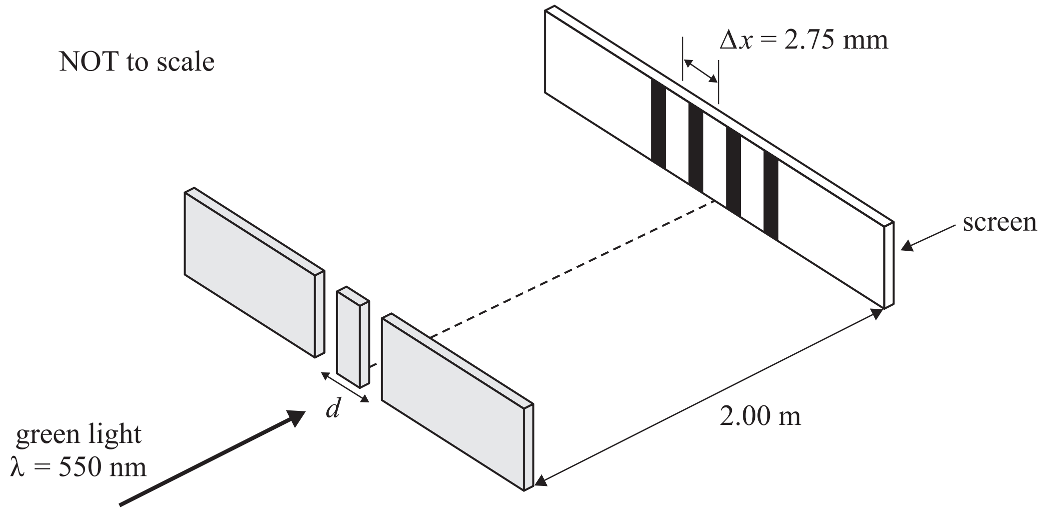


Figure 19

a. Calculate the slit separation, d. 2 marks

m

b. The green light source is replaced with a light source of lower frequency.

Explain the effect that the change of light source will have on the interference pattern observed on the screen. 2 marks

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Examination continues on the next page.

Question 16 (3 marks)

Jessica and Matthew investigate the photoelectric effect.

They expose a metal sample to light of constant intensity but varying frequency, and measure the voltage required to stop the most energetic electrons.

This allows them to calculate the maximum kinetic energy, $E_{k\ max}$, of the electrons.

The data collected is plotted and a trend line is drawn, as shown in Figure 20.

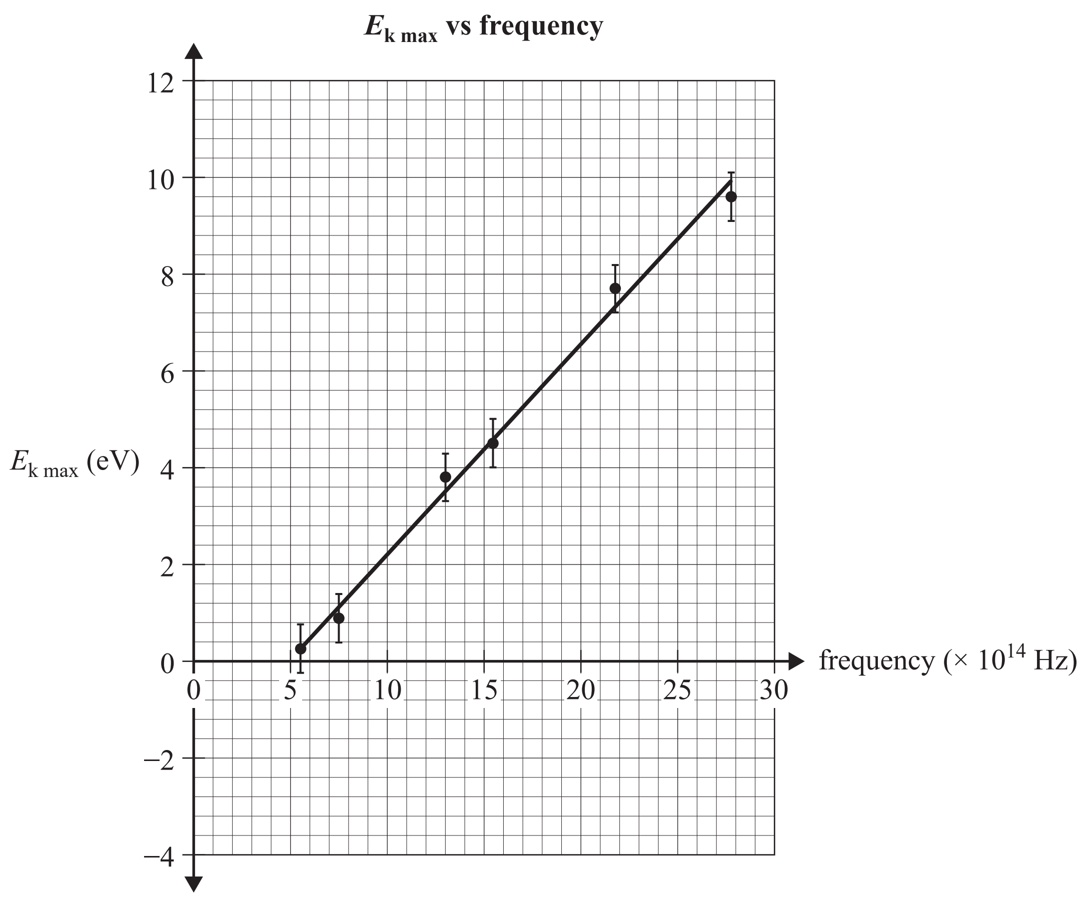

Figure 20

a. Using Figure 20, calculate Planck's constant. 2 marks

eV s

b. Using Figure 20, determine the work function for the metal used. 1 mark

eV

Question 17 (3 marks)

Consider the following hypothetical situation.

Rachel is driving her rocket-powered vehicle along a straight test track and travels at a constant velocity between two timing points. The dashboard of Rachel's vehicle shows that the time interval is 1.000 s.

Sandra is standing beside the track and measuring the time for the rocket-powered vehicle to move between the same timing points, but records a time interval of 1.010 s.

Calculate Rachel's speed relative to Sandra.

Give your answer as a multiple of c.

c

Question 18 (3 marks)

A hydrogen atom emits a photon with energy 2.9 eV.

a. Calculate the wavelength of the emitted photon in nanometres (nm). 2 marks

nm

b. Figure 21 shows some of the energy levels of hydrogen atoms.

Draw an arrow on Figure 21 that would represent the transition in **part a**. 1 mark

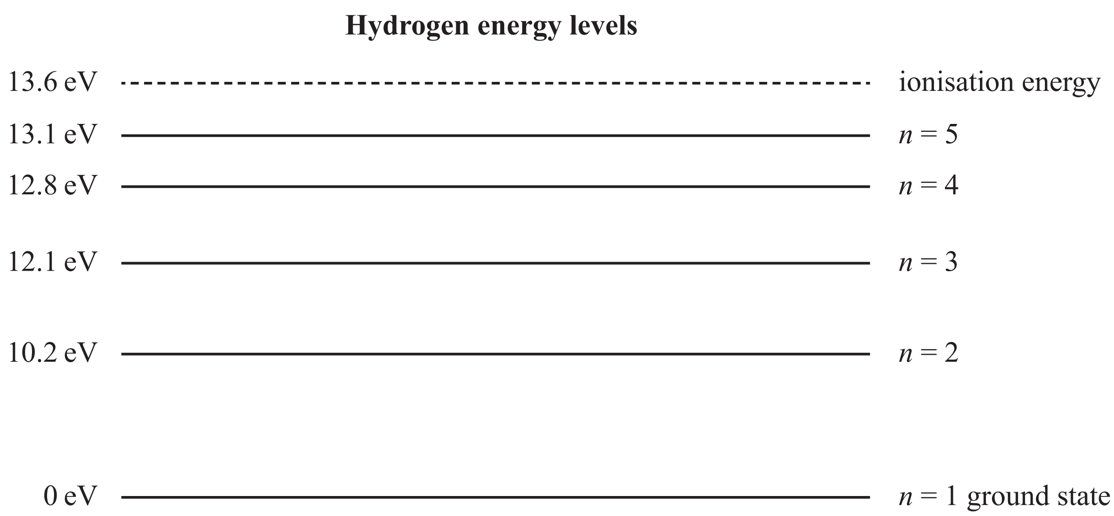

Figure 21

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Examination continues on the next page.

Question 19 (20 marks)

Luca and Declan are investigating how the magnetic force, F_B, on a current-carrying conductor in a magnetic field, B, depends on the current, I.

A diagram of the apparatus is shown in Figure 22. It consists of:

- a plastic beam to which a U-shaped current-carrying loop of wire, PQRS, is attached. The plastic beam is slightly heavier at the left end, to balance the weight of the wire on the other half of the beam. The beam is pivoted halfway along its length
- a solenoid used to produce a constant uniform magnetic field, B.

With the plastic beam level, the loop, PQRS, is inserted into the solenoid, as shown in Figure 22.

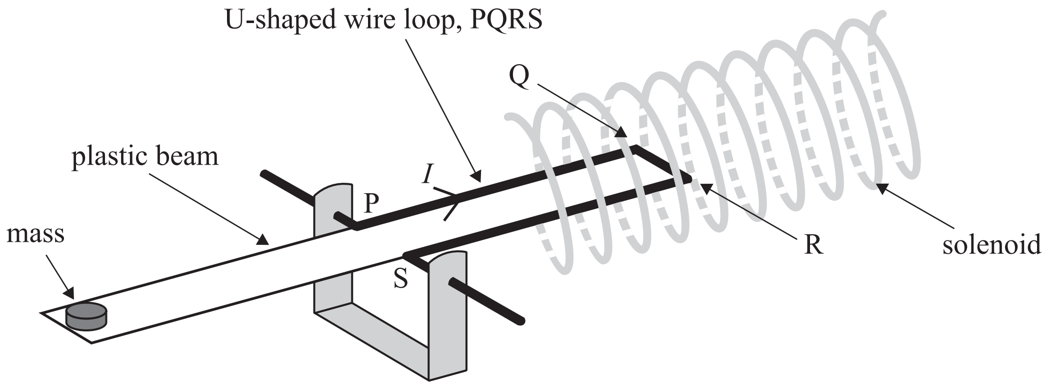

Figure 22

A very small mass, m, is placed on the left-hand end of the plastic beam. The force due to gravity, mg, acts on this mass.

A current, I, is then passed through the loop, PQRS, creating a downwards magnetic force, F_B, on the end of the loop, QR. The relevant forces on the plastic beam are shown in Figure 23.

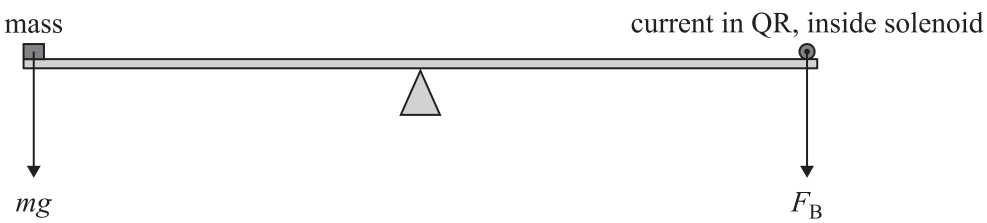

Figure 23

The current through the loop is adjusted until the beam is balanced and the downwards magnetic force, F_B, equals mg. The current, I, and the magnetic force, F_B, are then recorded. Luca and Declan repeat the experiment with different masses.

a. Complete the table below by providing **one** variable from the investigation for each classification. 3 marks

Classification	**Variable**
independent	
dependent	
controlled	

b. Explain why the effect of the magnetic field on the two sides of the U-shaped loop, PQ and RS, has not been considered in the experiment. 2 marks

c. It is important that the beam is pivoted at its centre. Explain why this is necessary. 2 marks

d. Each time Luca and Declan change the mass, m, they adjust the current, I, to rebalance the beam. They repeat the measurement for each mass five times and calculate the average.

State the importance of taking repeated measurements. 1 mark

Question 19 continues on the next page.

e. The results Luca and Declan obtained are shown in Table 1.

Table 1

Magnetic force, F_B ($\times 10^{-6}$ N)	**Average current, *I* (A)**
0	0.0
120	1.0
240	2.0
360	3.0
600	4.6

The uncertainty in the measurement of the current is ±0.2 A.

The uncertainty in the measurement of the force is negligible.

On Figure 24, plot a graph of the data in Table 1 with current, *I*, on the vertical axis and magnetic force, F_B, on the horizontal axis.

You must include uncertainty bars and a trend line. You may assume that the trend line passes through the origin. 5 marks

Current vs magnetic force

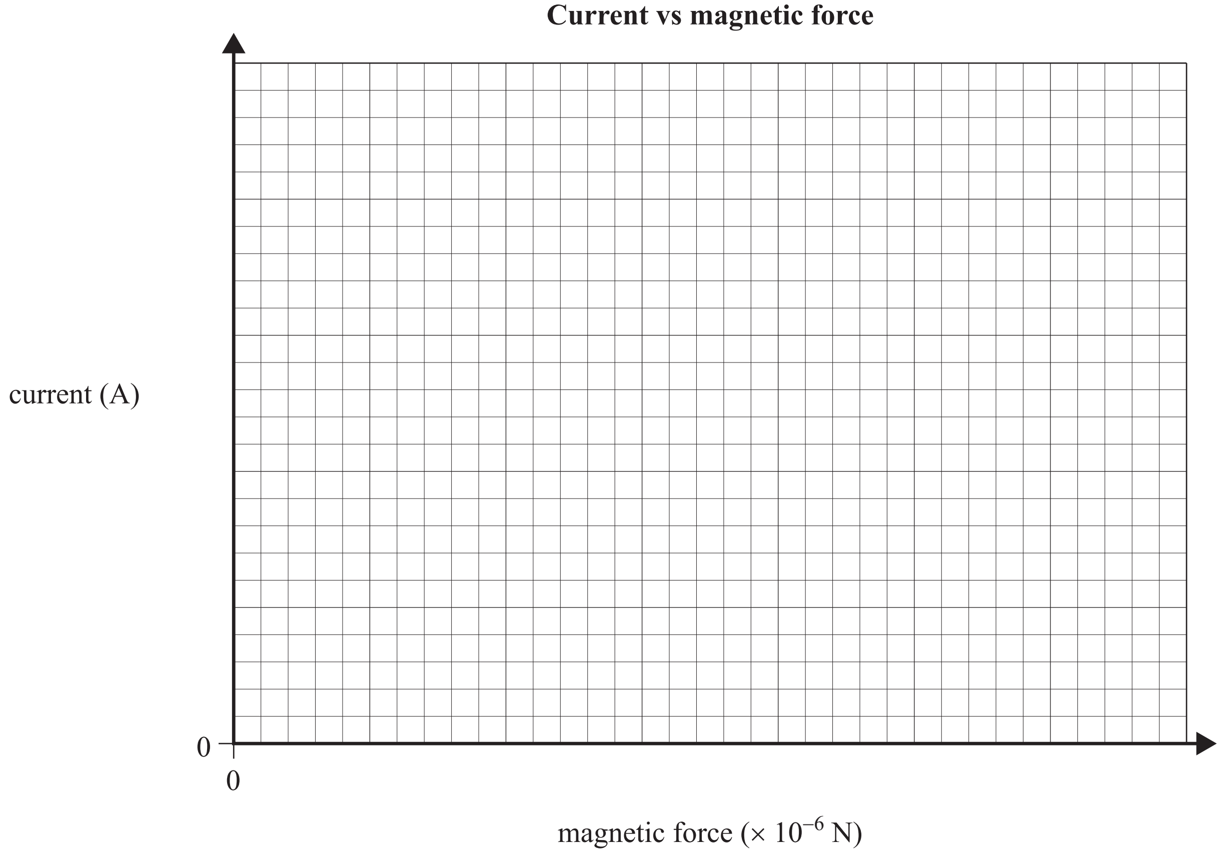

Figure 24

f. Using your graph in Figure 24, calculate the gradient of the trend line. Show your working. 2 marks

A N^{-1}

g. **i.** Luca measures the length of the wire QR to be 2.0 cm.

Use this length and the value of the gradient found in **part f** to estimate the strength of the magnetic field, B, inside the solenoid. 3 marks

T

ii. State what would happen to the magnetic force, F_B, if wire QR was shorter in length. Justify your answer. 2 marks

End of Question and Answer Book

Physics

2025 Formula Sheet

You may keep this Formula Sheet.

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Motion and related energy transformations

velocity; acceleration	$v = \frac{\Delta s}{\Delta t}$; $a = \frac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(u + v)t$
Newton's second law	$\Sigma F = ma$
uniform circular motion	$F_{\text{net}} = \frac{mv^2}{r}$ $v = \frac{2\pi r}{T}$
Hooke's law	$F = -kx$
elastic potential energy	$E_s = \frac{1}{2}kx^2$
gravitational potential energy	$E_g = mg\Delta h$
kinetic energy	$E_k = \frac{1}{2}mv^2$
Newton's law of universal gravitation	$F_g = G\frac{m_1 m_2}{r^2}$
gravitational field	$g = G\frac{M}{r^2}$
impulse	$F\Delta t = m\Delta v$
momentum	$p = mv$

Einstein's special theory of relativity

Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
time dilation	$t = \gamma t_0$
length contraction	$L = \frac{L_0}{\gamma}$
relativistic rest energy	$E_0 = mc^2$
relativistic total energy	$E_{\text{total}} = E_k + E_0 = \gamma mc^2$
relativistic kinetic energy	$E_k = (\gamma - 1)mc^2$

Fields and application of field concepts

uniform electric field between charged plates	$E = \frac{V}{d}$
energy transformations of charges in an electric field	$\frac{1}{2}mv^2 = qV$
field of a point charge	$E = k\frac{Q}{r^2}$
electric force on a charged particle	$F = qE$
Coulomb's law	$F = k\frac{q_1 q_2}{r^2}$
magnetic force on a moving charge	$F = qvB$
magnetic force on a current-carrying conductor	$F = nIlB$
radius of a charged particle in a uniform magnetic field	$r = \frac{mv}{qB}$

Generation and transmission of electricity

current; power	$I = \frac{V}{R}; \quad P = VI$
resistors in series	$R_T = R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
ideal transformer action	$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$
AC voltage and current	$V_{RMS} = \frac{1}{\sqrt{2}}V_{peak} \qquad I_{RMS} = \frac{1}{\sqrt{2}}I_{peak}$
electromagnetic induction	$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t} \qquad \Phi_B = B_\perp A$
transmission losses	$V_{drop} = I_{line} R_{line} \qquad P_{loss} = I^2_{line} R_{line}$

Waves

wave equation	$v = f\lambda$
constructive interference	path difference $= n\lambda$
destructive interference	path difference $= \left(n + \frac{1}{2}\right)\lambda$
interference pattern spacing	$\Delta x = \frac{\lambda L}{d}$ when $L >> d$

The nature of light and matter

photoelectric effect	$E_{k\,max} = hf - \phi$
photon energy	$E = hf = \frac{hc}{\lambda}$
photon momentum	$p = \frac{h}{\lambda}$
de Broglie wavelength	$\lambda = \frac{h}{p}$

Data

acceleration due to gravity at Earth's surface	$g = 9.81 \text{ m s}^{-2}$
mass of the electron	$m_e = 9.11 \times 10^{-31}$ kg
magnitude of the charge of the electron	$q_e = 1.60 \times 10^{-19}$ C
Planck's constant	$h = 6.63 \times 10^{-34}$ J s $h = 4.14 \times 10^{-15}$ eV s
speed of light in a vacuum	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$
universal gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
mass of Earth	$M_E = 5.97 \times 10^{24}$ kg
radius of Earth	$R_E = 6.37 \times 10^{6}$ m
Coulomb constant	$k = 8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$

Metric (SI) multipliers

p = pico = 10^{-12}	n = nano = 10^{-9}	μ = micro = 10^{-6}	m = milli = 10^{-3}
k = kilo = 10^{3}	M = mega = 10^{6}	G = giga = 10^{9}	T = tera = 10^{12}

Unit conversions

1 tonne (t) = 10^3 kg
1 kilowatt hour (kW h) = 3.6×10^6 J

Nomenclature

force due to gravity	F_g
terminology for force	$F_{\text{on A by B}}$
normal force	F_N

End of Formula Sheet