2026
NHT

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

Physics

Question and Answer Book

VCE (NHT) Examination – Monday 25 May 2026

- Reading time is **15 minutes**: 2.00 pm to 2.15 pm
- Writing time is **2 hours 30 minutes**: 2.15 pm to 4.45 pm

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

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

A ball moves horizontally to the right and collides with a baseball bat swung horizontally to the left, as shown in Diagram 1. The ball rebounds horizontally towards the left at a faster speed than before (Diagram 2). The speeds before and after the collision are indicated by the length of the arrows shown in the diagrams below.

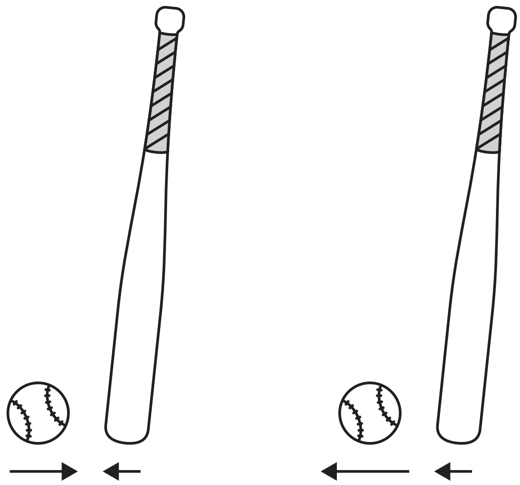


Diagram 1 **Diagram 2**

Which one of the following best describes the changes in the kinetic energy and the magnitude of the momentum of the ball due to this collision?

	Change in the kinetic energy of the ball	Change in the magnitude of the momentum of the ball
A.	increases	increases
B.	increases	constant
C.	increases	decreases
D.	decreases	constant

Question 2

A statue rests on the ground as shown.

The mass of the statue is 75 kg.

Which one of the following is closest to the force on the statue by the ground?

A. zero

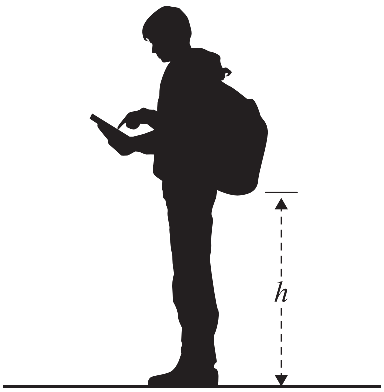
B. 736 N upwards

C. 736 N downwards

D. 1472 N upwards

Question 3

While George is waiting for the bus, he accidentally drops his schoolbag from a height, h, as shown below. It hits the ground after a time, t.



Source: Adapted from Yuriy2012/Shutterstock.com

The bag and its contents have a mass of m. Ignore air resistance.

Which one of the following is closest to the speed of the schoolbag just before it lands on the ground?

A. mgh

B. $2gh$

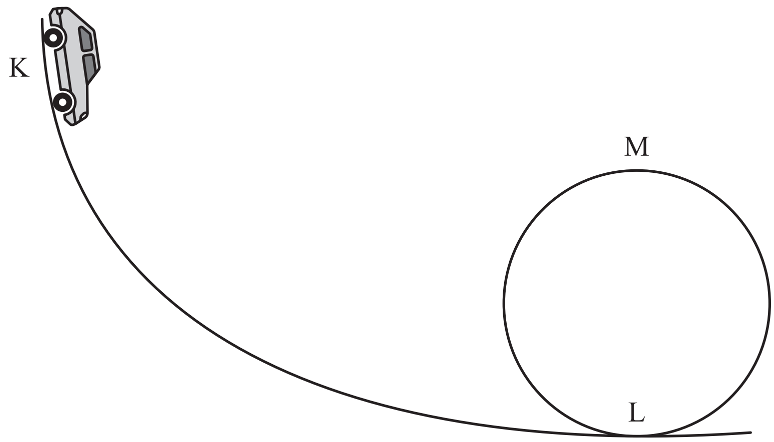
C. $\frac{h}{t}$

D. $\sqrt{2gh}$

Question 4

A toy car is released from point K and rolls along a curved section of track. It enters a vertical loop at point L to do a loop the loop, as shown below.

At the top point of the circle, M, the car maintains contact with the track.



Two forces acting on the car have magnitudes given by:

- F_g, the gravitational force
- $F_{\text{on car by track}}$, the normal force on the car by the surface of the track.

Which one of the following best describes the conditions under which the car can move in a vertical circle starting at point L and not fall off the track at point M?

	At point L, $F_{\text{on car by track}}$ is	At point M, the net force on the car is
A.	greater than F_g	$F_g - F_{\text{on car by track}}$
B.	less than F_g	$F_g + F_{\text{on car by track}}$
C.	greater than F_g	$F_g + F_{\text{on car by track}}$
D.	less than F_g	$F_g - F_{\text{on car by track}}$

Question 5

Which one of the following best describes gravitational, magnetic and electric fields?

A. All three fields can both attract and repel.

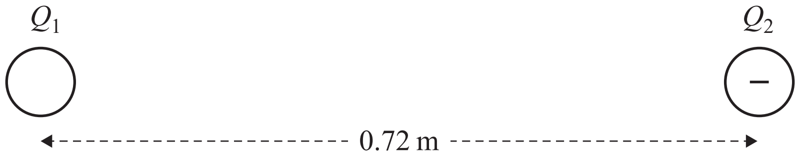
B. Gravitational and magnetic fields can only attract, while electric fields can attract or repel.

C. Gravitational and electric fields can only attract, while magnetic fields can attract or repel.

D. Gravitational fields can only attract, while magnetic and electric fields can attract or repel.

Question 6

Two electric charges, Q_1 and Q_2, are separated by a distance of 0.72 m, as shown below. The charge on Q_2 is −3.6 μC.



Q_1 experiences a force of 1.5×10^{-3} N to the left.

Which one of the following best describes the charge on Q_1?

A. -2.4×10^{-8} C

B. -3.3×10^{-8} C

C. $+2.4 \times 10^{-8}$ C

D. $+3.3 \times 10^{-8}$ C

Question 7

The Tiangong space station is in a circular orbit at an altitude of 389 km above Earth's surface.

The magnitude of Earth's gravitational field at this altitude is 8.72 N kg^{-1}.

An astronaut with a total mass of 100 kg including spacesuit is in the Tiangong space station orbiting Earth.

Source: Adapted from mentalmind/Shutterstock.com

Which one of the following is closest to the normal force acting on the astronaut while in orbit?

A. 0 N

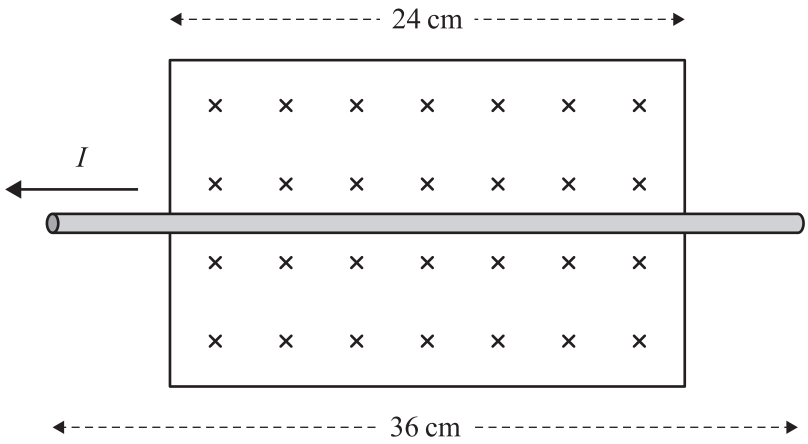
B. 109 N

C. 872 N

D. 981 N

Question 8

A wire carrying a current, *I*, of 4.8 A passes through a region with a magnetic field strength of 1.2 T, as shown below. Dimensions are shown in the diagram.

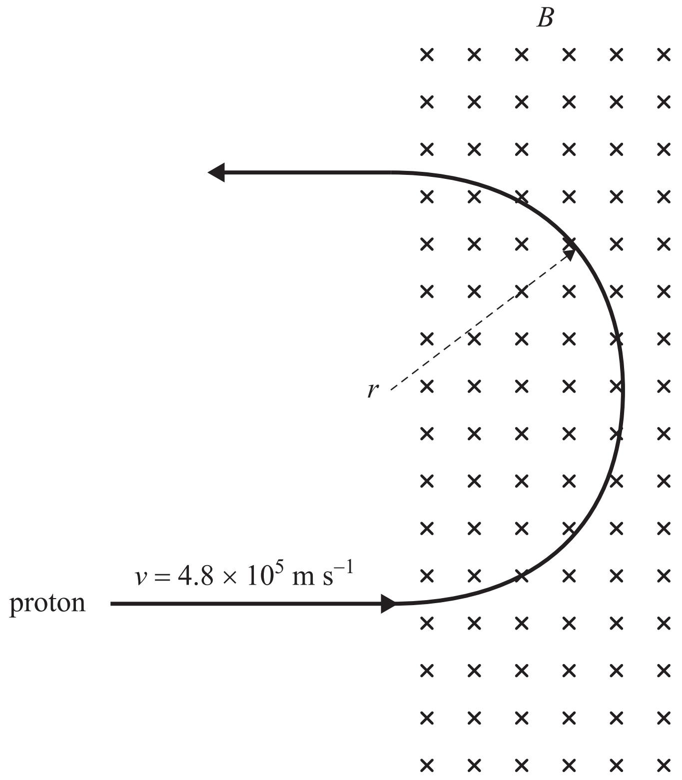


Which one of the following best shows the magnitude of the force acting on the wire and its direction?

	Force (N)	Direction
A.	1.4	up the page
B.	2.1	down the page
C.	2.1	up the page
D.	1.4	down the page

Question 9

A proton with a speed, v, of 4.8×10^5 m s^{-1} is injected into a uniform magnetic field, B, of strength 8.0×10^{-2} T, directed into the page, as shown in the diagram below. The proton moves in a vacuum in a semicircle of radius r, as shown. The charge on the proton is 1.6×10^{-19} C. Ignore relativistic effects.



Which one of the following best gives the speed of the proton as it exits the magnetic field?

A. 0 m s^{-1}

B. much less than 4.8×10^5 m s^{-1}

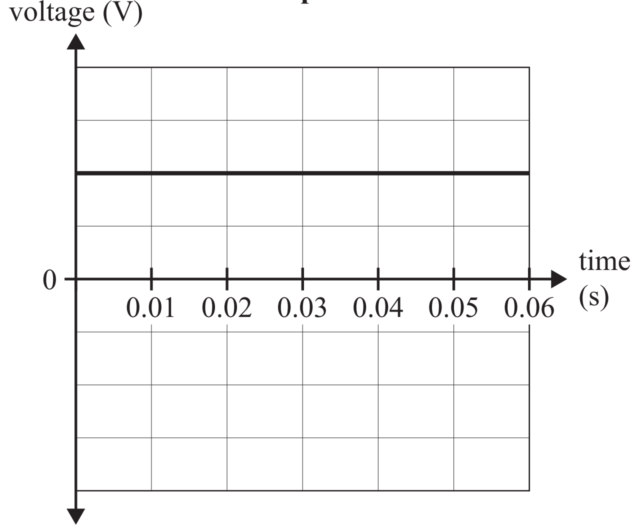
C. 4.8×10^5 m s^{-1}

D. greater than 4.8×10^5 m s^{-1}

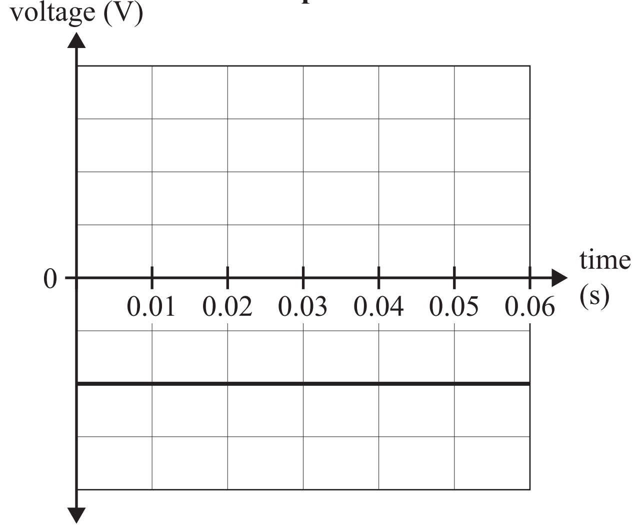
Question 10

A photovoltaic system is connected to an inverter to supply power for use in a home. Consider graphs 1–4 below, showing voltage versus time.

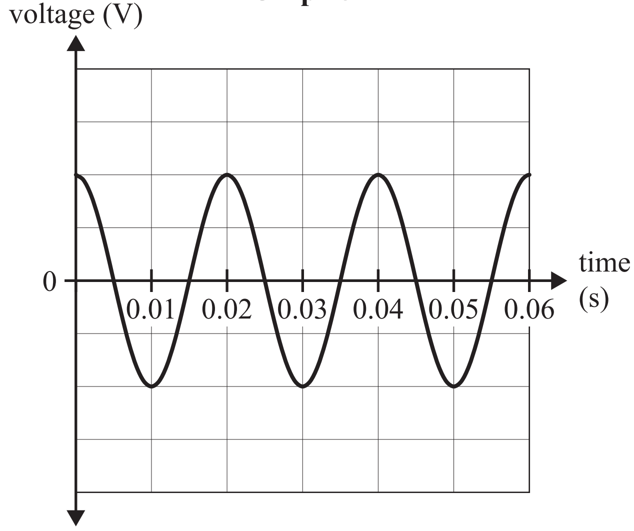
Graph 1



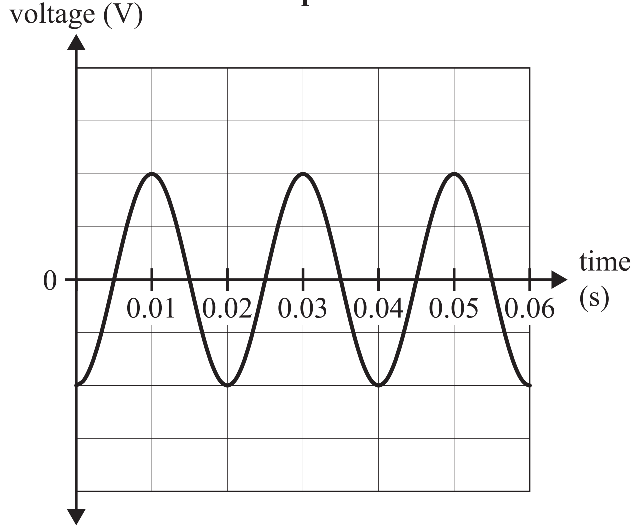
Graph 2



Graph 3



Graph 4

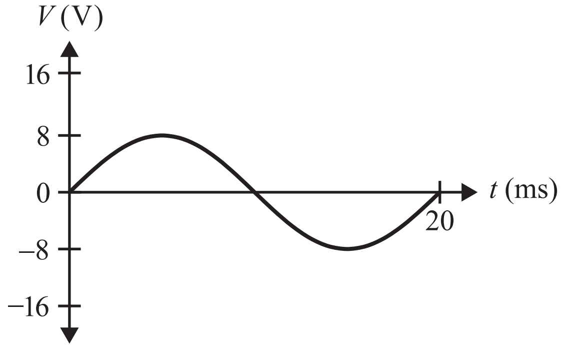


Which one of the following best represents the form of the voltages across the input and output of the inverter?

	Voltage across the input into the inverter	Voltage across the output from the inverter
A.	Graph 1	Graph 2
B.	Graph 1	Graph 4
C.	Graph 3	Graph 2
D.	Graph 3	Graph 4

Question 11

The output of an AC generator is shown below.

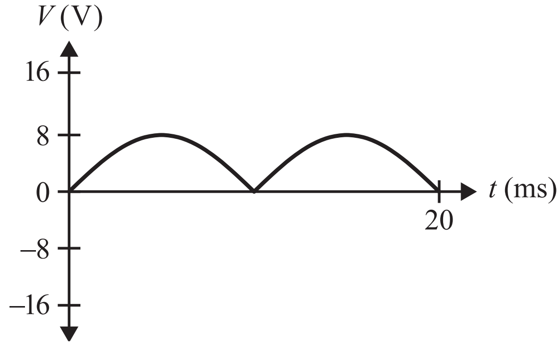


The following modifications are made to the generator:

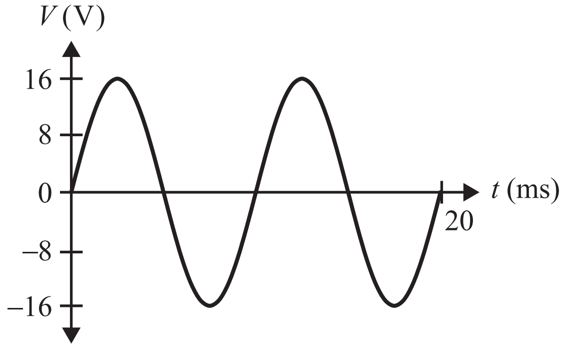
- Its frequency is doubled.
- The slip rings at its output are replaced with a split-ring commutator.

Which one of the following graphs best represents the resulting output?

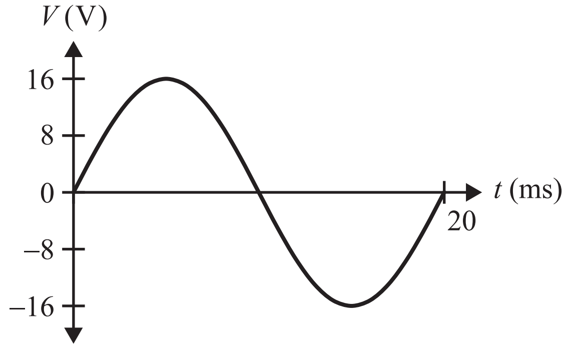
A.



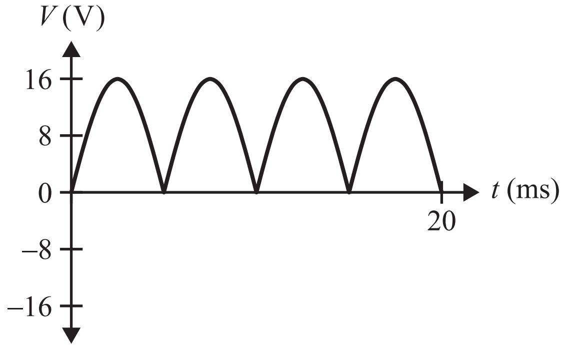
B.



C.

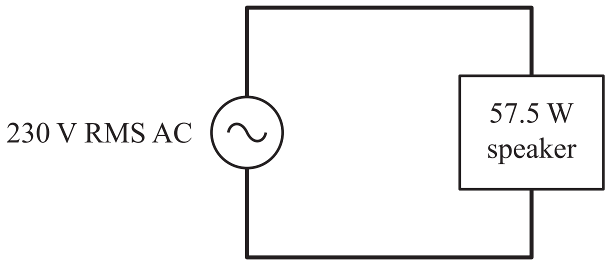


D.



Question 12

A speaker is operating at a maximum power of 57.5 W. It is connected to a 230 V RMS AC supply, as shown below.



Which one of the following is closest to the expected peak-to-peak current in the circuit?

A. 85.0 mA

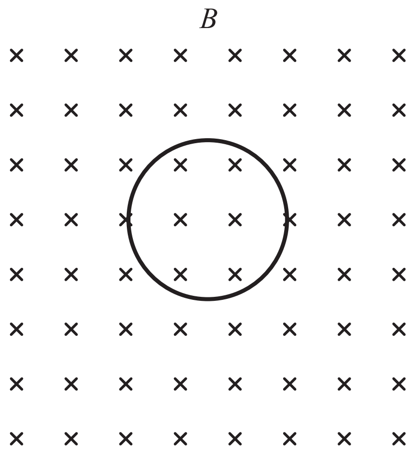
B. 250 mA

C. 354 mA

D. 707 mA

Question 13

A circular conducting loop is placed in a uniform magnetic field, *B*, directed into the page, as shown below.



The radius of the loop is then doubled and the strength of the magnetic field is halved.

Compared to the initial magnetic flux, the flux through the loop is now

A. halved.

B. doubled.

C. the same.

D. quadrupled.

Question 14

Which one of the following statements best describes how an electromagnetic wave is propagated?

A. An oscillating electric field causes an oscillating magnetic field parallel to the electric field.

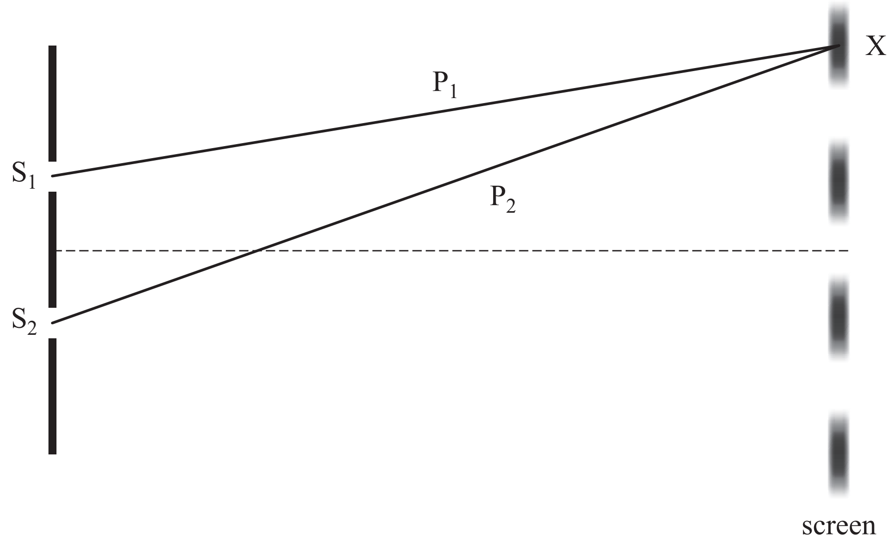
B. An oscillating magnetic field causes an oscillating electric field parallel to the magnetic field.

C. An oscillating electric field causes an oscillating magnetic field perpendicular to the electric field.

D. An oscillating magnetic field causes a constant electric field perpendicular to the magnetic field.

Question 15

Monochromatic light of wavelength λ strikes a double slit and produces bright and dark fringes on a screen. Light from slit S_1 travels along path P_1 and light from slit S_2 travels along path P_2 to produce the dark fringe shown below at point X.



Which one of the following is closest to the difference in path length between P_1 and P_2?

A. $\frac{\lambda}{2}$

B. $\frac{3\lambda}{2}$

C. 2λ

D. $\frac{5\lambda}{2}$

Question 16

An atom absorbs a photon of energy 9.7 eV.

Which one of the following is closest to the frequency of the photon?

A. 2.3×10^{-15} Hz

B. 2.3×10^{15} Hz

C. 4.0×10^{-14} Hz

D. 1.5×10^{34} Hz

Question 17

The mass of a neutron is about 0.14% greater than the mass of a proton.

Which one of the following statements best explains the difference between the de Broglie wavelengths of neutrons and protons travelling at the same speed?

A. The proton has a shorter wavelength because its mass is smaller.

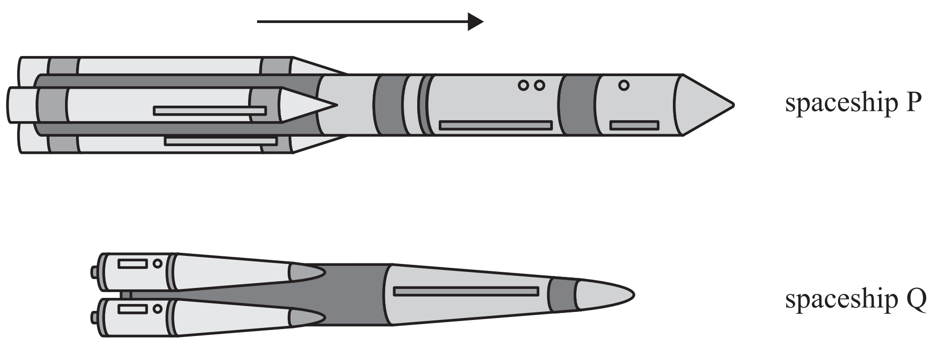
B. The neutron has a shorter wavelength because its mass is greater.

C. The proton has a longer wavelength because its momentum is greater.

D. The neutron has a longer wavelength because its momentum is greater.

Question 18

Spaceship P passes spaceship Q with a relative velocity of 0.86*c*, as shown in the diagram below.



The proper length of spaceship P is *L*.

Which one of the following correctly states the length of spaceship P as measured by a traveller on spaceship P and a traveller on spaceship Q?

	Traveller on spaceship P	Traveller on spaceship Q
A.	*L*	shorter than *L*
B.	*L*	longer than *L*
C.	shorter than *L*	*L*
D.	longer than *L*	*L*

Question 19

Students take turns to use a diffraction grating spectroscope to measure the wavelength of the brightest yellow line in the spectrum of sodium.

Their results are shown in the table below.

Student	Liam	Sophia	Angus	Jing	Dom
Wavelength (nm)	599 ±1	601 ±1	599 ±1	600 ±1	599 ±1

The wavelength of the brightest yellow line is known to be 589.0 nm.

Which one of the following conclusions could the students make about the difference between their measurements and the expected value?

A. All the data points are outliers.

B. The measurements are not precise.

C. There is a systematic error in their measurements.

D. The known wavelength value is within the uncertainty of each measurement.

Question 20

Students plan to investigate the motion of a sprinter on an athletics track. Timekeepers are positioned every 10 m along the track from the start. They each record the time taken by the sprinter to reach them.

Which one of the following correctly identifies the independent and dependent variables in this investigation?

	Independent variable	**Dependent variable**
A.	distance from start	time from start
B.	time from start	distance from start
C.	speed of sprinter	distance from start
D.	time from start	speed of sprinter

End of Section A

Examination questions continue on the next page.

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 (5 marks)

The ‘spring boots’ shown in Figure 1a (below) and Figure 1b (on page 16) have been designed to bounce with each step. This is achieved with a stiff spring attached to the bottom of each boot.

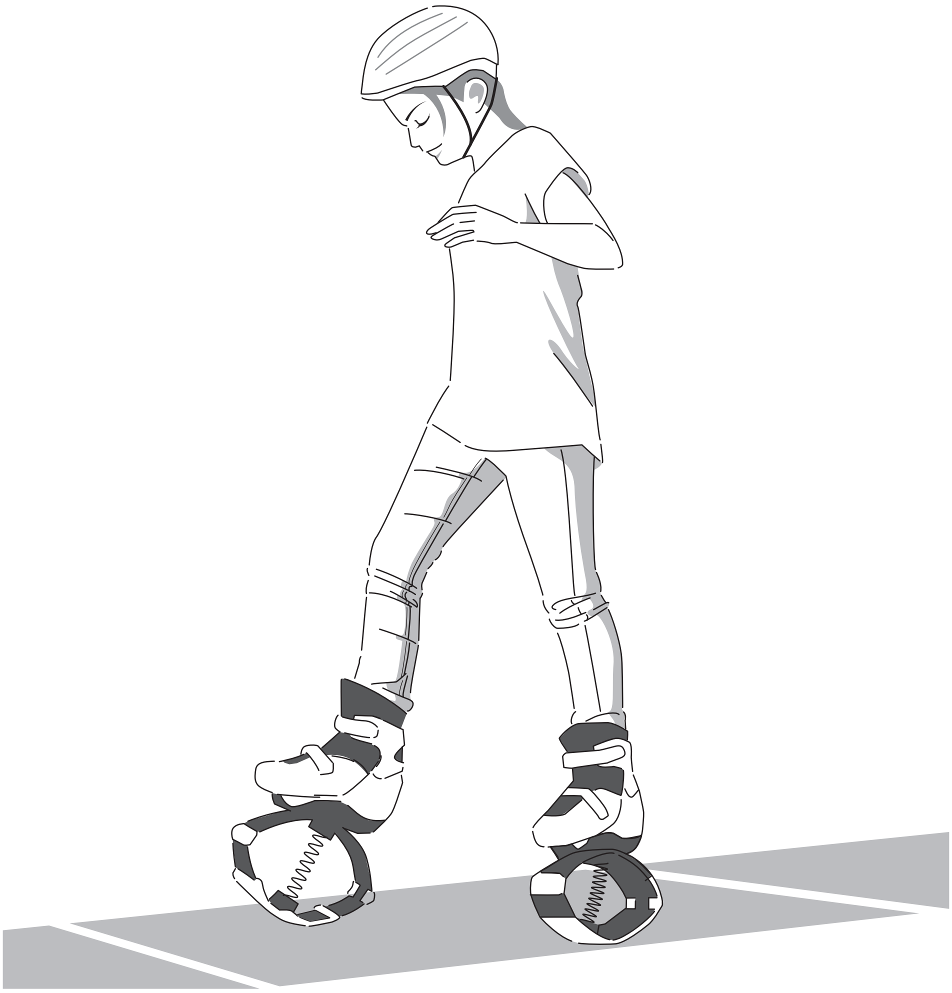


Figure 1a

Question 1 continues on the next page.

The length, l_0, of the spring when the empty boot rests on the ground is 14.0 cm.

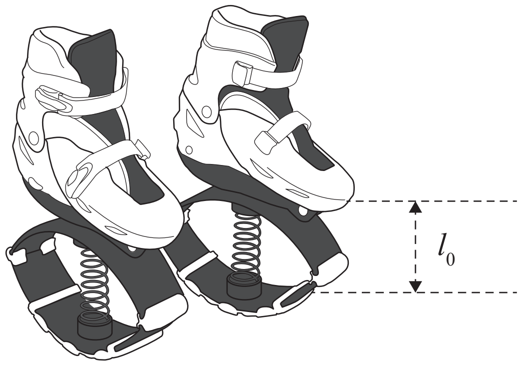


Figure 1b

Anna tests the compression of the spring by placing masses into one upright boot, while providing sideways support to keep the spring vertical. She measures the distance, x, that the spring compresses from its original length as she adds 5 kg masses. Ignore the mass of the boot–spring combination.

Anna draws a graph with the results she obtains to show force versus compression. The graph is shown in Figure 2.

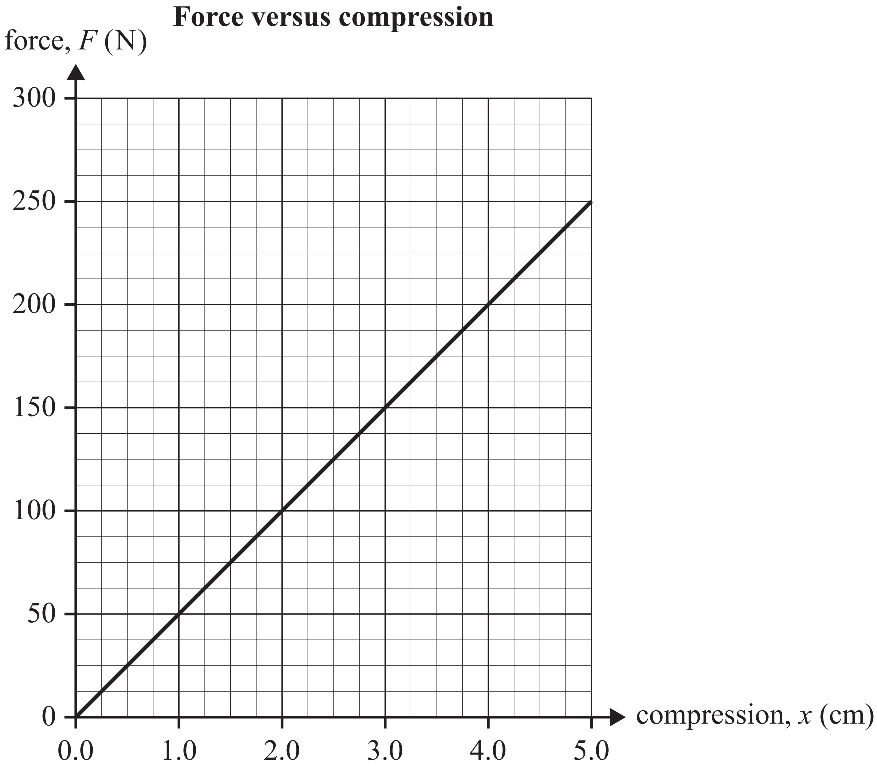


Figure 2

a. Show that the value of the spring constant, k, of the spring is 5.0×10^3 N m^{-1}. 1 mark

b. A child, Sam, stands motionless on one leg on a single spring boot.

Calculate how much energy is stored in the spring given that the spring is compressed by 5.0 cm. 2 marks

J

c. Anna designs a version of the boot with the same 5.0 cm spring compression for a child who is heavier than Sam.

Describe the change in the spring constant that would be useful for this boot. Justify your response. No calculations are required. 2 marks

Question 2 (8 marks)

A ceiling fan has radial blades, as shown in Figure 3.

At the lowest speed setting, the blades rotate horizontally at a frequency of 1.5 Hz, with a radius of 70 cm from the centre of the hub.

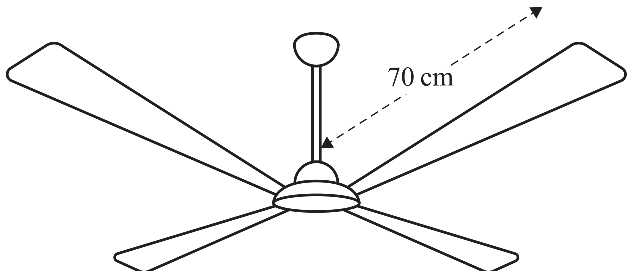


Figure 3

a. Show that the speed, v, of the tip of a blade is 6.6 m s^{-1}. 1 mark

b. A very small mass, m, sits on the end of one blade and rotates horizontally in uniform circular motion, as shown in Figure 4.

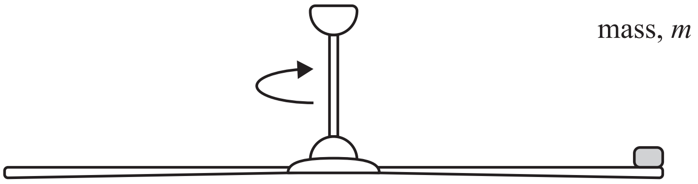


Figure 4

i. On Figure 4, draw an arrow to show the net force on the mass, m. 1 mark

ii. The mass, m, is 4.0 g.

Calculate the magnitude of the net force on the mass, m, while it is rotating on the blade in uniform circular motion. 2 marks

N

c. The speed setting is increased and the mass, m, slides off the blade.

i. Explain why this happens. 2 marks

ii. Describe the path taken by the mass, m, after it leaves the blade. You may use a labelled diagram in your response. 2 marks

Question 3 (5 marks)

Abbie and James are discussing a collision between a large insect and the windscreen of a car, as shown in Figure 5. The car was travelling at 70 km h^{-1} when it hit the insect, which was travelling at 5 km h^{-1} towards the car.

Figure 5

a. Compare the forces between the insect and the car during this collision. Give a reason for your response. 2 marks

b. Abbie says that the total energy and momentum of the car–insect system is the same before and after the collision.

James says that both the total energy and the total momentum decrease as a result of the collision, because the insect has lost its kinetic energy and the car has slowed down by a very small amount.

Who is correct – Abbie or James? Support your response using physics principles. 3 marks

Question 4 (3 marks)

Two solenoids are placed close to each other, as shown in cross-section in Figure 6.
A constant direct current flows through each coil.

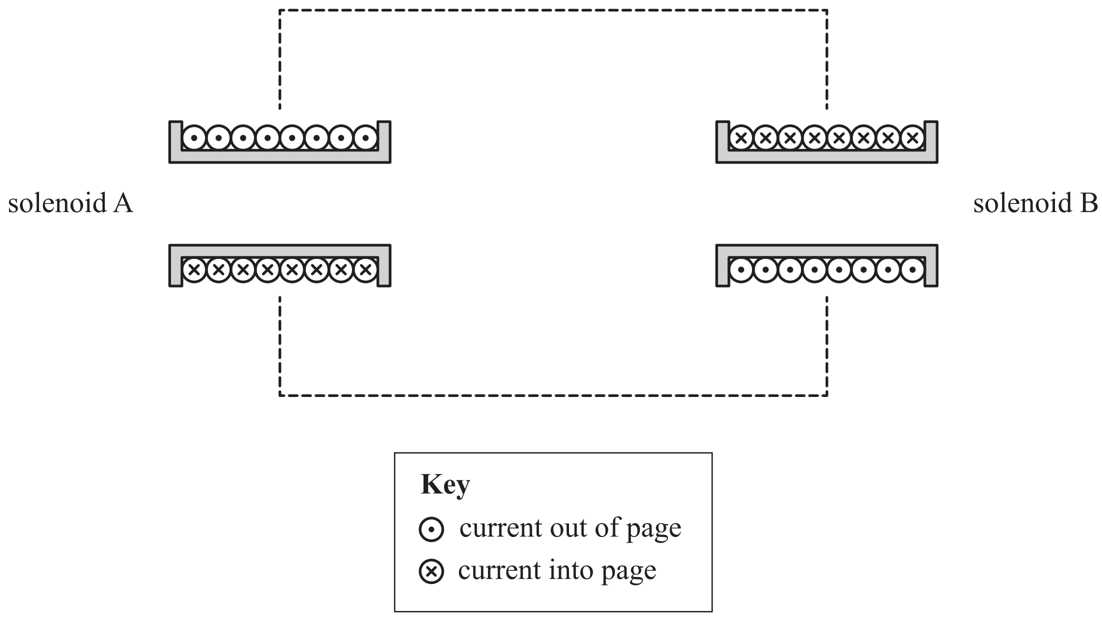


Figure 6

a. On Figure 6, label with an N the end of **each** solenoid that acts as a north pole. 1 mark

b. Sketch the shape and direction of at least **four** magnetic field lines on Figure 6.
Start two field lines inside each solenoid and continue them within the rectangular dashed lines shown on Figure 6. 2 marks

Question 5 (6 marks)

A uniform electric field of magnitude 1.50×10^4 N C^{-1} exists between a pair of oppositely charged plates, as shown in Figure 7. The plates are separated by a distance of 80.0 mm. A proton is allowed to move freely from rest at the top plate.

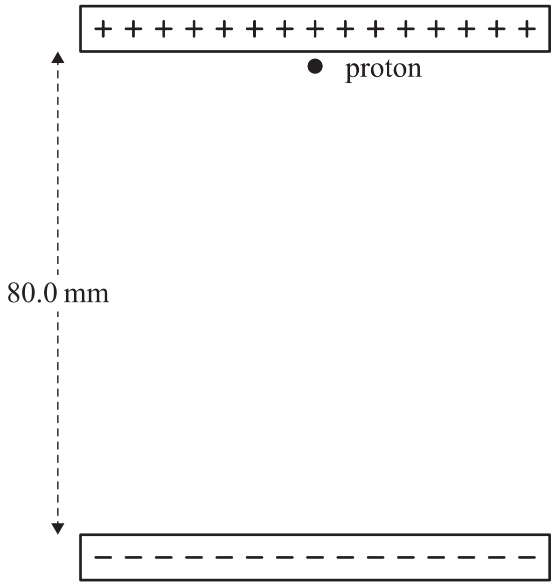


Figure 7

a. On Figure 7, draw an arrow showing the direction of the electric field. 1 mark

b. Show that the magnitude of the electric force acting on the proton is 2.4×10^{-15} N. The charge on a proton is 1.60×10^{-19} C. 1 mark

c. Calculate the magnitude of the change in electric potential energy as the proton moves from the top plate to the bottom plate. 2 marks

J

d. The proton is replaced with an alpha particle, which has twice the charge and approximately four times the mass of a proton. The alpha particle is released from the same position as the original proton.

Compare the change in electric potential energy of the alpha particle with that of the proton as the alpha particle moves from the top plate to the bottom plate. Explain your response. No calculations are required. 2 marks

Question 6 (7 marks)

A lunar probe is in a circular orbit around the Moon at an altitude of 1000 km above the Moon's surface. The mass of the Moon is 7.35×10^{22} kg and its radius is 1.74×10^{6} m. The mass of the probe is 920 kg.

a. Calculate the acceleration of the lunar probe. 2 marks

m s^{-2}

b. A 2.0 kg sphere is released from the lunar probe. The gravitational field strength versus altitude graph for the Moon is shown in Figure 8.

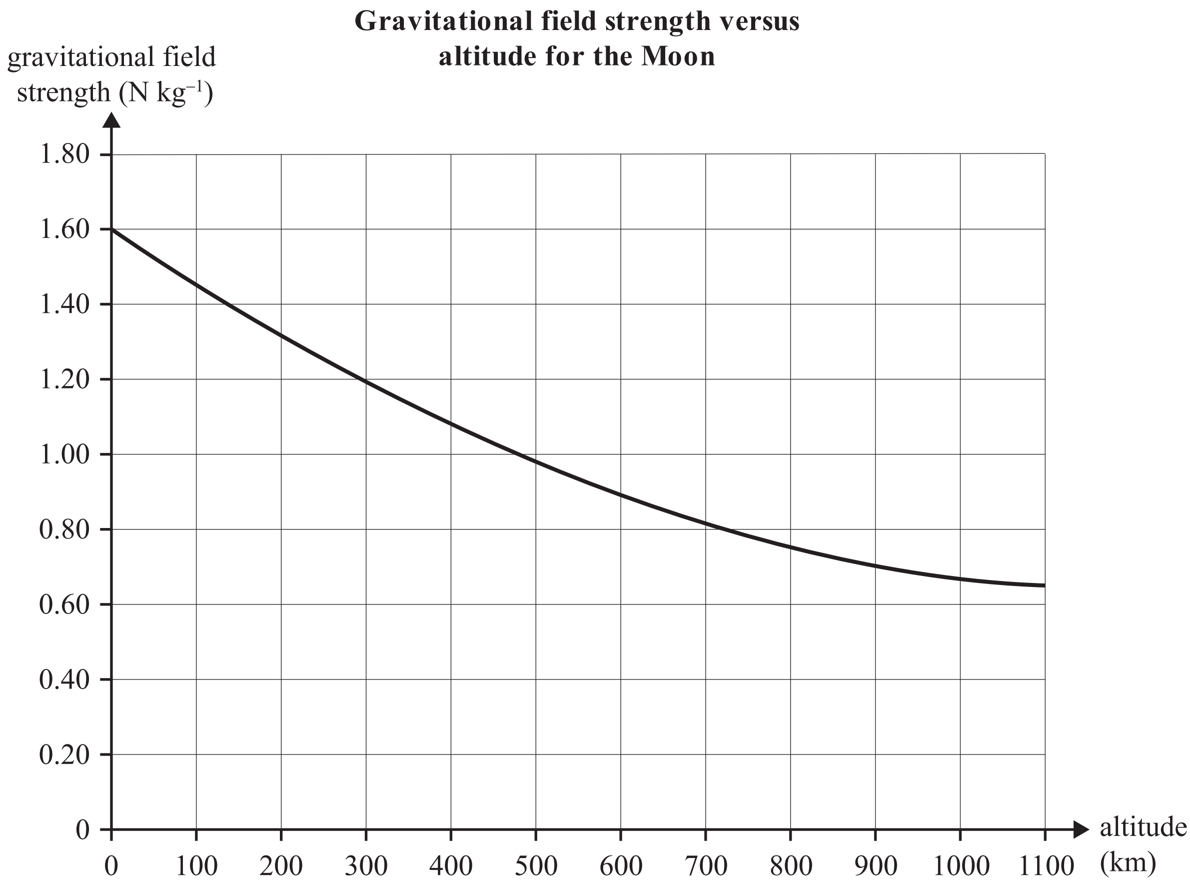


Figure 8

Estimate the total change in gravitational potential energy of the sphere as it falls from its altitude of 1000 km to the Moon's surface. 3 marks

J

c. If the mass of the lunar probe were halved, by what factor would its orbital period change? Justify your response. 2 marks

Question 7 (7 marks)

A simple DC motor consists of a single rectangular loop of wire placed between a pair of magnets, as shown in Figure 9. The magnets provide a uniform magnetic field.

The loop is connected to an external battery and the direction of current flow, I, is produced as shown. The loop of wire is initially parallel to the field between the two magnets. The loop of wire is free to rotate about its axis. The initial direction of rotation is shown.

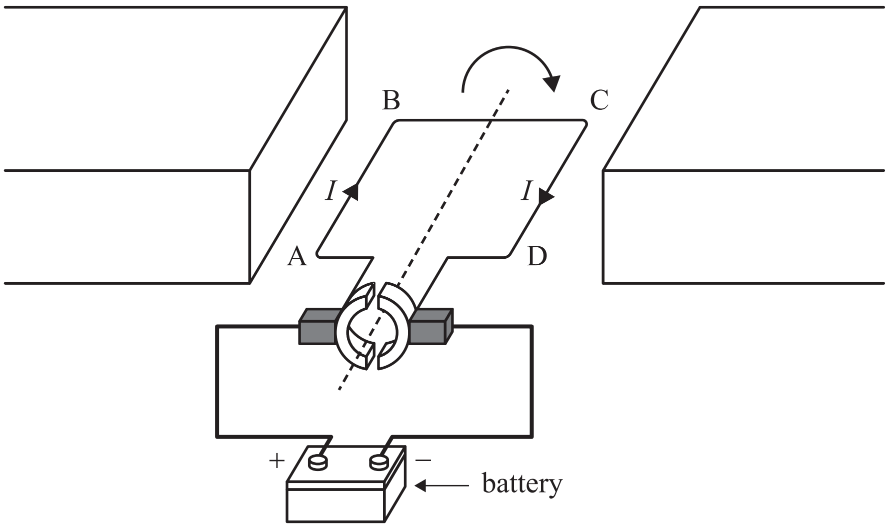


Figure 9

a. On Figure 9, label the poles of each of the magnets as either **N** or **S**. Give a reason for your response. 2 marks

b. Consider Figure 9. Explain in detail how the loop is able to rotate continuously in one direction. 3 marks

c. Jackie and Jet consider methods of increasing the torque produced by their simple DC motor. Jackie suggests that they increase the number of loops. Jet suggests that they reduce the strength of the magnetic field by replacing the magnets.

Which change would increase the torque? Explain your reasoning. 2 marks

Question 8 (4 marks)

Jarrod powers the light on his old bicycle using an electrical generator known as a dynamo, as shown in Figure 10a and Figure 10b.

As the wheel turns, the dynamo's magnet rotates due to friction between the tyre and the cylindrical end of the spindle. The changing magnetic flux, Φ, through the iron rod and the coil induces an EMF, which powers the light.

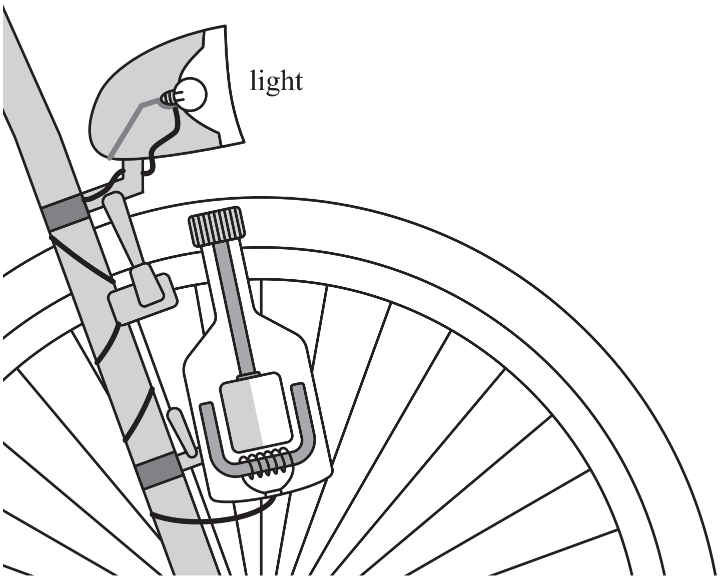


Figure 10a

Source: Adapted from Peteri/Shutterstock.com

Close-up of dynamo

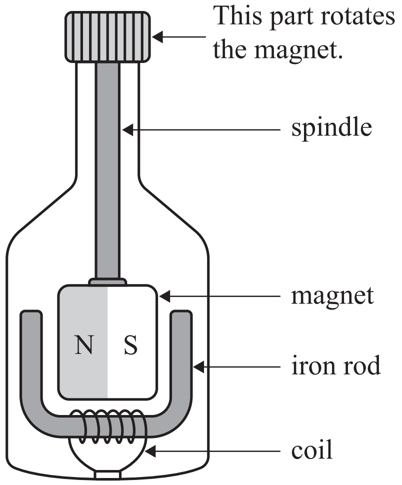


Figure 10b

Source: Adapted from Vadober/Shutterstock.com

Jarrod is cycling steadily along a flat road and the magnetic flux through the coil varies with time, as shown in Figure 11.

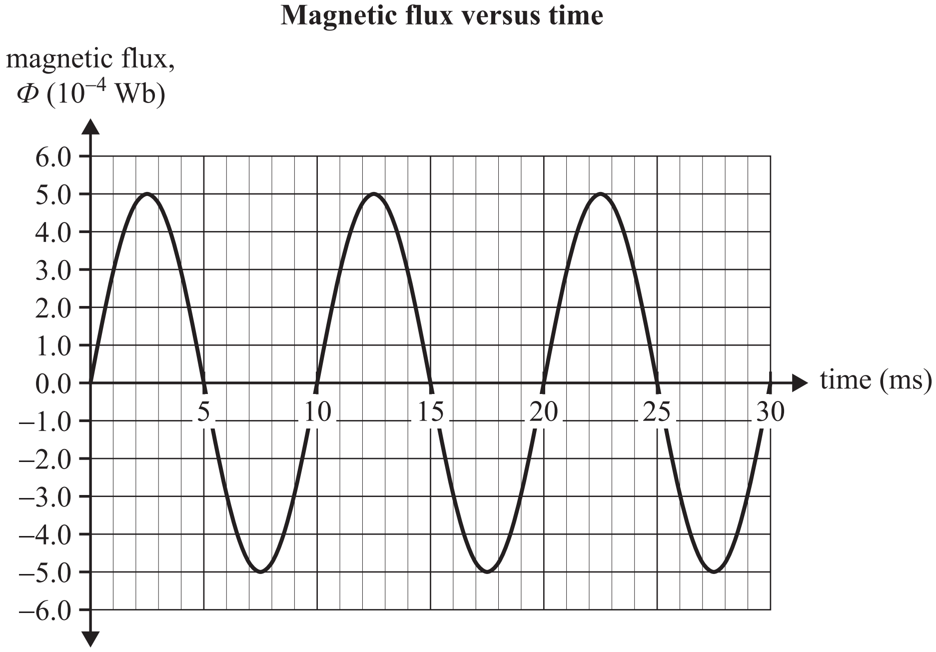


Figure 11

a. The dynamo's coil has 80 turns.

Show that the average EMF induced in the coil during the first 2.5 ms of time shown in Figure 11 is 16 V. 2 marks

b. Is the dynamo shown in Figure 10a and Figure 10b an example of an AC or DC generator? Give a reason to support your response. 2 marks

Question 9 (5 marks)

Stacy has a system of solar panels connected to an inverter with an output voltage of 230 V RMS AC.

A digital promotional sign is installed on her front fence, 400 m away from the inverter, as shown in Figure 12.

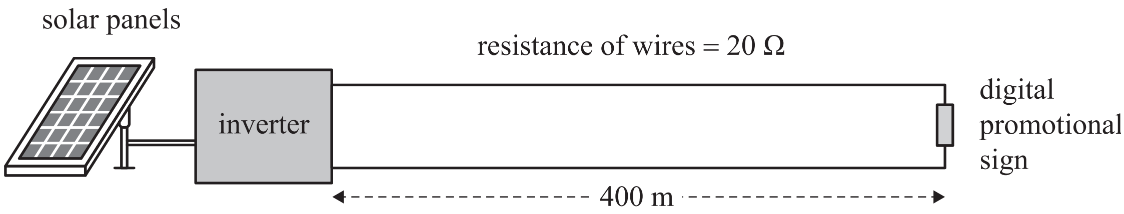


Figure 12

The sign requires 460 W at 230 V RMS AC to operate at full brightness.

Thin copper wires with a total resistance of 20 Ω connect the sign to the inverter.

a. On a sunny day, the inverter outputs 460 W at 230 V RMS AC.

Calculate the potential difference across the sign. 3 marks

V

b. Stacy installs a pair of transformers, T_1 and T_2, to reduce power loss in the copper wires, as shown in Figure 13.

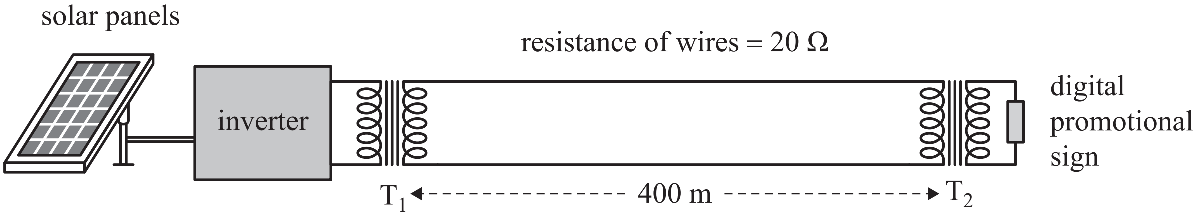


Figure 13

Stacy wants to reduce the power loss in the wires to one-quarter of the power loss that occurs without transformers.

Assuming the transformers are ideal, calculate the primary to secondary turns ratio required on the step-up transformer. 2 marks

Question 10 (7 marks)

Adriana and Caleb obtain a long iron rod and insert it through two insulated copper wire solenoids, as shown in Figure 14. Solenoid 1 is connected to a variable power supply. Solenoid 2 is connected to a resistor.

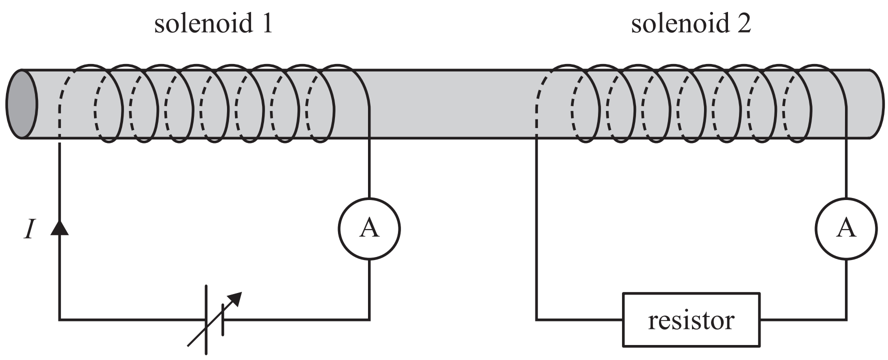


Figure 14

As Adriana and Caleb increase the current, I, through solenoid 1, a current is detected in the resistor connected to solenoid 2.

a. Explain why a current is detected in the resistor. 2 marks

b. In which direction does the current in the resistor flow? Circle the correct answer.

from right to left from left to right

Justify your response. 3 marks

c. The current through solenoid 1 is increased to a maximum of 1.5 A then held constant, as shown in Figure 15.

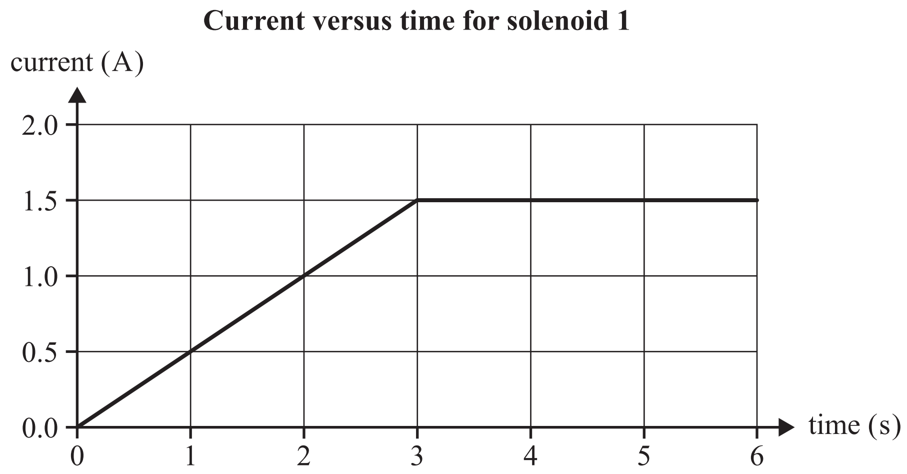


Figure 15

On the axes in Figure 16, sketch the shape of the expected current versus time graph for solenoid 2. Numerical units are not required on the current axis. 2 marks

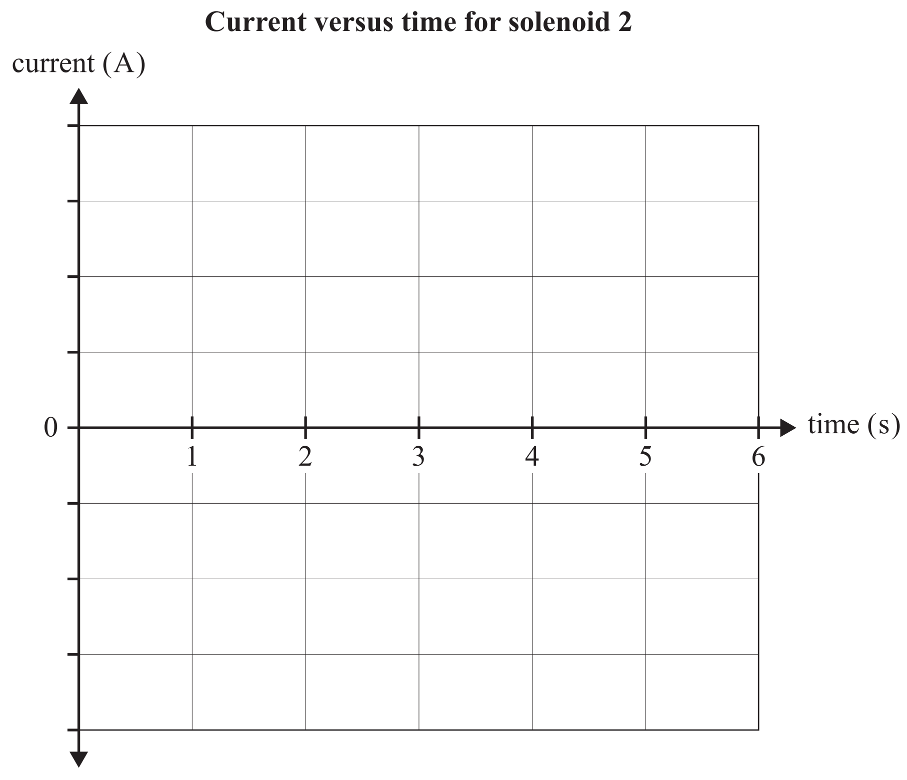


Figure 16

Question 11 (3 marks)

A small AC generator supplies 6.0 W of power to a light globe, as shown in Figure 17.

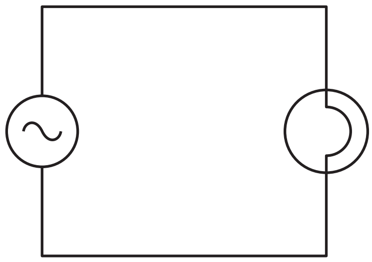


Figure 17

The current in the light globe is shown in Figure 18.

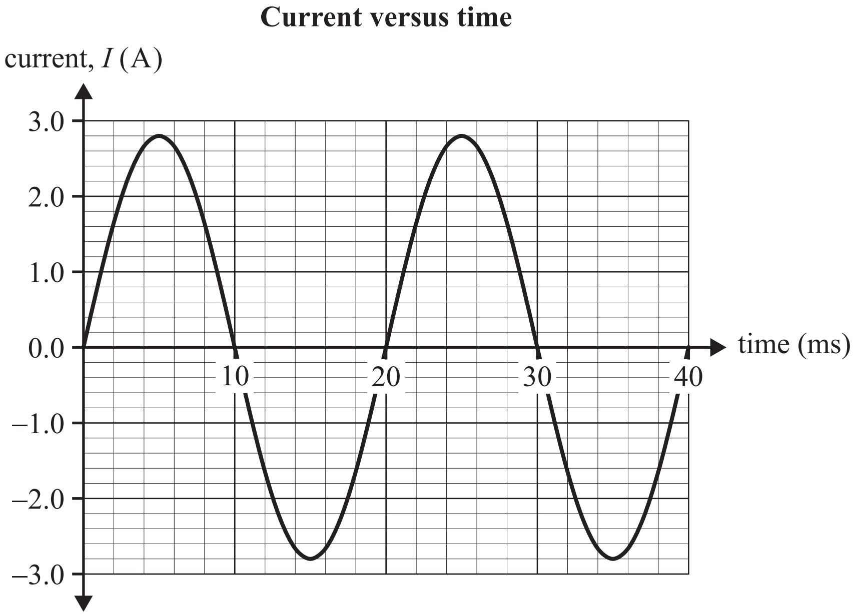


Figure 18

a. Using the information in Figure 18, show that the RMS current, I_{RMS}, in the light globe is 2.0 A. 1 mark

b. The AC generator is replaced with a battery, but the average brightness of the light globe does not change.

Calculate the EMF of the battery. 2 marks

V

Question 12 (5 marks)

Astrid and Leelyn are discussing Einstein's famous thought experiment involving a 'photon clock', where a single light photon travels from a light source p to a mirror q and returns back to p.

An observer in a train carriage travelling to the right at velocity, *v*, measures a single tick of the photon clock, as shown in Figure 19.

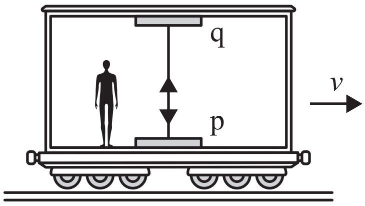


Figure 19

To a trackside observer, the photon takes the path shown in Figure 20.

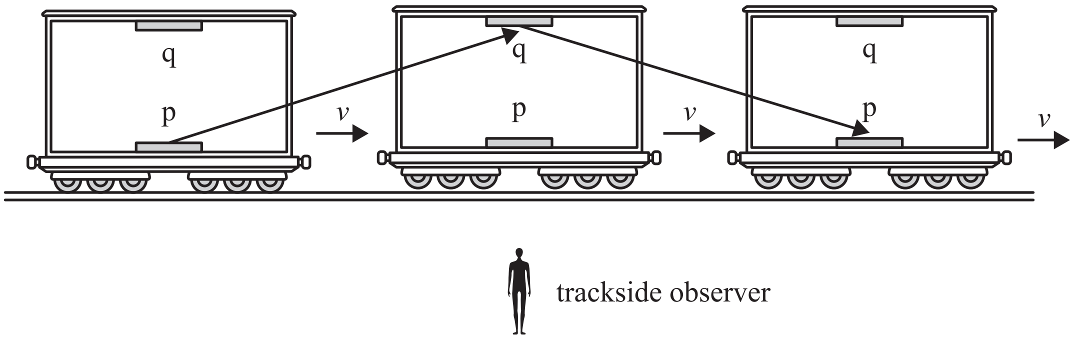


Figure 20

Astrid says that Newton would reason that a single tick takes the same time for the two observers, but that for the trackside observer the photon has travelled further and, therefore, faster.

a. How would Leelyn challenge Newton's argument using Einstein's special theory of relativity? 3 marks

b. The relative velocity of the train is $0.86c$.

The observer in the train carriage measures the time taken for a single tick of the clock as 16 nanoseconds.

What is the time taken for a single tick of the clock as measured by the trackside observer? 2 marks

nanoseconds

Question 13 (3 marks)

An X-ray photon of wavelength 0.744 nm travelling to the left collides with a stationary electron, as shown in Figure 21.

Figure 21

a. Show that the magnitude of the momentum of the X-ray photon is 8.91×10^{-25} kg m s^{-1}. 1 mark

b. After the collision, the X-ray photon rebounds to the right with momentum of 8.85×10^{-25} kg m s^{-1}, while the electron moves off in the opposite direction, as shown in Figure 22.

Figure 22

Calculate the speed of the electron after the collision. Ignore any relativistic effects. 2 marks

m s^{-1}

Examination questions continue on the next page.

Question 14 (6 marks)

Lisa and Chris are investigating the photoelectric effect.

The apparatus they use is shown in Figure 23. A light source shines light through a filter that only allows a specific frequency of light to pass through. This monochromatic light shines onto a metal plate and, under certain conditions, photoelectrons can be emitted.

Different filters allow different frequencies to strike the metal plate. For each frequency, the maximum kinetic energy of the emitted photoelectrons is measured by determining the stopping voltage.

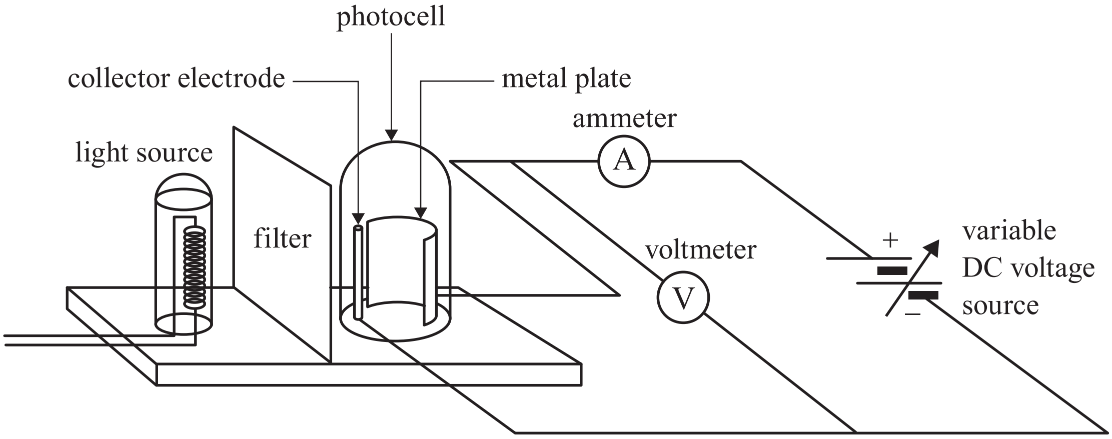


Figure 23

Lisa and Chris collect data for a graph showing the maximum kinetic energy of emitted photoelectrons versus frequency. The solid line on the graph in Figure 24 is the trend line determined by their data. They extrapolate the line below the horizontal axis. This is shown as a dashed line.

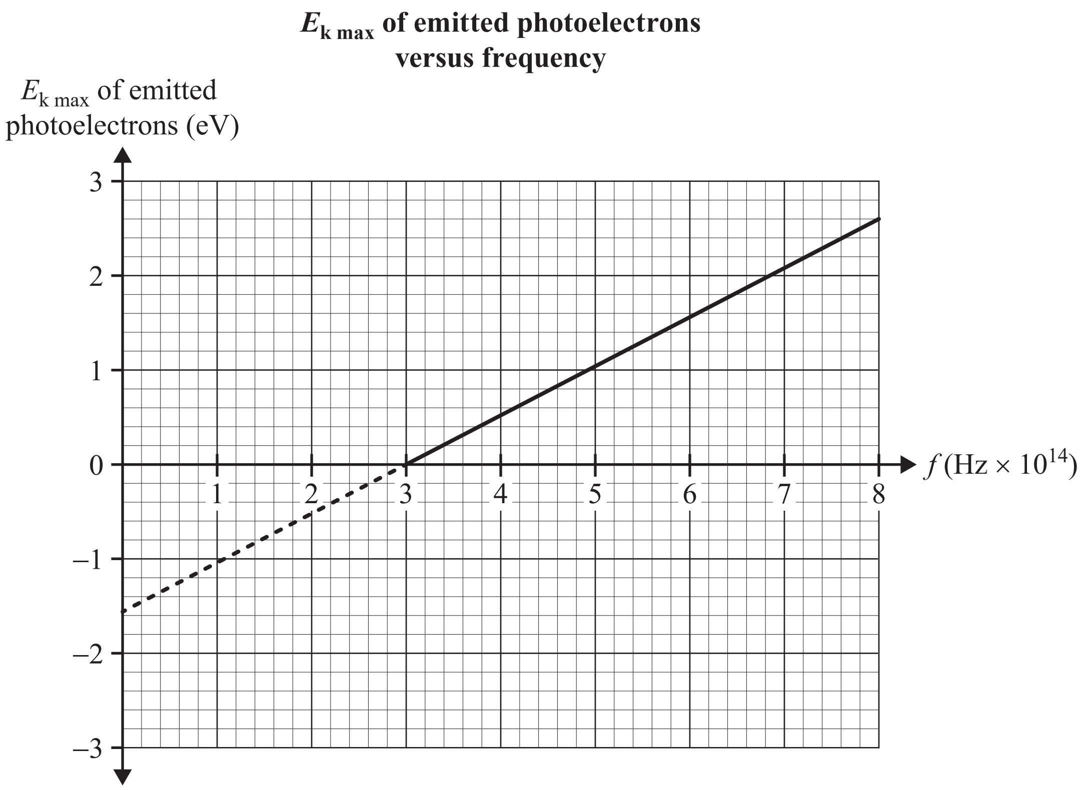


Figure 24

a. Use Figure 24 to answer **parts a.i–iii**.

i. Determine the value of Planck's constant, h, that Lisa and Chris obtained. 2 marks

eV s

ii. Determine the value of the cut-off frequency, f_0, that Lisa and Chris obtained. 1 mark

Hz

iii. Determine the value of the work function of the metal plate. 1 mark

eV

b. Lisa and Chris replace the photocell with one that has a different metal plate with a work function of 2.2 eV and repeat their measurements.

On Figure 24, draw the graph they would now expect to see. 2 marks

Question 15 (5 marks)

Green light of wavelength 500 nm is emitted from a laser.

a. Calculate the energy of a photon emitted from this laser, in electron volts. 2 marks

eV

b. The green laser light is shone through a 0.7 µm slit onto a wall 1.0 m away.

Would a diffraction pattern be observed? Justify your response. 3 marks

Question 16 (3 marks)

Explain how the discrete dark lines in a hydrogen gas absorption spectrum are produced.

Question 17 (18 marks)

Jagger and Sienna were fascinated by their teacher's demonstration of the 'three holes in a bottle' experiment. The experiment used a cylinder with holes made at various depths. The cylinder was filled with water. Figure 25 shows the parabolic paths made by the water streams emitted from the holes.

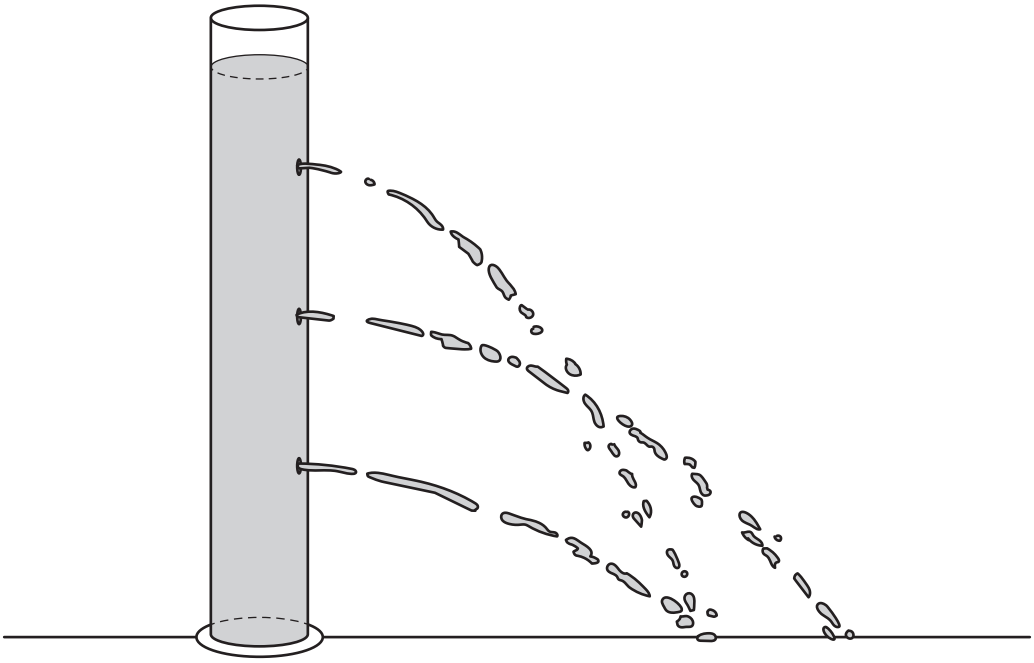


Figure 25

The path of the water can be modelled as projectile motion, in which the water stream is emitted horizontally from the holes.

The speed of the water emitted from the holes depends on the depth of the hole.

Question 17 continues on the next page.

Jagger and Sienna decided to investigate how the horizontal distance travelled by the water, which they called the range, *R*, was affected by the depth of the hole, *d*, as shown in Figure 26.

They decided to use a 200 cm length of plastic tube and drill holes every 25 cm from the top down to 50 cm above the bottom of the tube. All the holes were initially plugged. The holes had the same diameter and were smooth.

The plastic tube was filled and one hole was unplugged. The water level was kept constant by continuously adding the right amount of water to keep the tube filled as water came out through the unplugged hole.

Figure 26 shows water emitted from an unplugged hole.

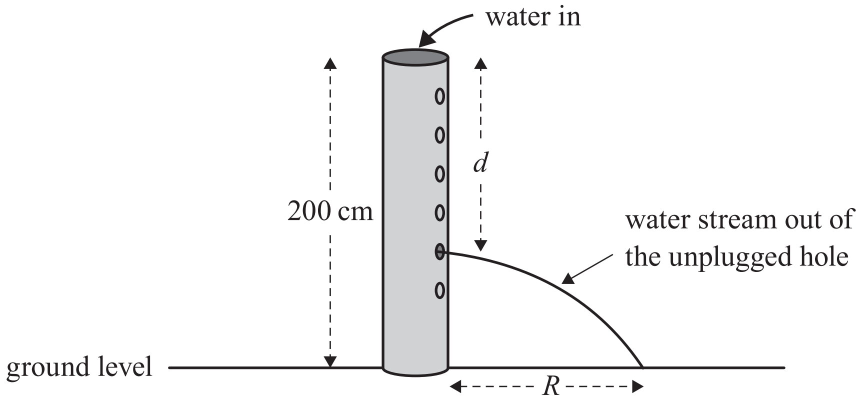


Figure 26

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 it was important to keep the plastic tube completely filled with water at all times. 1 mark

c. Jagger suggested that they should repeat the range measurement five times for each hole.

What is the benefit of repeating the measurements? 1 mark

d. The results Jagger and Sienna obtained for the experiment are shown in the table below.

Hole depth, *d* (cm)	**Average range, *R* (cm)**
25	130
50	160
75	180
100	180
125	150
150	110

On Figure 27, plot a graph of the data in the table above with range, *R*, on the vertical axis and hole depth, *d*, on the horizontal axis.

The uncertainty in the measurement of the range is ±10 cm. The uncertainty in the measurement of the hole depth is negligible. You **must** include uncertainty bars and a trend line or curve. 6 marks

Average range, *R*, versus hole depth, *d*

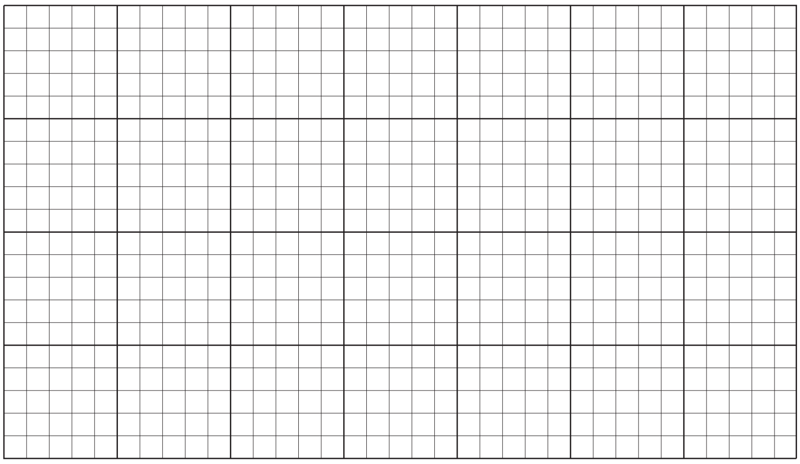


Figure 27

e. Using your graph in Figure 27, estimate the maximum range and the hole depth that gives the maximum range. 2 marks

Maximum range [ ] cm   Hole depth for maximum range [ ] cm

Question 17 continues on the next page.

f. Jagger and Sienna wonder if any resistance, including air resistance, might have affected the maximum range. Analysis shows that the maximum range without any resistance would be 200 cm when the depth of the hole was 100 cm.

State whether the effects of resistance can be ignored by Jagger and Sienna when analysing their data. Justify your response. 3 marks

Do not write in this area.

g. Jagger and Sienna were surprised at the depth at which the maximum range occurred. They had seen diagrams on the internet that indicated that the maximum range occurred at the greatest hole depth. Figure 28 is such an example.

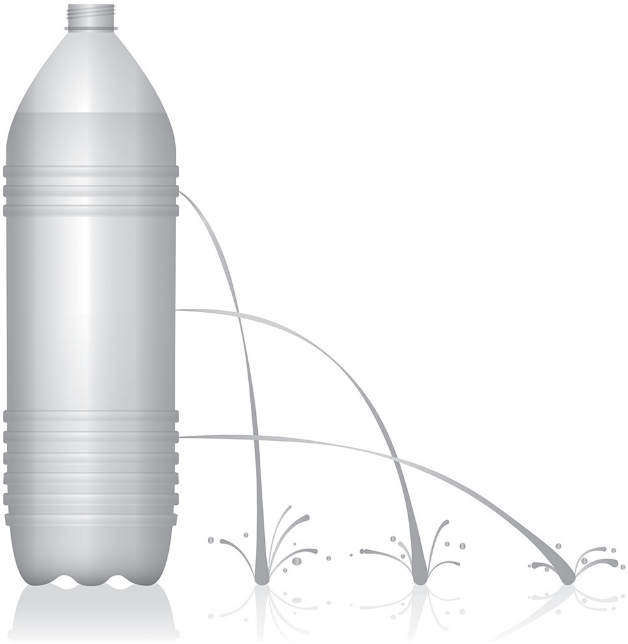


Figure 28

Source: Peter Hermes Furian/Shutterstock.com

Justify why this diagram is wrong about the range, given that the water is emitted from the deepest hole with the greatest speed. Ignore air resistance. 2 marks

End of Question and Answer Book

2026 NHT

Physics

Formula Sheet

You may keep this Formula Sheet.

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Motion and related energy transformations

velocity; acceleration	$v = \frac{\Delta s}{\Delta t}; \quad a = \frac{\Delta v}{\Delta t}$
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	$F_{\text{net}} = \frac{mv^2}{r} \qquad v = \frac{2\pi r}{T}$
Hooke's law	$F = -kx$
elastic potential energy	$E_{\text{s}} = \frac{1}{2}kx^2$
gravitational potential energy	$E_{\text{g}} = mg\Delta h$
kinetic energy	$E_{\text{k}} = \frac{1}{2}mv^2$
Newton's law of universal gravitation	$F_{\text{g}} = G\frac{m_1 m_2}{r^2}$
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	$E_{\text{total}} = E_{\text{k}} + E_0 = \gamma mc^2$
relativistic kinetic energy	$E_{\text{k}} = (\gamma - 1)mc^2$

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	$I = \frac{V}{R}$; $P = VI$
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	$V_{RMS} = \frac{1}{\sqrt{2}}V_{peak}$ $I_{RMS} = \frac{1}{\sqrt{2}}I_{peak}$
electromagnetic induction	$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$ $\Phi_B = B_\perp A$
transmission losses	$V_{drop} = I_{line} R_{line}$ $P_{loss} = I^2_{line} R_{line}$

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