SUPERVISOR TO ATTACH
PROCESSING LABEL HERE

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

Physics

Question and Answer Book

VCE Examination – Day Date Month Year

- Reading time is **15 minutes**: — to —
- Writing time is **2 hours 30 minutes**: — to —

SAMPLE

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 52 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

Version 2 – September 2024

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VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

VICTORIA State Government

Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on the 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

John measures the mass of his suitcase using a luggage scale, as shown below. He holds the suitcase stationary off the ground. The luggage scale indicates $19.4\ \text{kg}$.

Source: New Africa/Shutterstock.com

SAMPLE

The net force acting on the scale is closest to

A. $0\ \text{N}$

B. $190\ \text{N}$

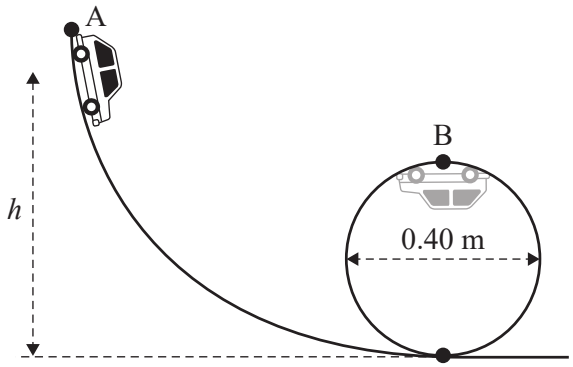
C. $380\ \text{N}$

D. $760\ \text{N}$

Do not write in this area.

Question 2

A $250\ \text{g}$ toy car performs a loop in the apparatus shown below.



The radius of the car's circular path in the loop is $0.20\ \text{m}$. When the car reaches point B, it is travelling at a speed of $1.4\ \text{m s}^{-1}$

Which one of the following best describes the magnitude and direction of the force exerted by the track on the car when the car is at point B, at the top of the circular section of track? Ignore friction and air resistance.

A. $0\ \text{N}$

B. $2.45\ \text{N}$ downwards

C. $2.45\ \text{N}$ upwards

D. $4.90\ \text{N}$ downwards

SAMPLE

Question 3

A recent article in *The Conversation* noted that changing the speed limit from $50\ \text{km h}^{-1}$ to $30\ \text{km h}^{-1}$ in local residential streets in suburban Australia would substantially reduce pedestrian injuries and trauma.

For example, lower speed limits would reduce the braking distance required for cars to come to a full stop, and thus reduce the number of collision incidents with pedestrians.

A particular car driving at a speed of $50\ \text{km h}^{-1}$ has a braking distance of d under a full braking force.

Which one of the following is closest to the braking distance for the same car, under the same road conditions, under a full braking force but driving at a speed of $30\ \text{km h}^{-1}$?

A. $0.25d$

B. $0.35d$

C. $0.50d$

D. $0.60d$

Source: Matthew Mclaughlin et al. 'Busted: 5 myths about 30 km/h speed limits in Australia', *The Conversation*, 20/05/2021, <https://theconversation.com/busted-5-myths-about-30km-h-speed-limits-in-australia-160547>

Do not write in this area.

Question 4

As part of their Physics course, Anna, Bianca, Chris and Danshirou investigate the physics of collisions involving cars. On an internet site that describes what happens during a collision, they find the following statement.

> In an instant, your car goes from driving to impacting the car in front of you – or something else. The car slows abruptly and, at the point of impact, the car's structure will bend or break. **The crumpling action works to absorb some of the initial collision forces, protecting the passenger compartment**.

Source: Adapted from Kathleen Poling (2018), <csftl.org/crash-dynamics-dummies>

The students disagree about the use of the word 'forces' in the statement in bold text above.

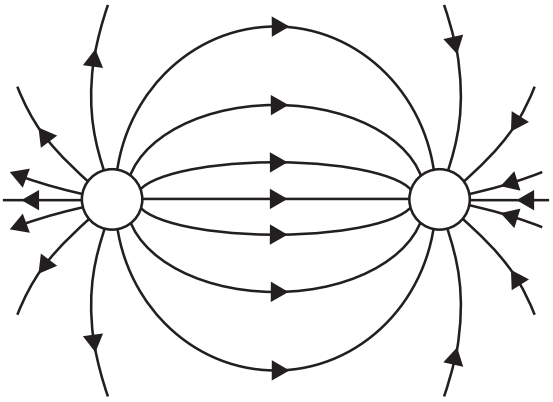
Which one of the following statements made by the students best identifies the physics of how the crumpling action protects the passengers?

		The crumpling action works …
A.	Anna	' … to absorb some of the initial collision **speed**, protecting the passenger compartment.'
B.	Bianca	' … to absorb some of the initial collision **kinetic energy**, protecting the passenger compartment.'
C.	Chris	' … to absorb some of the initial collision **momentum**, protecting the passenger compartment.'
D.	Danshirou	' … to absorb some of the initial collision **forces**, protecting the passenger compartment.'

SAMPLE

Question 5

The diagram below shows the electric field lines between two charges of equal magnitude.



Which of the following best describes the two charges?

A. The charges are both positive.

B. The charges are both negative.

C. The left-hand charge is positive, and the right-hand charge is negative.

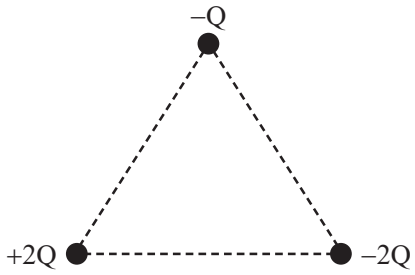
D. The left-hand charge is negative, and the right-hand charge is positive.

Do not write in this area.

Do not write in this area.

Question 6

Three charges ($-Q$, $+2Q$, $-2Q$) are placed at the vertices of a triangle, as shown below. The charges are the same distance from each other.



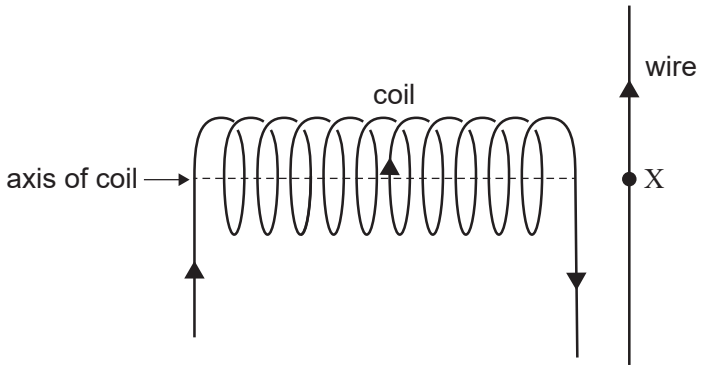
Which one of the following arrows best represents the direction of the net force on the charge $-Q$?

A. **B.** **C.** **D.**

Question 7

The diagram below shows a coil placed next to a straight wire. When both the coil and the wire carry an electric current, there is a force exerted on the wire. The directions of the currents are shown by arrows on the diagram. The point X lies on the axis of the coil.

SAMPLE



Which one of the following best describes the direction of the force on the wire at point X?

A. left

B. right

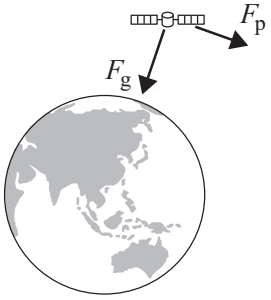
C. into the page

D. out of the page

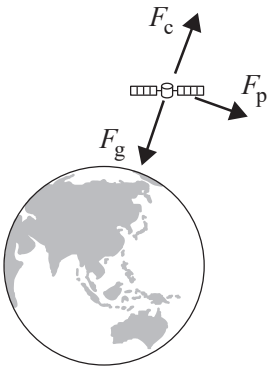
Question 8

Which one of the following diagrams correctly represents the force(s) acting on a satellite above Earth's atmosphere in a stable circular orbit around Earth?

A.



B.



Key

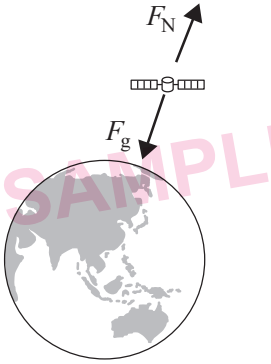
F_g = gravitational force

F_p = thrust force

F_c = centripetal force

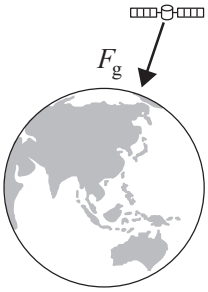
F_N = normal force

C.



SAMPLE

D.



Question 9

A light globe rated at $15\ \text{W}$ carries an RMS current of $1.5\ \text{A}$ when connected to an AC power source.

Which one of the following is closest to the peak-to-peak potential difference that would be measured across the light globe?

A. $7\ \text{V}$

B. $10\ \text{V}$

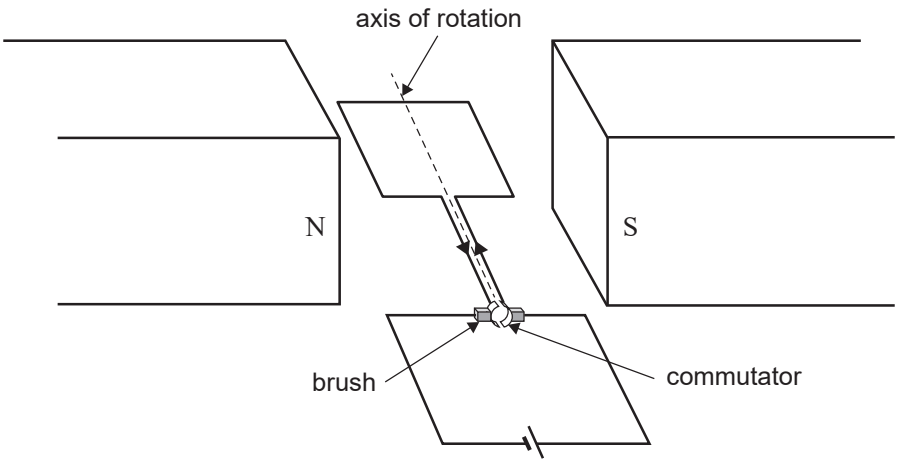
C. $14\ \text{V}$

D. $28\ \text{V}$

Do not write in this area.

Question 10

Students build a simple DC electric motor using a split-ring commutator, a coil of wire, two magnets, a battery and two brushes, as shown in the diagram below.



Which one of the following modifications to the design of the students' DC motor would increase the torque of the DC motor in the starting position shown?

A. replacing the split ring with slip rings

B. removing the brushes from their design

C. increasing the resistance of the wire of the coil

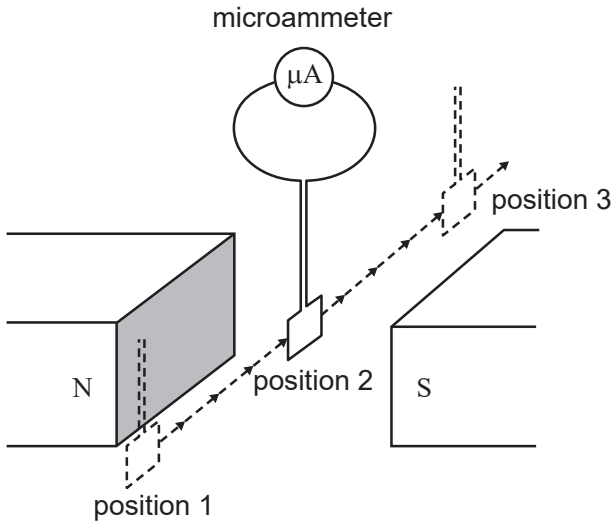
D. decreasing the resistance of the wire of the coil

SAMPLE

Do not write in this area.

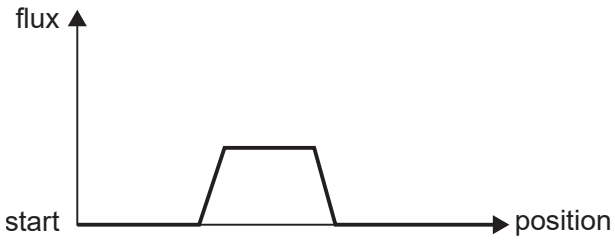
Question 11

A square loop of wire is moved through a uniform magnetic field at a constant speed, as shown below. The magnetic field can be assumed to be zero at position 1 and position 3.



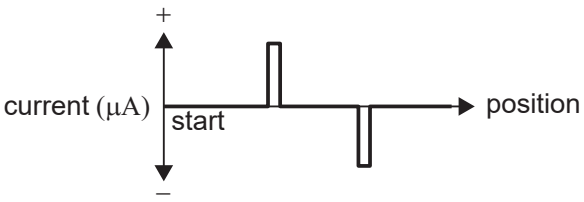
The graph below shows the flux through the loop as a function of position of the leading edge of the loop.

SAMPLE

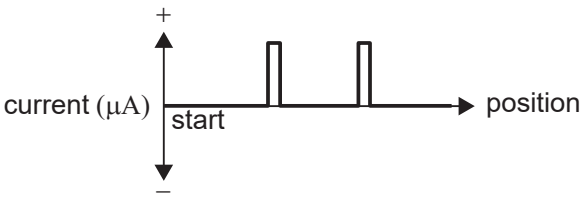


Which one of the following diagrams best describes the current in the loop, measured by the microammeter as the loop passes through the magnetic field?

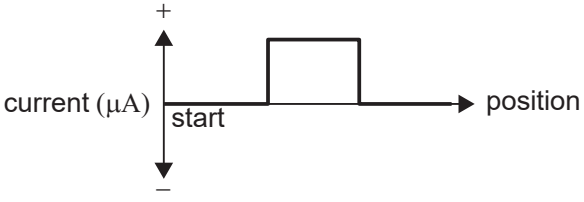
A.



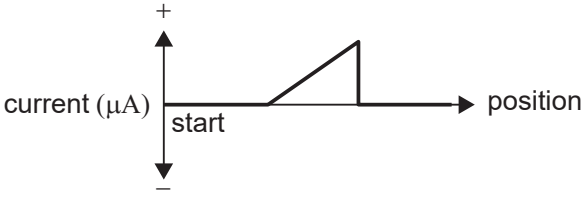
B.



C.



D.



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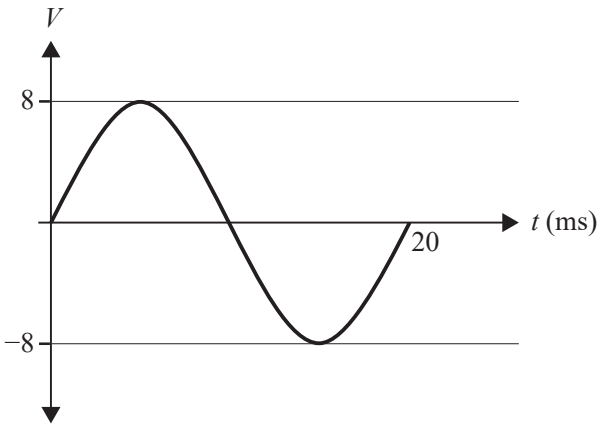
Question 12

The output of an AC generator is shown below.

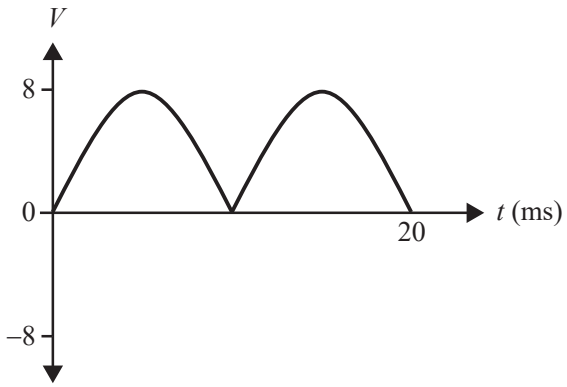


The following modifications are made to the generator:

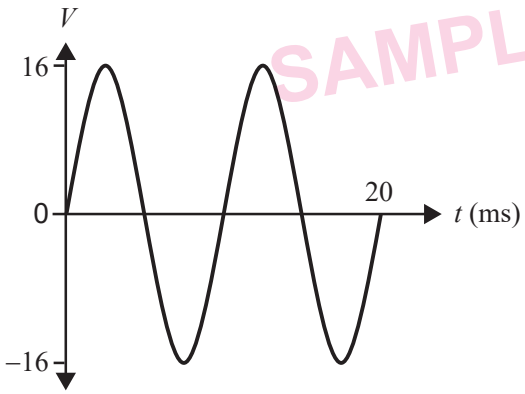
- its frequency is doubled
- the slip rings at its output are replaced with a split-ring commutator.

Which of the following represents its resulting output?

A.

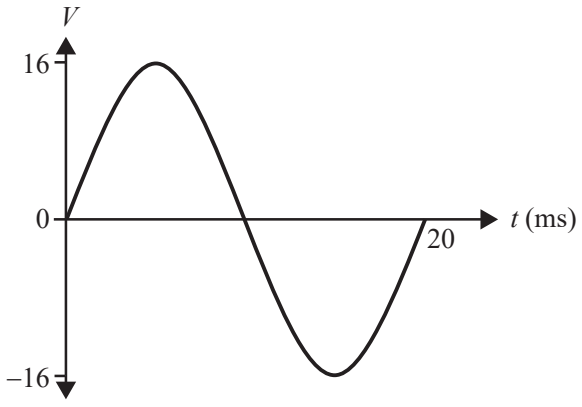


B.

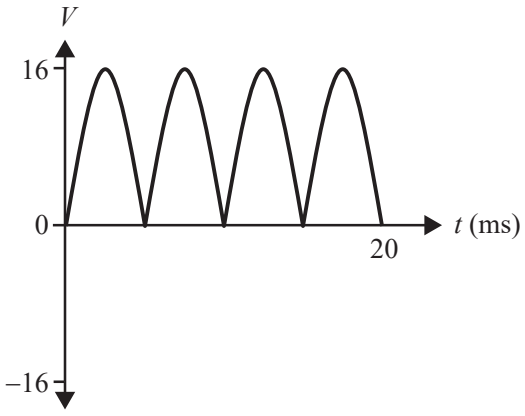


SAMPLE

C.



D.



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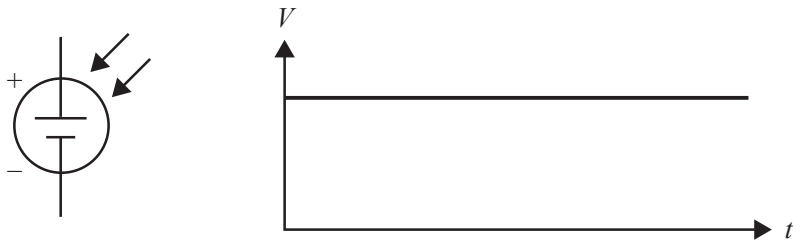
Question 13

The DC output, V, of a photovoltaic cell versus time, t, when exposed to full sunlight is shown in the diagram below.



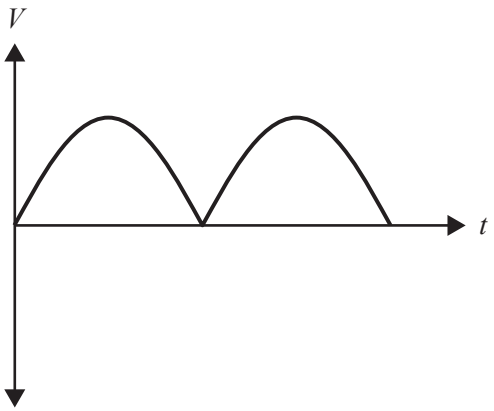
This output is connected to an **inverter** in a household rooftop photovoltaic system.

Which of the following graphs best represents the output of the inverter?

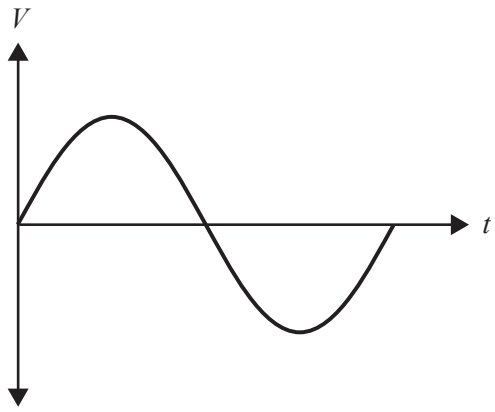
A.

SAMPLE

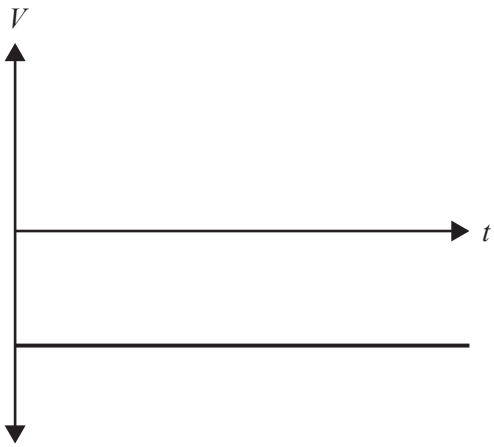
B.



C.



D.



Do not write in this area.

Question 14

Synchrotron light is produced by electrons travelling at very high velocities. The electrons emit light when they are travelling at a constant speed in the curved paths in the synchrotron.

Electrons emit light in the curved paths of the synchrotron because

A. they emit light when they are accelerated.

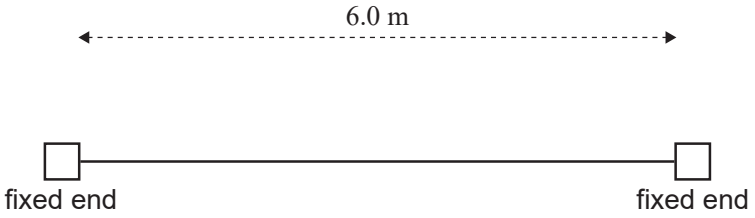
B. they emit light when moving near a speed of $3 \times 10^8 \text{ m s}^{-1}$

C. they only emit light when they pass through magnetic fields.

D. they only emit light when they transition between shells in an atom.

Question 15

The diagram below shows a 6.0 m string attached to two fixed ends. The string is vibrated, and a standing wave is produced on the string.



Which one of the following wavelengths could **not** be produced as a standing wave on the string if it were vibrated?

A. 12.0 m

B. 5.0 m

C. 4.0 m

D. 3.0 m

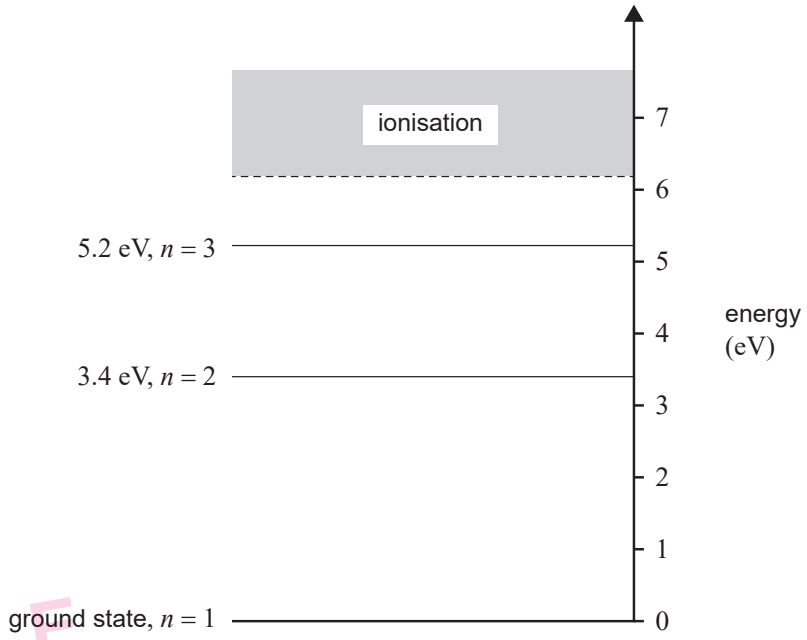
SAMPLE

Do not write in this area.

Question 16

The spectrum of photons emitted by excited atoms is being investigated by two Physics students. The atomic energy level diagram of the atom being studied is shown below.

Although most of the atoms are in the ground state, some atoms are known to be excited to the $n = 2$ and $n = 3$ excited states. The ionisation energy for this atom is 6.2 eV.



SAMPLE

The lowest energy photon that could be emitted from the excited atoms is

A. 1.0 eV

B. 1.8 eV

C. 3.4 eV

D. 5.2 eV

Do not write in this area.

Do not write in this area.

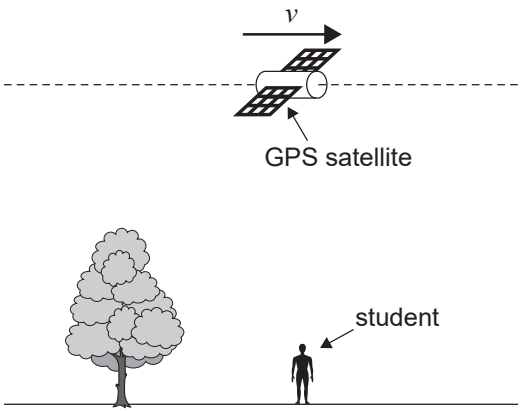
Question 17

The global positioning system (GPS) makes use of satellites in orbit around Earth.

The student shown in the diagram below is standing on the ground while a GPS satellite passes directly overhead. The Lorentz factor, γ, of the GPS satellite is $\left(1+\left[5\times10^{-11}\right]\right)$.

Assume that the GPS satellite is travelling along a horizontal path, and ignore the effect of Earth's gravitational field.

Assume that both the GPS satellite and the student are in inertial reference frames.



If exactly one second (1 s) passes as measured on the GPS satellite, how much time elapses for the student?

SAMPLE

A. exactly 1 s

B. $\left(1-\left[5\times10^{-11}\right]\times1\text{ s}\right)$

C. $\left(1+\left[5\times10^{-11}\right]\times1\text{ s}\right)$

D. $\dfrac{1}{\left(1+\left[5\times10^{-11}\right]\right)}\times1\text{ s}$

Question 18

Classical physics predicts that an electron travelling at $2.85\times10^{8}\text{ m s}^{-1}$ should have a kinetic energy of $3.70\times10^{-14}\text{ J}$. However, experiments with electrons travelling at these speeds show that their kinetic energy is greater. This difference in kinetic energy is due to relativistic effects.

Given that the Lorentz factor, γ, of electrons at this speed is 3.2, which one of the following gives the relativistic kinetic energy of an electron travelling at a speed of $2.85\times10^{8}\text{ m s}^{-1}$?

A. $2.62\times10^{-13}\text{ J}$

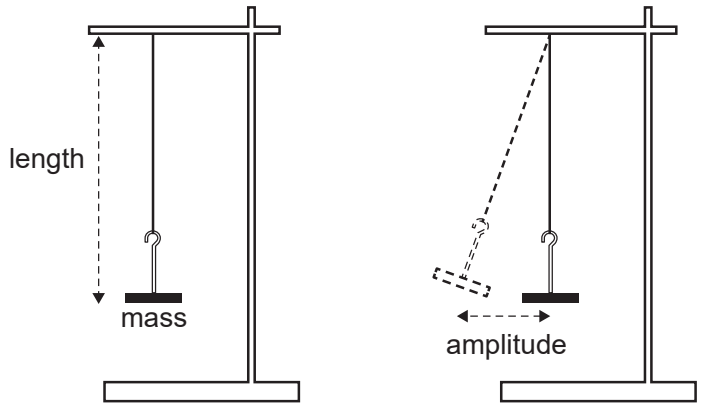
B. $1.80\times10^{-13}\text{ J}$

C. $1.18\times10^{-13}\text{ J}$

D. $3.70\times10^{-14}\text{ J}$

Question 19

As part of an experimental investigation, Physics students use a pendulum, as shown below, to indirectly measure the magnitude of Earth's gravitational field at their location.



The students use a constant mass and a constant amplitude of swing, changing only the length of the pendulum and then measuring the time for five oscillations. They obtain four different time readings for four different lengths of the pendulum.

Which one of the following best explains why the students measured the time for five oscillations rather than the time for one oscillation?

A. One oscillation is too quick to see.

B. Five oscillations reduce the effect of air resistance.

C. Five oscillations reduce the uncertainty of the measured period.

D. Five oscillations reduce the uncertainty of the measured length.

SAMPLE

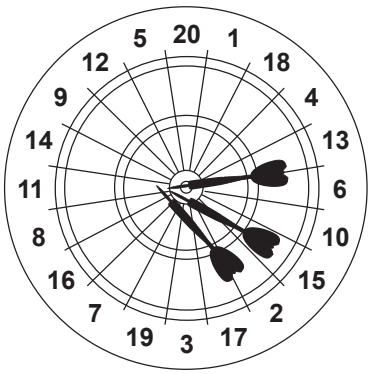
Do not write in this area.

Question 20

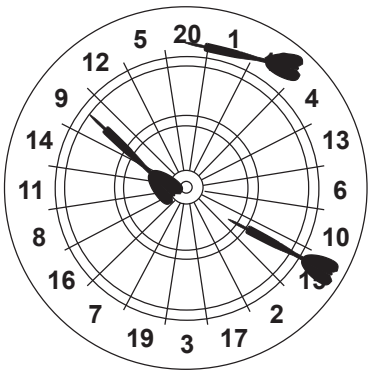
Four darts players, A, B, C and D, played a modified game of darts. The aim was to hit the bullseye at the centre of the dartboard.

Each player threw three darts. The results of their throws are shown below.

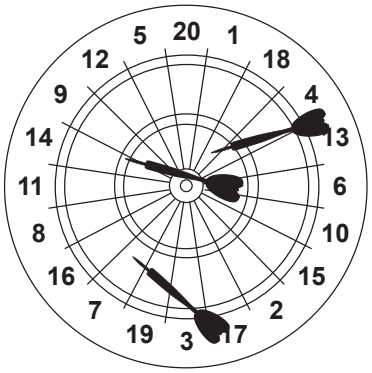
Player A



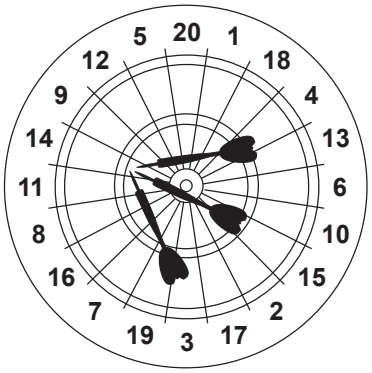
Player B



Player C



Player D



SAMPLE

Which one of the players produced a set of attempts that could be described as being precise but inaccurate?

A. Player A

B. Player B

C. Player C

D. Player D

Do not write in this area.

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.
- 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 (4 marks)

Shanna has a tricycle with an attached trailer that she can use to give her little brother a ride, as shown in Figure 1.

SAMPLE

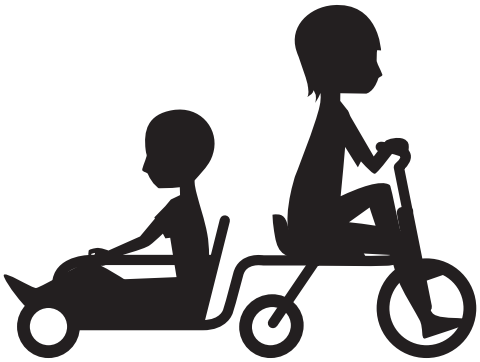


Figure 1

Shanna and her tricycle have a combined mass of $45\ \text{kg}$, and her brother and the trailer have a combined mass of $25\ \text{kg}$. This situation can be modelled by representing Shanna and her brother as blocks A and B respectively, treating Shanna's efforts as an external force of $35\ \text{N}$ and ignoring retarding friction. The model is shown in Figure 2.

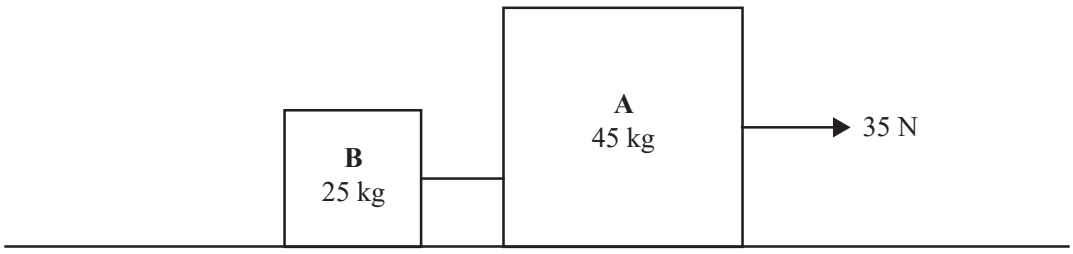


Figure 2

Do not write in this area.

a. Calculate the magnitude of the acceleration of Shanna, her brother and the tricycle with the trailer. Ignore the mass of the rod that connects the trailer to the bike. 1 mark

m s^{-2}

b. Calculate the magnitude of the force exerted on Shanna and the tricycle by her brother and the trailer. 1 mark

N

SAMPLE

c. State the magnitude of the force exerted by Shanna and the tricycle on her brother and the trailer. 1 mark

N

d. In real life, Shanna finds that once she has got the tricycle and trailer moving, they travel at a steady speed.

Which one of the assumptions made in modelling her motion needs to be changed in order to explain why Shanna does not continue to accelerate? 1 mark

Do not write in this area.

Question 2 (4 marks)

Lucinda is running at a speed of $6.0\ \text{m s}^{-1}$ along a horizontal diving platform that is $8.0\ \text{m}$ vertically above the water. She runs horizontally off the end of the diving platform and lands at a horizontal distance, d, from the end of the diving platform, as shown in Figure 3.

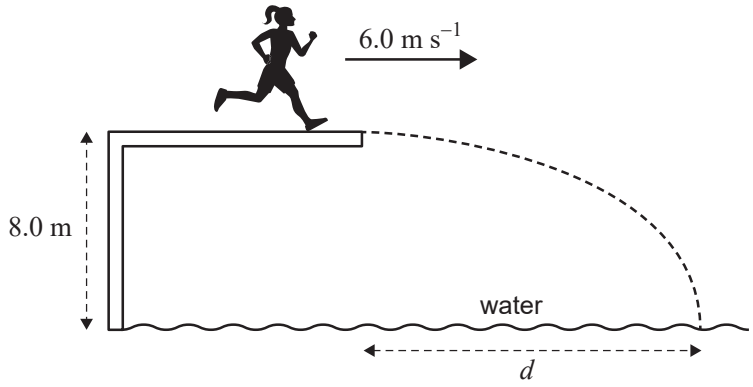


Figure 3

a. Calculate d, the horizontal distance between the end of the diving board and the point where Lucinda lands in the water, modelling Lucinda as a point mass. 2 marks

SAMPLE

m

b. Lucinda would like to spend more time in the air before she lands in the water.

How might she achieve this? Justify your reasoning. No calculations are required. 2 marks

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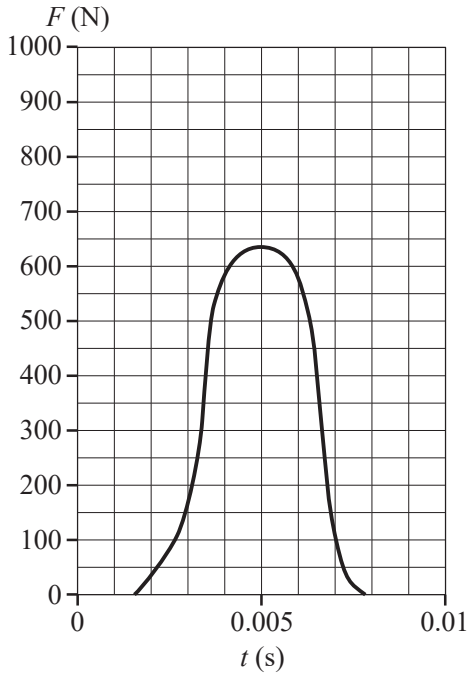
SAMPLE

Question 3 (6 marks)

The graph in Figure 4 shows the force, F, versus time, t, for a competition tennis ball while it is being hit by a tennis racquet. The ball is at rest before the collision with the tennis racquet.



SAMPLE

Figure 4

a. Calculate the impulse acting on the tennis ball during this collision. Show your reasoning. 2 marks

N s

Do not write in this area.

b. The competition tennis ball has a mass of $0.060\ \text{kg}$.

i. Calculate the speed of the tennis ball in km hr^{-1}. Show your working. 2 marks

km hr^{-1}

ii. Practice tennis balls are heavier than competition tennis balls.

Determine what effect, if any, this will have on the speed of a practice tennis ball if the tennis racquet produces the same force versus time graph as shown in Figure 4 on the practice tennis ball. Explain your reasoning. 2 marks

SAMPLE

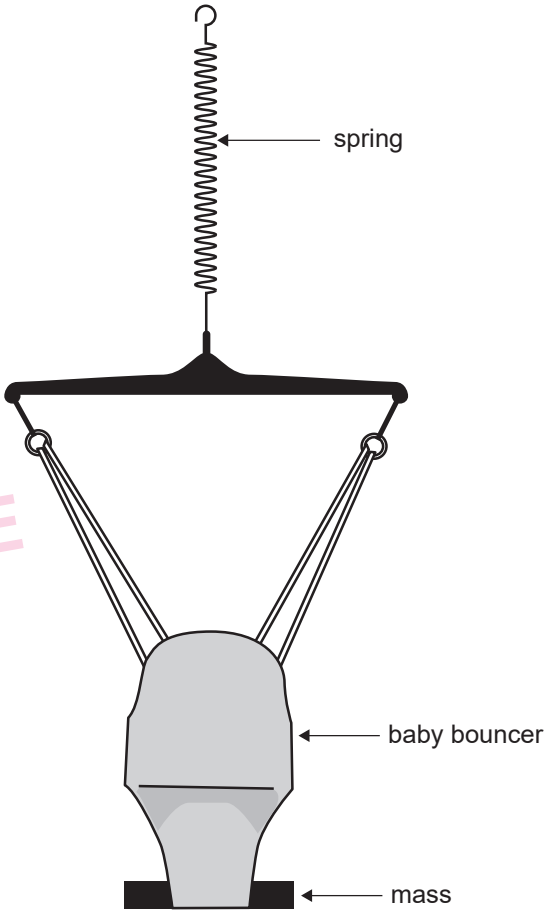
Do not write in this area.

Question 4 (6 marks)

Genevieve and Lee are experimenting with springs, using a baby bouncer of the type shown in Figure 5. They hang the bouncer vertically from a doorway. The mass of the baby bouncer is $1.0\ \text{kg}$.

Genevieve and Lee place a mass of $4.0\ \text{kg}$ in the bouncer and gently lower it to the equilibrium position, where the mass is stationary when released.

The bouncer's spring extends by $0.050\ \text{m}$.



SAMPLE

Figure 5

a. Calculate the magnitude of the change in the gravitational potential energy of the mass as the bouncer is lowered. 2 marks

J

Do not write in this area.

b. Calculate the elastic strain potential energy of the stretched spring in the equilibrium position. 2 marks

J

c. Has energy been conserved in the mass-spring system? Explain your answer. 2 marks

SAMPLE

Do not write in this area.

Question 5 (8 marks)

A commercial company, AlphaSpace, has launched more than 4000 satellites in low Earth orbits around Earth to provide global high-speed internet access.

Figure 6 shows an artist's impression of a small number of satellites in Earth's orbit.

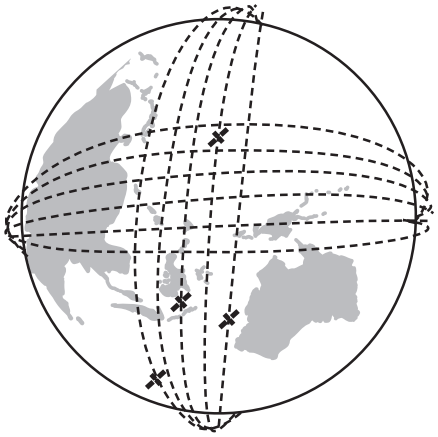


Figure 6

a. The latest satellites placed in orbit have a mass of $800\ \text{kg}$ and orbit at an altitude of $550\ \text{km}$.

i. Show that the period of orbit of a satellite is $5.73 \times 10^3\ \text{s}$. Assume that the orbit is circular and stable. 2 marks

s

ii. How many complete orbits will a satellite make in one day? 1 mark

SAMPLE

Do not write in this area.

b. Calculate the speed of a satellite in orbit. 2 marks

m s^{-1}

c. AlphaSpace already has approval to place $12\,000$ satellites in orbit, and plans to eventually put a further $30\,000$ satellites in orbit. AlphaSpace refreshes its satellite system every five years with newer technology.

At the end of their service, the old satellites are steered out of their stable orbits into descending paths into Earth's upper atmosphere, where they burn up.

Take the edge of Earth's atmosphere to be $100\ \text{km}$ above Earth's surface.

i. Will the satellites be going slower, at the same speed or faster as they descend towards Earth's upper atmosphere? Justify your answer. 2 marks

SAMPLE

ii. Suggest a physics reason why the old satellites burn up when they enter Earth's upper atmosphere. 1 mark

Do not write in this area.

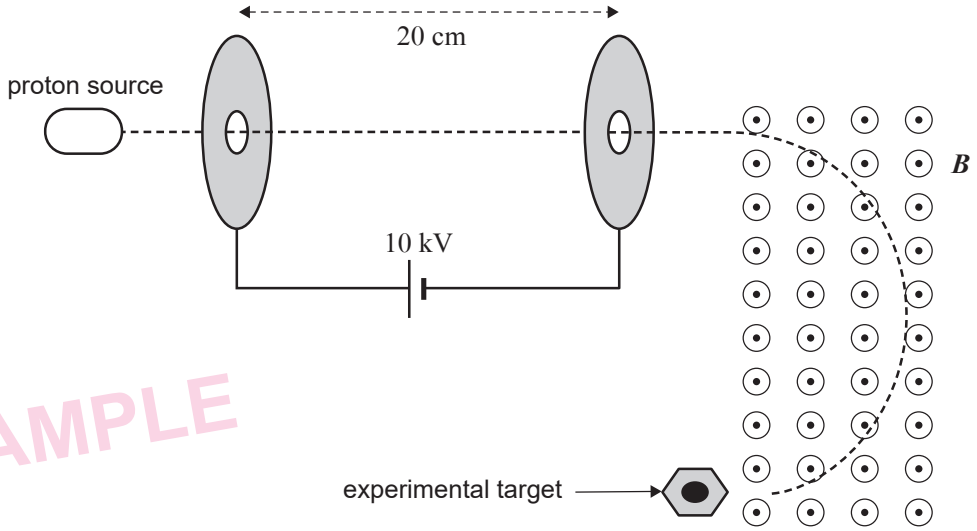
Question 6 (7 marks)

Proton accelerators are used to investigate the effect of low-energy proton beams on simple biological cells.

The paths of these protons are controlled using magnetic fields in an apparatus similar to that shown in Figure 7a.

An electric field, E, initially accelerates a proton between two plates.

The proton then exits into a region of uniform magnetic field, B, at right angles to its path, which is directed out of the page, as shown in Figure 7a. The magnetic field is used to change the direction of travel of the proton so that it can accurately hit the experimental target containing the biological cells.



SAMPLE

Figure 7a

Data	
mass of proton	1.7×10^{-27} kg
charge on proton	$+1.6 \times 10^{-19}$ C
accelerating voltage	10 kV
distance between plates	20 cm
strength of magnetic field	2.0×10^{-2} T

a. Calculate the strength of the uniform electric field, E, between the plates. 1 mark

$\mathrm{V\ m^{-1}}$

Do not write in this area.

b. Determine the energy of a proton in eV as it exits the electric field. 1 mark

eV

c. Calculate the speed of a proton as it exits the electric field. Show your working. 2 marks

$\mathrm{m\ s^{-1}}$

d. With a different accelerating voltage, a proton now exits the electric field at a speed of $1.0 \times 10^6\ \mathrm{m\ s^{-1}}$

Calculate the radius of the path of this proton in the magnetic field.
Show your working. 2 marks

m

SAMPLE

Do not write in this area.

Question 6 continues on the next page.

e. The experimental target is moved as shown in Figure 7b below, and with the same initial accelerator settings.

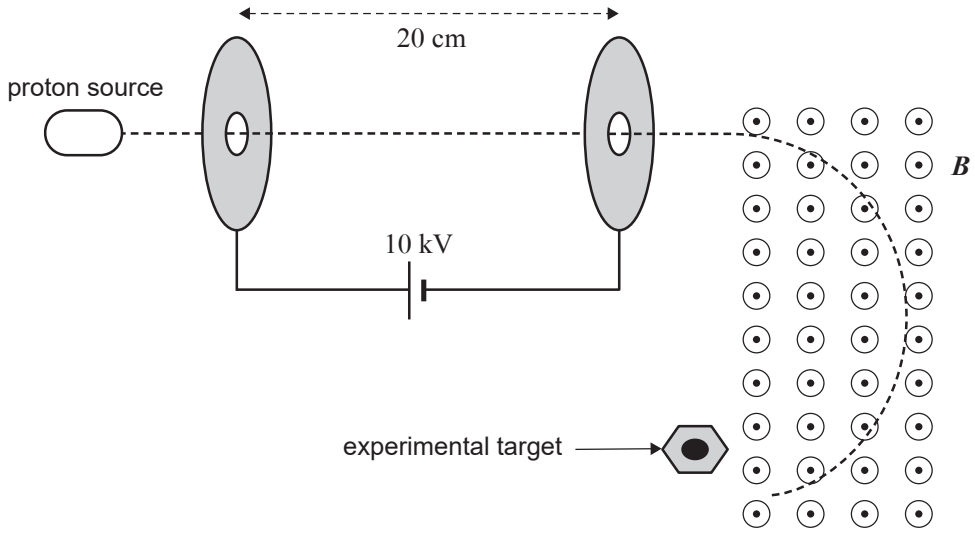


Figure 7b

Suggest one modification to the values set for the experimental equipment that will allow the proton to hit the experimental target in this new position. 1 mark

SAMPLE

Do not write in this area.

Question 7 (5 marks)

Figure 8 shows a small DC electric motor, powered by a battery that is connected via a split-ring commutator. The rectangular coil has sides KJ and LM. The magnetic field between the poles of the magnet is uniform and constant.

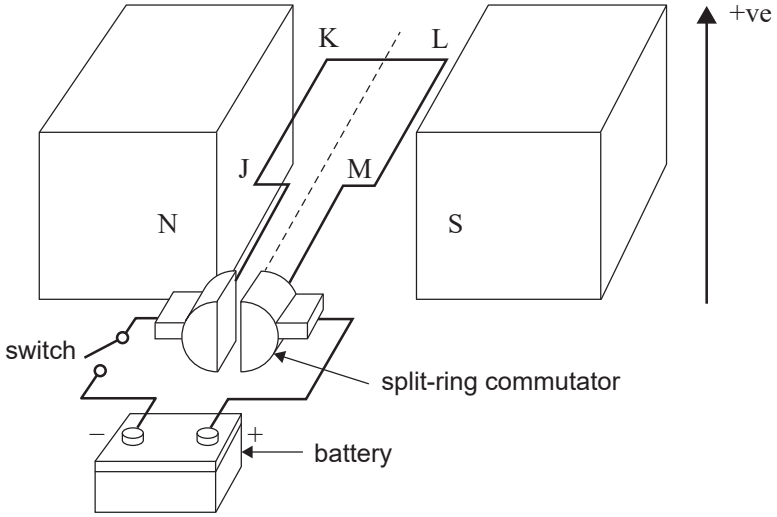


Figure 8

The switch is now closed and the rectangular coil rotates.

a. Explain the function of the split-ring commutator. 2 marks

SAMPLE

b. On the axes below, sketch the force on side JK of the rectangular coil, F_{JK}, versus time, t, for one complete revolution of the DC motor. Take directly up the page as being positive and take $t = 0$ from the position of the coil shown in Figure 8. 3 marks

Do not write in this area.

Question 8 (8 marks)

Figure 9 shows a simple AC generator consisting of a rectangular coil of 500 turns that rotates in a uniform magnetic field. The output voltage can be displayed on an oscilloscope.

The magnetic flux through the coil at the position shown in Figure 9 is 2.0×10^{-3} Wb and the magnetic field strength is 0.8 T.

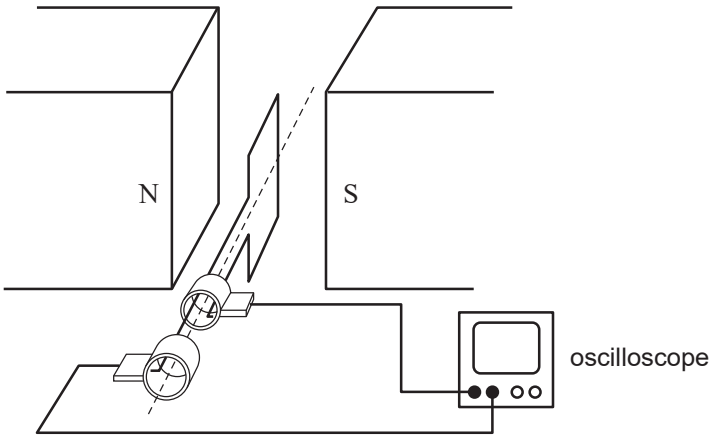


Figure 9

a. Calculate the area of the coil. 1 mark

SAMPLE

m^2

Do not write in this area.

b. The generator starts rotating from rest and its speed of rotation is gradually increased until it is rotating at a constant rate after two cycles have elapsed. Throughout its motion it produces an AC output.

On the axes below, sketch the EMF output versus time graph from the coil, beginning when the coil is at rest to when it produces a constant AC output. Show at least three cycles of the coil's rotation. Values on the axes are not required. 2 marks

c. The generator coil is now rotated at a constant frequency. The maximum magnetic flux is still 2.0×10^{-3} Wb.

The average EMF induced over a quarter of a cycle, starting from the position of maximum magnetic flux, is 40 V.

Calculate the frequency of rotation of the generator. 3 marks

Hz

d. Explain the role of the slip rings in the AC generator. 2 marks

SAMPLE

Do not write in this area.

Question 9 (10 marks)

Dairy farmers Joe and Phoenix are not connected to mains electricity. They use a diesel generator to generate electrical energy. Concerned about their carbon dioxide emissions, they decide to install a $12.0\ \text{kW}$ bank of solar photovoltaic cells (solar panels) in a paddock on their farm.

They have 24 solar panels in their system, as shown in Figure 10. These solar panels can deliver $12.0\ \text{kW}$ of electrical energy in full sunlight.

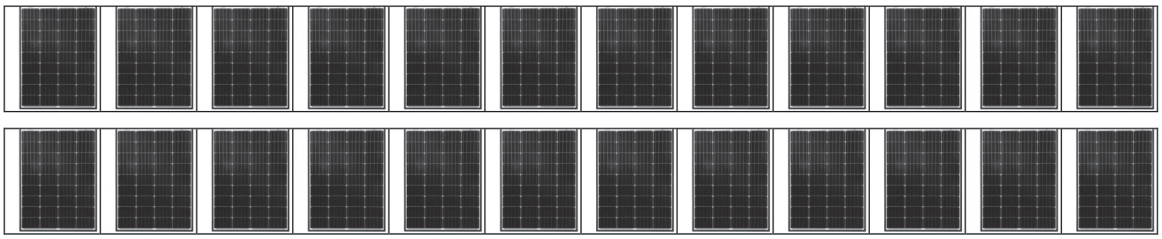


Figure 10

Joe and Phoenix connect their bank of solar panels to an inverter attached to their dairy so that they can run the standard electrical equipment that would normally be powered by mains power.

A schematic diagram is shown in Figure 11.

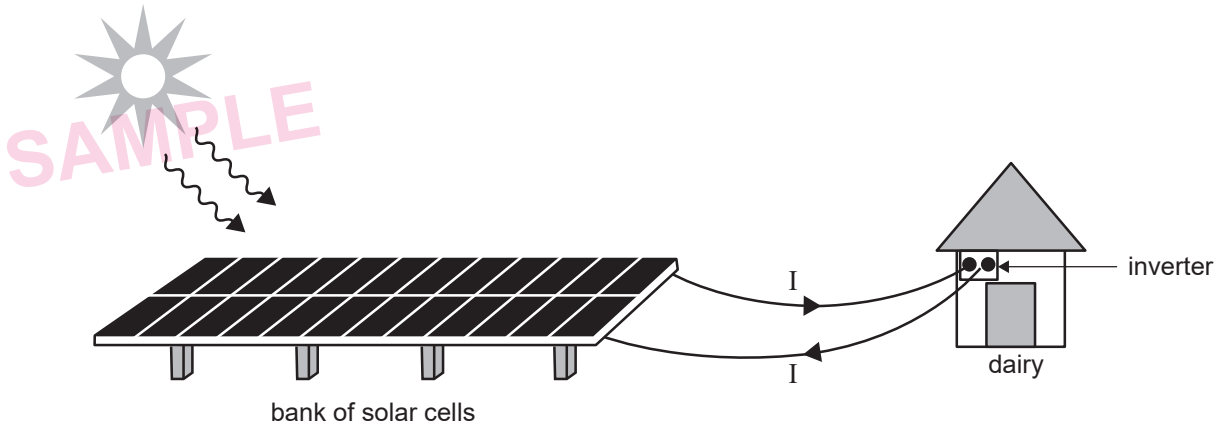


Figure 11

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a. Show that the output of each solar panel under full sunlight conditions is $500\ \text{W}$. 1 mark

b. Joe and Phoenix have lost the instructions that detail how to connect the individual solar panels together.

They measure the output current of one solar panel in full sunlight and it gives a steady $20\ \text{A}$.

Calculate the voltage output of one solar panel. 1 mark

V

SAMPLE

Do not write in this area.

Question 9 continues on the next page.

Use the following information to answer parts c, d and e.

Joe and Phoenix measure the resistance of the wires connecting their bank of solar cells to the dairy and find that the total resistance of the two wires is $1.0\ \Omega$.

Joe suggests that the 24 panels should be placed in a series circuit, as shown in Figure 12a, while Phoenix suggests that the 24 panels should be placed in a parallel circuit, as shown in Figure 12b.

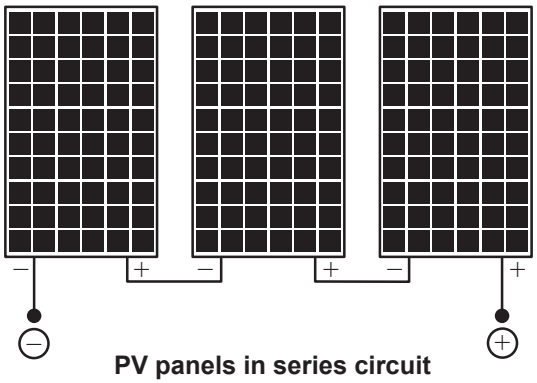

Figure 12a

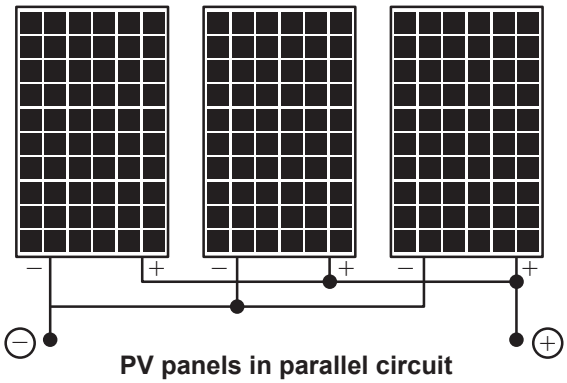

Figure 12b

c. Calculate the total voltage and current output for the 24 solar panels if they are placed in a series circuit. 2 marks

SAMPLE

V A

d. Calculate the total voltage and current output for the 24 solar panels if they are placed in a parallel circuit. 2 marks

V A

Do not write in this area.

e. Determine who is correct regarding the type of circuit they should choose:

- Joe, who suggests a series circuit; or
- Phoenix, who suggests a parallel circuit.

Justify your answer. 3 marks

f. Explain the role of the inverter to ensure the correct operating of all the standard electrical equipment in the dairy from the input provided by the $12.0\ \text{kW}$ bank of solar photovoltaic cells. 1 mark

SAMPLE

Do not write in this area.

Question 10 (6 marks)

Students are looking at a Young's double-slit interference pattern produced by a monochromatic light source and note the central bright band with alternating dark and light bands on either side, as shown in Figure 13.

The bright region marked C is in the centre of the pattern. The dark region marked X is the third dark band to the right of the centre.

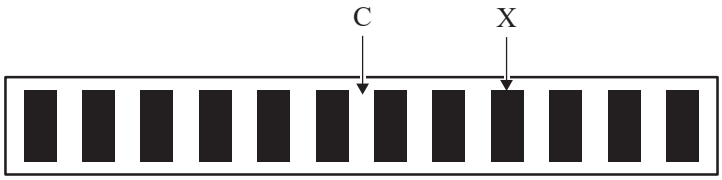

Figure 13

a. Explain why the band marked X in Figure 13 is a dark band. 2 marks

b. The frequency of the light source is increased, and the students note a change in the spacing.

What would need to be done to the slit separation to return the pattern to its original spacing? Justify your answer. 2 marks

c. Explain how the results of this experiment could support a wave model of light. 2 marks

SAMPLE

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SAMPLE

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Question 11 (6 marks)

Bruce and Denise are discussing the effect of light frequency on photocurrent in a photoelectric cell while investigating the photoelectric effect.

Figure 14 shows a graph of the photocurrent against the voltage applied across the photocell.

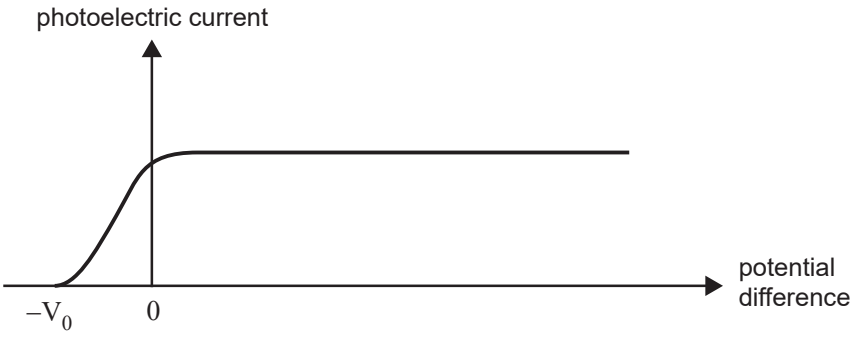


Figure 14

Using a monochromatic light source of wavelength $450\ \text{nm}$, they record a maximum photocurrent of $1.8\ \text{mA}$ and a stopping voltage, $-V_0$, of $-0.47\ \text{V}$.

a. Determine the work function of the metal in the photocell Bruce and Denise are using. 3 marks

SAMPLE

eV

Do not write in this area.

b. The monochromatic light source is now changed to one of wavelength $400\ \text{nm}$ and delivers the same light output power as the original source.

Bruce predicts that the stopping voltage, $-V_0$, will become $-0.82\ \text{V}$ and the maximum photocurrent will decrease.

Denise agrees with the stopping voltage prediction but states that changing the wavelength will only affect the stopping voltage, as photocurrent is dependent on intensity.

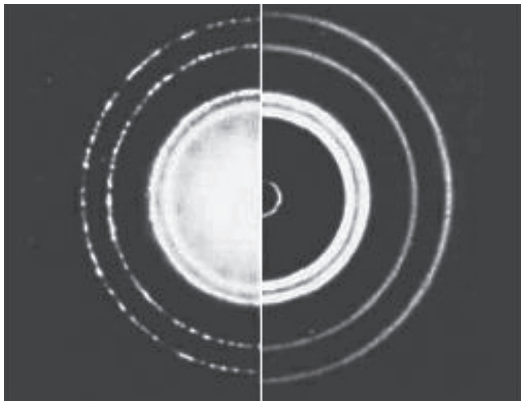
Evaluate Bruce's and Denise's arguments. 3 marks

SAMPLE

Do not write in this area.

Question 12 (6 marks)

Students are comparing the diffraction patterns produced by electrons and X-rays, in which the same spacing of bands is observed, as shown in Figure 15. Note that both patterns shown are to the same scale and use the same sample.



electrons X-rays

Figure 15

a. Explain why electrons can produce the same spacing of bands as X-rays in a diffraction pattern. 3 marks

SAMPLE

Do not write in this area.

b. The electron diffraction pattern is produced by electrons with energy, E, of 3.0×10^3 eV.

Calculate the wavelength of these electrons. 3 marks

m

SAMPLE

Do not write in this area.

Question 13 (4 marks)

Up until the late 1800s, it was thought that light waves, like other waves, needed a medium to travel through. Scientists at the time theorised that space was filled with a medium called ‘the ether’ and that electromagnetic waves travelled through this ether. In the late1800s, Michelson and Morley performed an experiment to try to provide evidence for the existence of the ether.

Michelson and Morley hypothesised that as Earth moves around the Sun, it travels through the ether, hence there should be a difference in the measured speed of light depending on whether the light is travelling parallel to, or perpendicular to, the direction of Earth’s movement through the ether.

Identify what Michelson and Morley’s experiment actually showed and explain how this result supports Einstein’s special theory of relativity.

SAMPLE

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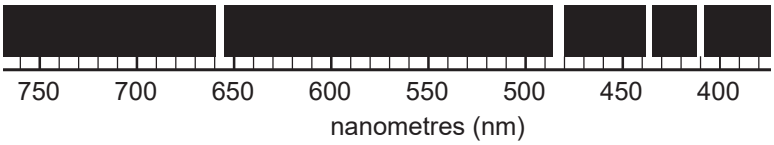
Question 14 (4 marks)

The visible spectra for hydrogen absorption and hydrogen emission under certain conditions are as shown in Figure 16.

Hydrogen absorption spectrum



Hydrogen emission spectrum

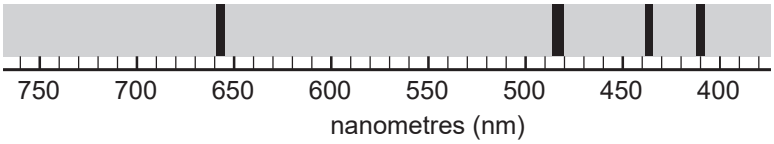


Figure 16

Source: Adapted from 'Bohr's model of hydrogen atom: absorption / emission lines', *Physical Chemistry (Essentials)* – Online Course, Khan Academy, <https://www.khanacademy.org/science/physical-chemistry-essentials>

a. Explain how the hydrogen absorption spectrum is produced. 2 marks

SAMPLE

b. Explain how the hydrogen emission spectrum is produced. 2 marks

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Question 15 (16 marks)

Two Physics students, Ishva and Magnus, are investigating circular motion and centripetal force. Figure 17 shows the experimental set-up and the apparatus that the students use.

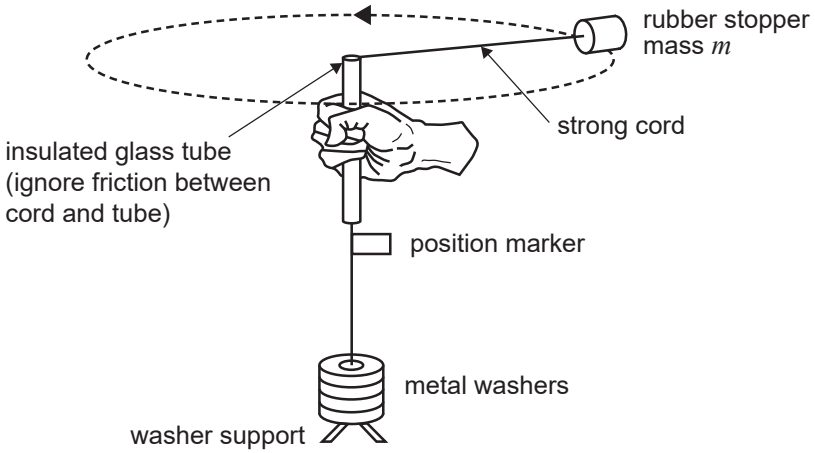

Figure 17

In reality, the students find that the cord is not quite horizontal but dips downward slightly due to the gravitational force acting on the rubber stopper. Their Physics teacher assures them that this will not invalidate their investigation.

SAMPLE

Ishva holds the glass tube and sets the rubber stopper rotating in a horizontal circle of radius $0.75\ \text{m}$. She maintains a constant radius of the circle by keeping the position marker at a fixed position just below the bottom of the glass tube.

Magnus uses a stopwatch to measure the time for 20 revolutions of the rubber stopper, repeating this measurement three times. He notes all the data collected in their logbook. The experiment is then repeated five more times, with extra metal washers being added before each new trial is undertaken. Each washer has a stated mass of $30.0\ \text{g}$ with an uncertainty of $\pm\ 0.1\ \text{g}$.

a. What information about the uncertainty in the measurement value of the washer mass is conveyed by the addition of $\pm\ 0.1$? 1 mark

Do not write in this area.

b. The tension in the cord supplies the centripetal force that the rubber stopper needs to rotate in a circle.

What is the cause of this tension? 1 mark

c. Magnus and Ishva record their results in a table but accidently leave two blank spaces, as shown below.

Fill in the blank spaces in the table below.

Use $g = 9.81\ \text{N kg}^{-1}$ for your calculations. 2 marks

Total mass of washers M (kg)	Gravitational force acting on washers Mg (N)	Average time for 20 rotations (s)	Period, T (s)	Frequency, f (Hz)	f^2 (Hz^2)
0.40	3.92	16.4	0.82	1.22	1.49
0.60	5.89	14.0	0.70	1.43	2.04
0.72	7.06	12.8		1.56	2.44
0.80	7.85	11.4	0.57	1.75	
0.96	9.42	11.0	0.55	1.82	3.31
1.08	10.59	10.4	0.52	1.92	3.70

SAMPLE

Do not write in this area.

Question 15 continues on the next page.

d. Ishva and Magnus fill in the blank spaces in their table and then plot the gravitational force acting on the washers, Mg, on the y-axis and the frequency squared, f^2, on the x-axis.

They then draw their straight line of best fit through the plotted points, as shown in Figure 18.

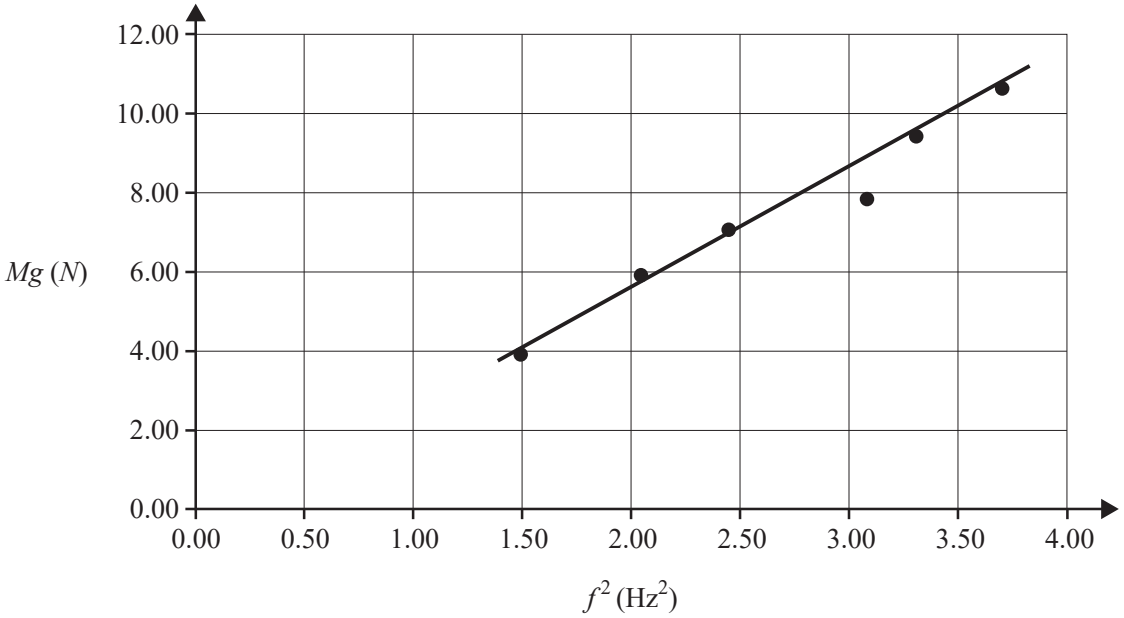

Figure 18

SAMPLE

i. Show that the relationship between the variables f, M and the constants g, π, R (the radius of the circle) and m (the mass of the rubber stopper) for an ideally performed investigation of this kind can be expressed as:

$$Mg = 4\pi^2 Rmf^2$$

Show all the steps of your reasoning. 2 marks

Do not write in this area.

ii. On Figure 18, extend the straight line of best fit the students have plotted until it intersects the x-axis.

Comment on the implications of this intersection point with respect to the students' investigation and the relationship in **part d.i**. 4 marks

iii. Calculate the gradient of the line of best fit plotted in Figure 18. 2 marks

iv. Using the gradient calculated in **part d.iii**, determine the mass of the rubber stopper m. 2 marks

kg

SAMPLE

Do not write in this area.

Question 15 continues on the next page.

v. The graph in Figure 18 shows one data point $(7.85, 3.08)$ that clearly does not fit the line of best fit drawn by Ishva and Magnus. They discuss the possible reasons for this.

Ishva suggests that the number of washers might have been incorrectly counted, and Magnus suggests that the frequency might have been incorrectly measured.

Given the experimental method used, which student is more likely to be correct? Justify your answer. 2 marks

SAMPLE

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End of examination questions

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Answers to multiple-choice questions

Section A

Question	Answer
1	A
2	A
3	B
4	B
5	C
6	A
7	D
8	D
9	D
10	D
11	A
12	D
13	C
14	A
15	B
16	B
17	C
18	B
19	C
20	D

SAMPLE