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SUPERVISOR TO ATTACH
PROCESSING LABEL HERE

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

Physics

Question and Answer Book

VCE (NHT) Examination – Monday 26 May 2025

- Reading time is **15 minutes**: 10.30 am to 10.45 am
- Writing time is **2 hours 30 minutes:** 10.45 am to 1.15 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 44 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

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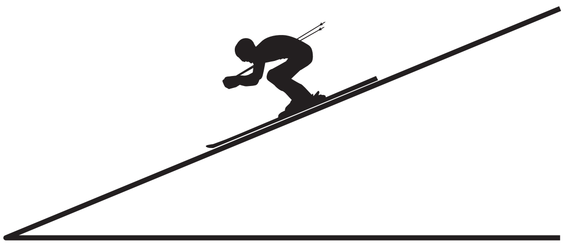
Section A

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 skier is accelerating down on a perfectly smooth frictionless snow-covered slope, as shown in the diagram below.



Which one of the arrows shown below best represents the direction of the force exerted by the slope on the skier's skis?

A.

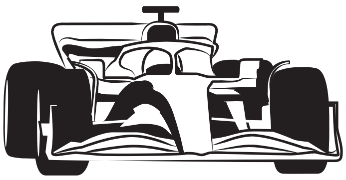
B.

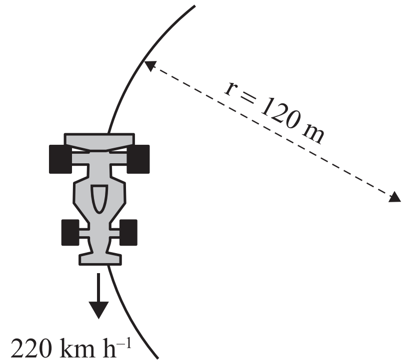
C.

D.

Question 2

A race car travels at a constant speed of 220 km h^{-1} around a curve. The total mass of the car and its driver is 800 kg. The track is horizontal and the curve forms part of a circle of radius 120 m, as shown in the diagram below.





Which one of the following is closest to the magnitude of the net force acting on the race car as it travels around the curve?

A. 4.14×10^2 N

B. 1.33×10^3 N

C. 2.49×10^4 N

D. 3.23×10^5 N

Question 3

A tennis ball falls vertically down onto a solid wooden floor from a height, *h*, and then bounces vertically back up to a height of 0.6 *h*. The ball is in contact with the floor for a very short time and at one instant is stationary.

Which one of the following statements best describes the forces acting on the ball during the time the ball is in contact with the solid wooden floor and stationary?

A. There are no forces acting on the ball as it is stationary.

B. The gravitational force acting on the ball is less than the normal force from the floor.

C. The gravitational force acting on the ball is equal to the normal force from the floor.

D. The gravitational force acting on the ball is greater than the normal force from the floor.

Question 4

A ball of mass 0.25 kg is launched horizontally from the edge of a 36 m high cliff with an initial speed of 10 m s^{-1}. Assume that there is no air resistance.

Which one of the following is closest to the horizontal distance that the ball lands from the base of the cliff?

A. 27 m

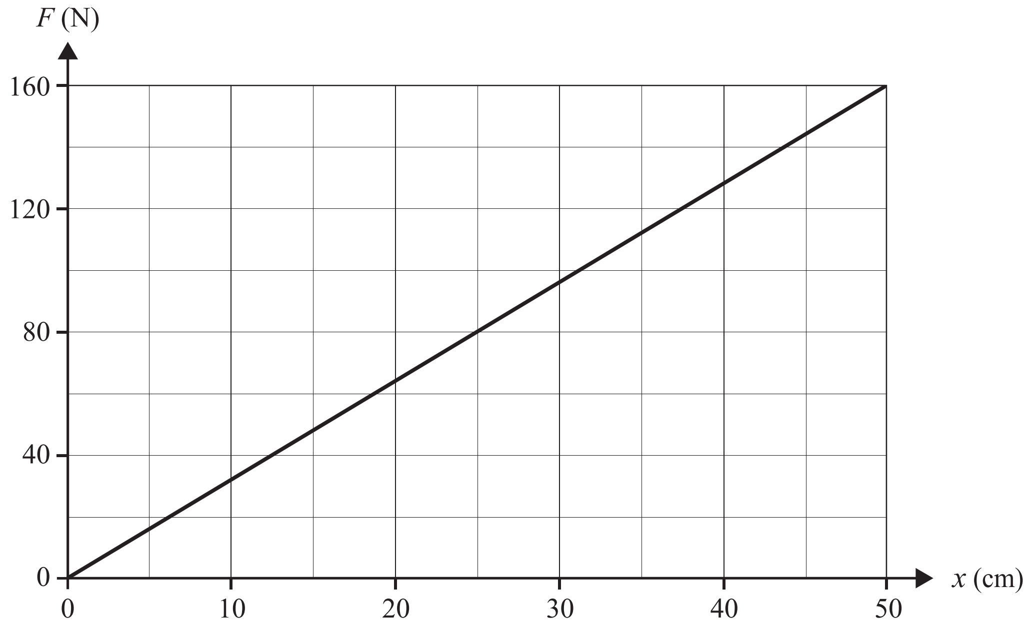
B. 37 m

C. 73 m

D. 98 m

Question 5

The force–distance graph shown below is for an ideal spring when compressed.



Which one of the following is closest to the elastic potential energy stored in the spring when the spring is compressed by 25 cm?

A. 10 J

B. 20 J

C. 40 J

D. 80 J

Question 6

A positive charge is initially located at point *X*, on the positive plate of a pair of charged parallel plates as shown in Diagram 1 below.

The potential difference between the plates is 100 V.

The positive charge is then moved from point *X* to point *Y* a distance of *d*, as shown in Diagram 1.

The magnitude of the potential energy change in moving from point *X* to point *Y* is 20 J.

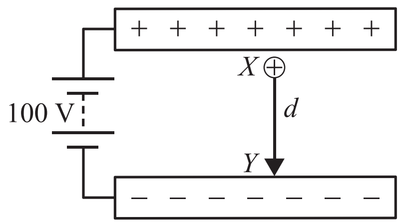


Diagram 1

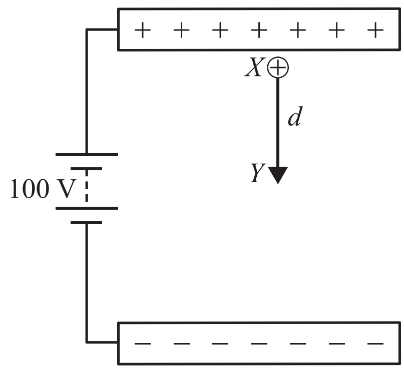


Diagram 2

The distance between the plates is then doubled, as shown in Diagram 2. The positive charge is again moved from point *X* to point *Y*.

Which one of the following is closest to the magnitude of the change in the positive charge's electrical potential energy moving through the same distance from point *X* to point *Y* as shown in Diagram 2 above?

A. 5.0 J

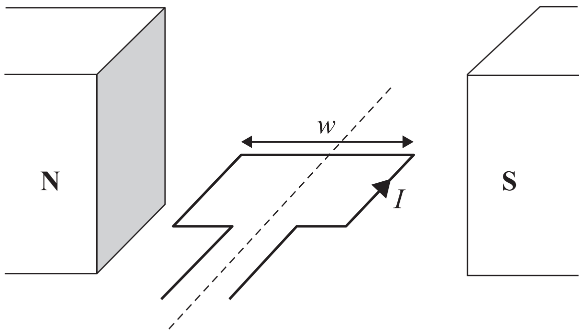
B. 10 J

C. 20 J

D. 40 J

Question 7

The diagram below shows a loop of wire, width w, carrying a current, I, within a uniform magnetic field, B.



Which one of the following statements concerning the torque experienced by the loop of wire is correct?

The torque is

A. dependent on the current, I, the magnetic field, B, but not the width of the loop, w.

B. dependent on the current, I, the width of the loop, w, but not the magnetic field, B.

C. dependent on the magnetic field, B, the width of the loop, w, but not the current, I.

D. dependent on each of the current, I, the magnetic field, B, and the width of the loop, w.

Question 8

The magnitude of the acceleration due to gravity at Earth's surface is g.

Planet Argus-3 is 1.5 times the mass of Earth and has half Earth's radius.

Which one of the following best represents the acceleration due to gravity at planet Argus-3's surface?

A. $3\,g$

B. $4\,g$

C. $6\,g$

D. $8\,g$

Question 9

When a rectangular coil of wire is rotated in a uniform magnetic field, B, both the magnetic flux through the coil and the induced voltage vary. The diagrams below show the coil of wire when it is parallel to the magnetic field (Diagram 1), and when it is perpendicular to the magnetic field (Diagram 2).

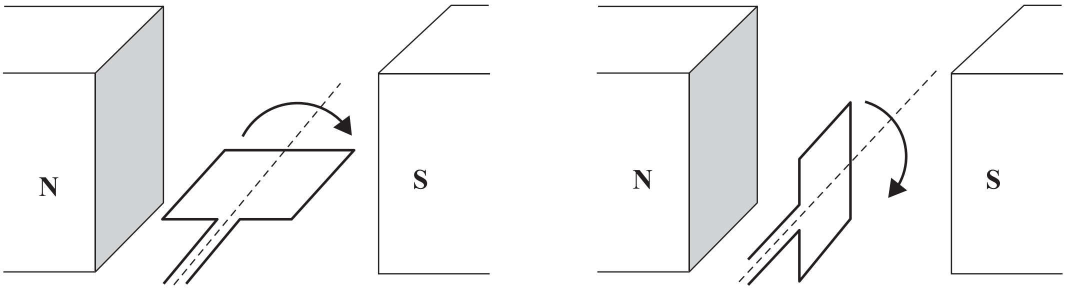


Diagram 1 **Diagram 2**

Which one of the following options best describes the conditions for maximum magnetic flux and for maximum induced voltage as the coil rotates?

	Maximum magnetic flux occurs when the coil is	**Maximum induced voltage occurs when the coil is**
A.	parallel to the B field	parallel to the B field
B.	parallel to the B field	perpendicular to the B field
C.	perpendicular to the B field	perpendicular to the B field
D.	perpendicular to the B field	parallel to the B field

Question 10

The main reason that high AC voltages (e.g. 300 kV) are commonly used for the long-distance (e.g. 100 km) transmission of a fixed amount of electrical energy is because a higher voltage means

A. less current, resulting in lower energy losses.

B. greater current, resulting in lower energy losses.

C. less current, resulting in higher energy losses.

D. greater current, resulting in higher energy losses.

Question 11

An ideal transformer is designed to transform 360 V RMS AC to 12 V RMS AC.

The ratio of $\frac{\textit{primary turns}}{\textit{secondary turns}}$ for this transformer is closest to

A. 0.030

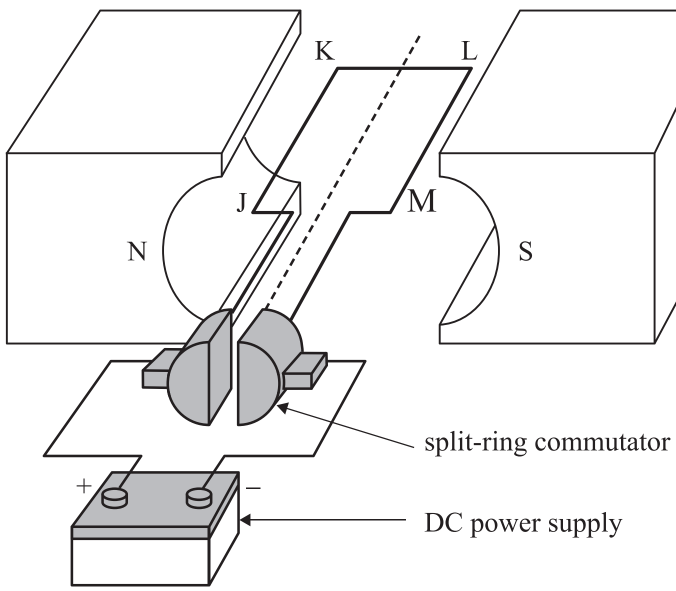
B. 0.30

C. 3.0

D. 30

Question 12

A schematic diagram of a simple DC motor is shown below.



Which one of the following arrows best gives the direction of the force acting on the side LM in the position shown in the diagram?

A.

B.

C.

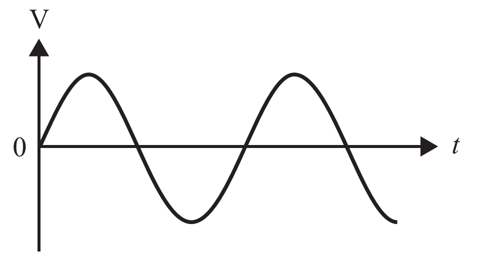
D.

Question 13

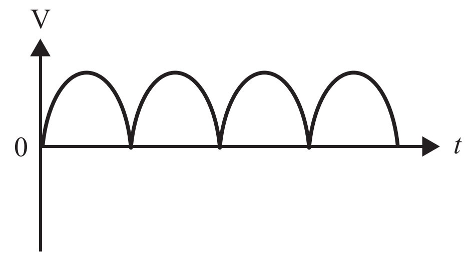
The output of a household rooftop solar photovoltaic system is connected to an inverter.

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

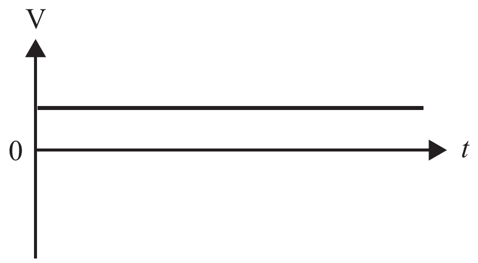
A.



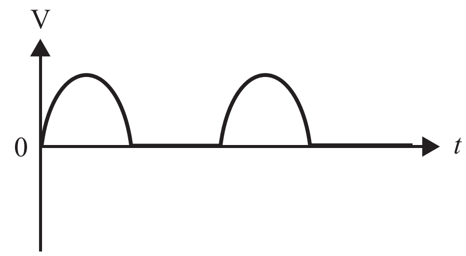
B.



C.

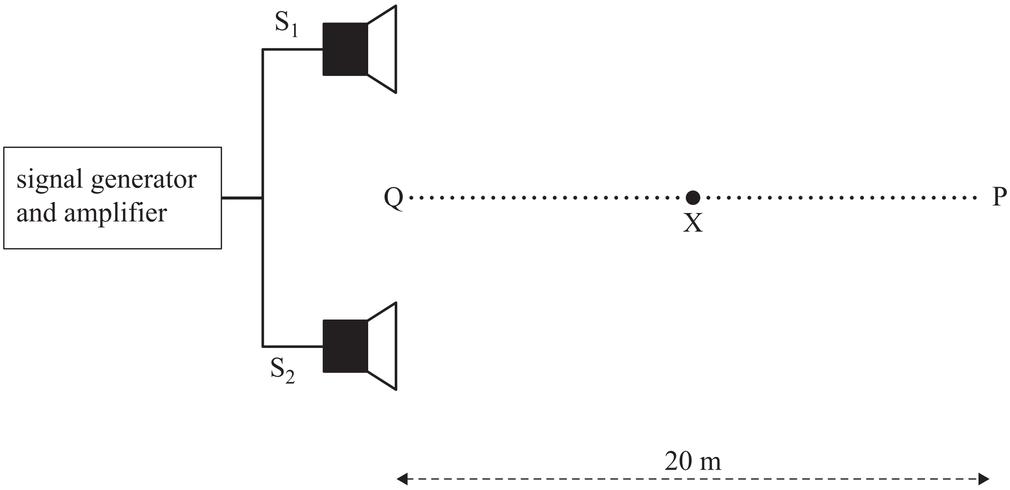


D.



Question 14

Sam and Simon are investigating interference effects using sound waves. On the school sports field they set up two speakers, S_1 and S_2, connected to a signal generator and an amplifier as shown.



The dotted line QP is drawn perpendicularly out from midway between the two speakers. X is a point half way between P and Q.

Sam uses a sound level meter to record the loudness of the sound as she walks from point P to point X.

Which one of the following best describes the recording?

A. constant loudness

B. quiet all the way

C. sound level gradually increases

D. sound level repeatedly varies between loud and quiet

Question 15

An electron is accelerated from rest through a potential difference of 10 V and has a de Broglie wavelength of L.

Which one of the following is closest to the de Broglie wavelength of an electron that is accelerated from rest through a potential difference of 1000 V?

A. $100L$

B. $10L$

C. $\frac{L}{10}$

D. $\frac{L}{100}$

Question 16

In an experiment to investigate standing waves, a length of string is fixed at both ends as shown below. The string is under constant tension so that the speed of the transverse wave pulses created is 40.0 m s^{-1}.

The string is set vibrating with a fundamental frequency of 8.00 Hz.

Which one of the following is closest to the length of the string?

A. 1.25 m
B. 2.50 m
C. 5.00 m
D. 10.0 m

Question 17

Light of wavelength 500 nm is just able to cause the photoelectric emission of electrons from a metallic surface.

Which one of the following would happen if light of wavelength 600 nm were incident on the same metallic surface?

A. No photoelectric emission would occur.
B. More electrons would be ejected per second.
C. Fewer electrons would be ejected per second but with more energy.
D. The same number of electrons would be ejected per second but with more energy.

Question 18

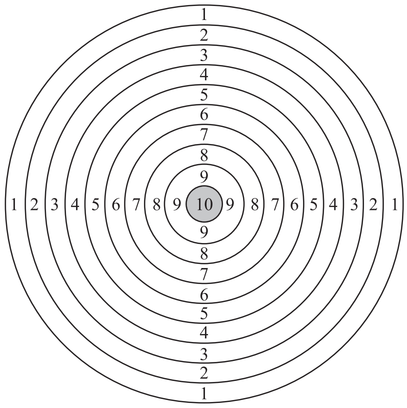
The result of the Michelson–Morley experiment supports a postulate of Einstein's special theory of relativity.

Which one of the following is a postulate of Einstein's theory that is supported by the Michelson–Morley experiment?

A. $E = mc^2$
B. The speed of light has a constant value for all observers.
C. The laws of physics are the same in all inertial frames of reference.
D. The speed of light depends on the speed of the observer's frame of reference.

Question 19

The Olympic air pistol event involves hitting a cardboard target as shown in the diagram below.



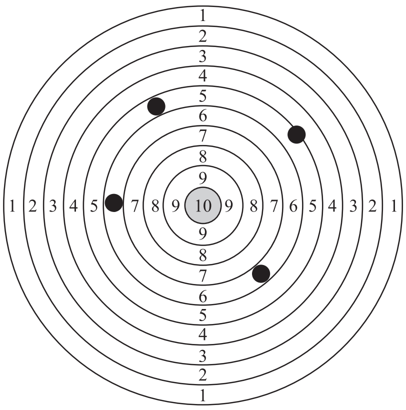
The contestants fire four small pellets from an air pistol at the target.

They aim to get as close to the middle as possible.

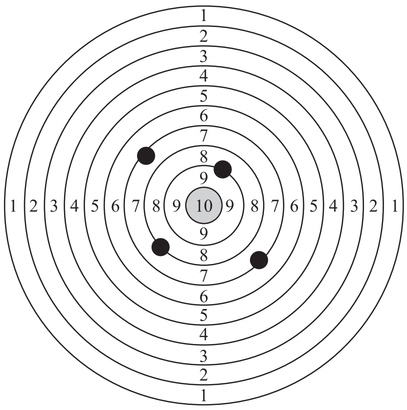
The resulting score sheets for four different contestants (A, B, C and D) are shown below.

Which one of the following score sheets best shows an example of precise but inaccurate shooting?

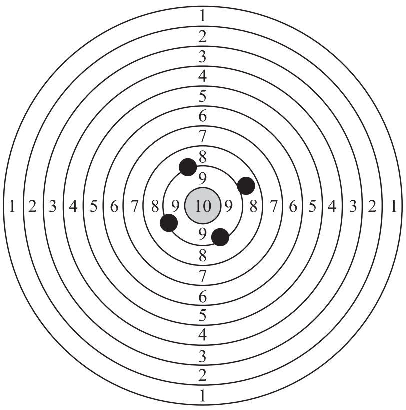
A.



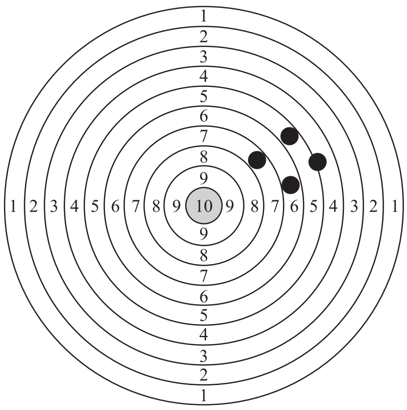
B.



C.

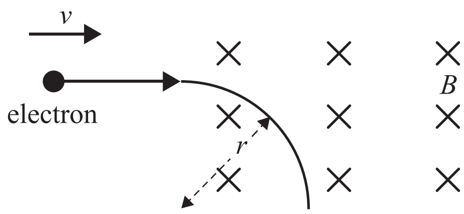


D.



Question 20

Students are undertaking an experiment on electrons entering a region of uniform magnetic field, B, at a speed, v, as shown in the diagram below. The direction of the electron is perpendicular to the magnetic field. The path of the electron inside the magnetic field is circular with radius, r. The strength of the magnetic field, B, is kept constant.

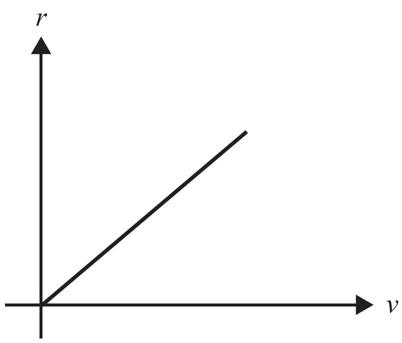


The speed of the electron is varied to obtain different values of r.

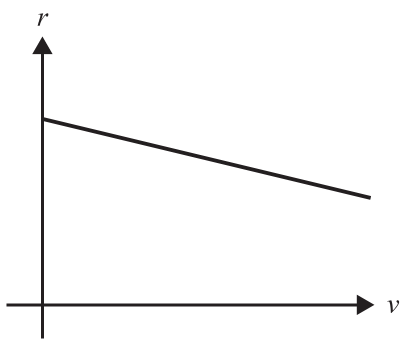
Relativistic effects can be ignored as the electron is travelling at a low speed.

Which one of the following graphs would the students expect to represent the variation of the speed, v, of the electron with the radius, r, of its path in the uniform magnetic field?

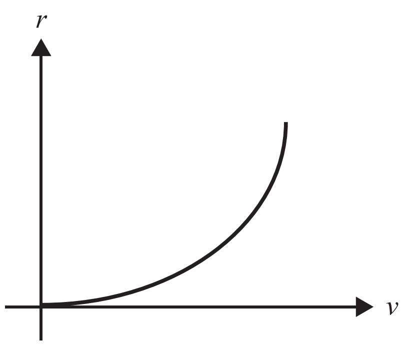
A.



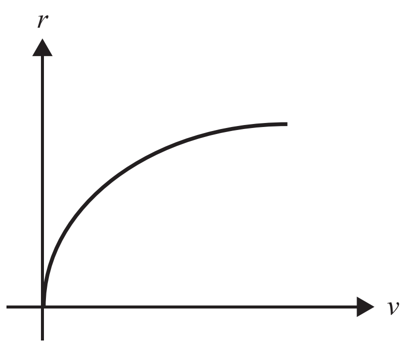
B.



C.



D.



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 horizontal force of 64 N is applied to two masses A and B as shown in Figure 1.

A and B accelerate from rest at 4.0 m s^{-2}. Assume the surface is frictionless and that air resistance is negligible.

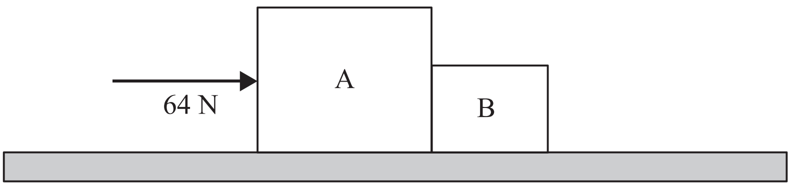


Figure 1

a. The mass of object A is 12 kg.

Calculate the mass of object B.

Show your working. 2 marks

kg

b. Calculate the magnitude of the force exerted on object B by object A.

Show your working. 2 marks

N

NHT

Do not write in this area.

c. Would the magnitude of the force exerted on object B by object A be the same, less than, or more than the magnitude of the force exerted on object A by object B?

Circle the correct option below and justify your answer. No calculations or numerical values are required. 2 marks

same   less than   more than

Question 2 (2 marks)

Airbags are designed to protect you in a crash by increasing the time interval, Δt, over which your momentum changes when your car suddenly comes to a stop.

Explain, using physics principles, why this should reduce the severity of injuries for people in the car.

Question 3 (5 marks)

Anna, of mass 40.0 kg, steps off a diving board at a height of 2.50 m above the water.

Assume that air resistance is negligible.

a. Show that her kinetic energy just before hitting the water is 981 J. 1 mark

b. Calculate her speed just before hitting the water. 2 marks

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

c. Determine the height Anna would have to drop from so that the speed reached just before hitting the water is double the answer to **part b**. 2 marks

m

NHT

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Examination continues on the next page.

Question 4 (6 marks)

A small car travels in a circle of radius 50.0 m at a constant speed.

Figure 2 shows the car as seen from **above**.

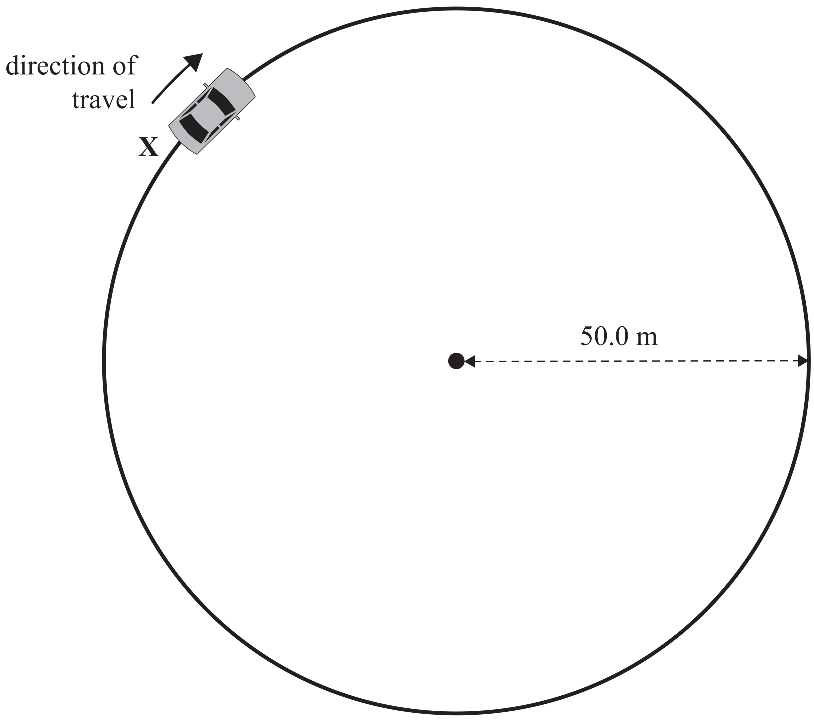


Figure 2

a. Which one of the arrows below (**A**–**I**) best shows the direction of the net force on the car when it is in the position **X**, shown in Figure 2 above? 1 mark

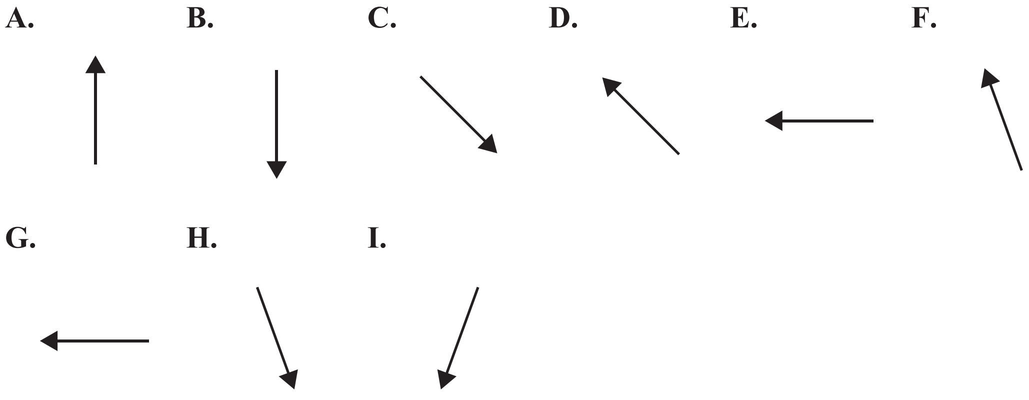


Figure 3 below shows the car from **behind**.

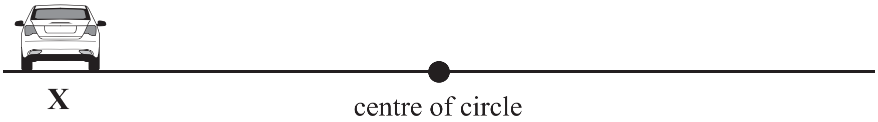


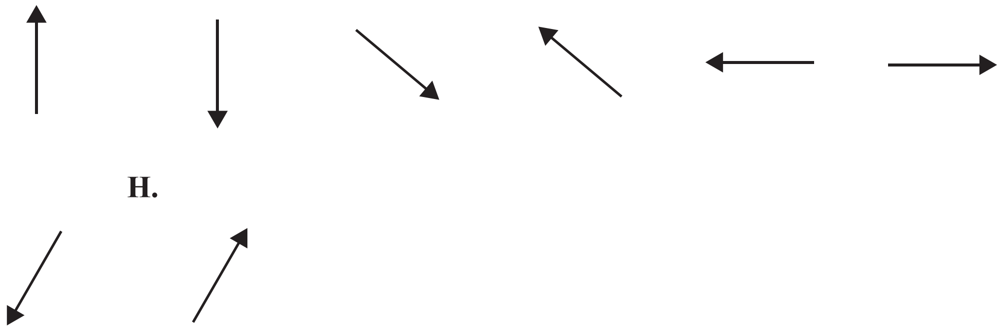
Figure 3

b. On Figure 3, draw labelled arrows to show all the separate vertical and horizontal forces acting on the car at the position **X**, ignoring air resistance. 3 marks

c. Which one of the arrows (**A–H**) below best shows the direction of the force that a tyre exerts on the road in the position **X**, shown in Figure 3 above? Justify your answer. 2 marks

A. **B.** **C.** **D.** **E.** **F.**

G. **H.**



Question 5 (8 marks)

Vesta, shown in Figure 4 below, is one of the largest asteroids in the asteroid belt, which is located between the planets Mars and Jupiter.

A NASA probe named Dawn was sent to orbit Vesta in order to collect data on its geology and composition.

Figure 4

Source: Claudio Caridi/Shutterstock.com

a. Vesta's orbit around the Sun has an orbital radius of 3.53×10^{11} m.

Given that Earth is 1.50×10^{11} m from the Sun and has an orbital period of 365 days, calculate the orbital period of Vesta around the Sun in Earth days.

Assume both orbits are circular. 3 marks

days

Do not write in this area.

b. Vesta has a mass of 2.59×10^{20} kg and a radius of 262 km.

Dawn orbits Vesta at a height of 140 km above its surface. It orbits under the force of gravity by Vesta alone.

Calculate Dawn's orbital speed around Vesta. 3 marks

$\boxed{\qquad\qquad \text{m s}^{-1}}$

c. Dawn is placed at a lower orbit at 120 km above the surface of Vesta.

At this new orbit, will Dawn's orbital speed decrease, stay the same or increase compared to the answer to **part b**? Circle the correct option below.

decrease stay the same increase

Justify your answer. 2 marks

Question 6 (9 marks)

Figure 5 shows a schematic representation of a cathode ray tube.

The cathode ray tube consists of an electron gun producing electrons, which are accelerated by an electric field produced by a 5.0 kV potential difference.

The electrons then pass into an area containing both an electric field and a magnetic field, *B*, each of which can be independently varied to change the path followed by the electrons. The whole apparatus is encased in a glass envelope and evacuated to a low pressure so that the electrons can move freely through the tube.

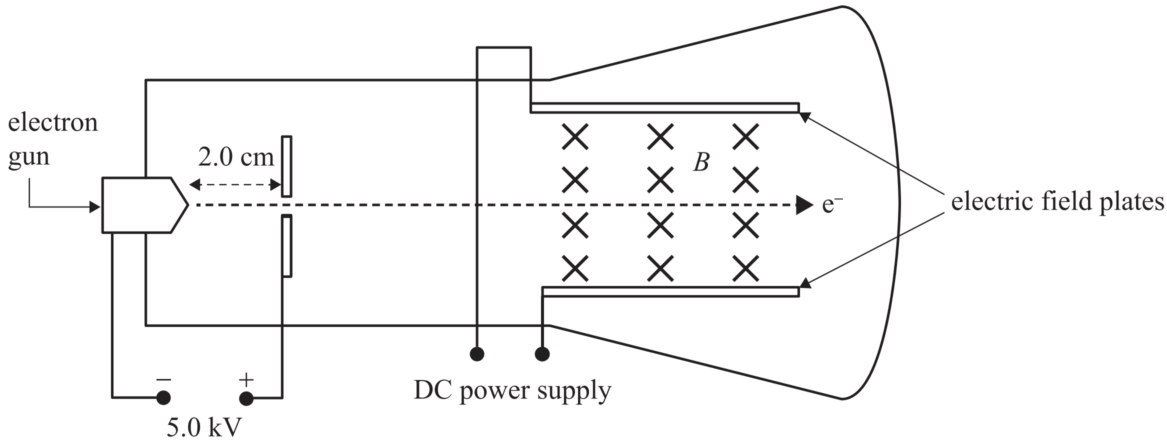


Figure 5

a. Calculate the strength of the electric field used to accelerate the electrons, assuming it is a uniform field. 2 marks

V m^{-1}

N
H
T

Do not write in this area.

b. The electrons now enter a region with a uniform magnetic field $B = 3.6 \times 10^{-3}$ T and a uniform electric field $E = 1.5 \times 10^{5}$ V m^{-1}.

The electrons pass through the region in a straight line.

i. What is the direction of the electric field between the plates? Justify your answer. 2 marks

ii. Calculate the speed of these electrons. 2 marks

m s^{-1}

iii. Explain what would happen to the path of the electrons if they were travelling at a slightly slower speed than that calculated in **part ii**. Justify your answer. 3 marks

Question 7 (5 marks)

Two physics students, Chen and Darika, are viewing a live video stream from the International Space Station (ISS) which shows an astronaut ‘floating’ around the cabin.

Figure 6 below shows a still image from the live video stream.

Figure 6

Source: Gorodenkoff/Shutterstock.com

Chen and Darika then have a discussion on how the force due to Earth’s gravity is experienced by an astronaut floating in the ISS as it travels in a stable circular orbit around Earth.

Chen states that the astronaut does not experience a force due to gravity in the ISS because there is no gravity where there is no air, and since space is a vacuum no gravitational force can be experienced.

Darika states that the force due to gravity is acting on the astronaut in the ISS but her movement along with the spacecraft in a stable circular orbit around Earth creates a force that cancels out the gravitational force.

a. Evaluate each of the students' statements, indicating whether they accurately describe the astronaut's situation when in orbit. 3 marks

b. Describe the astronaut's actual situation, including all forces acting on the astronaut. 2 marks

Question 8 (6 marks)

Hilary and Michael live on a farm with a river that is 2.0 km from the house. To run their LED lights and their low-power electrical appliances in the house, they invest in a micro hydroelectric generator, with specifications of 500 W, 220 V RMS and 50 Hz. A schematic diagram of the micro hydroelectric generator, supply cables and the house is shown in Figure 7.

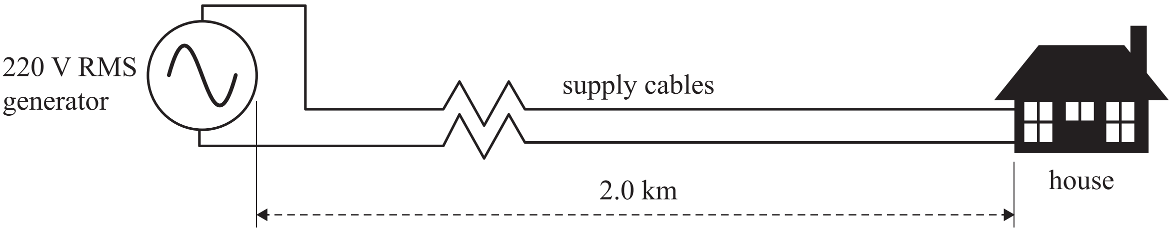


Figure 7

The generator produces a maximum power output of 500 W.

a. What is the maximum output current (RMS) of the generator? 2 marks

____

____

____

____

A

NHT

Do not write in this area.

b. The house is 2.0 km from the generator and the supply cables have an electrical resistance.

i. When many appliances are turned on, Hilary and Michael note that the voltage as measured at the house changes.

Explain why this occurs. 2 marks

ii. On one occasion, the voltage received at the house is measured at 210 V RMS. The current being drawn at the time is 2.1 A RMS.

Calculate the resistance of the supply cables. 2 marks

Ω

Question 9 (6 marks)

Emerald and Waamil are investigating the output of a model hand-cranked generator. It has several output terminals, one set for AC and two other sets for DC power. They connect the AC output of the generator to an oscilloscope.

A schematic drawing is shown in Figure 8.

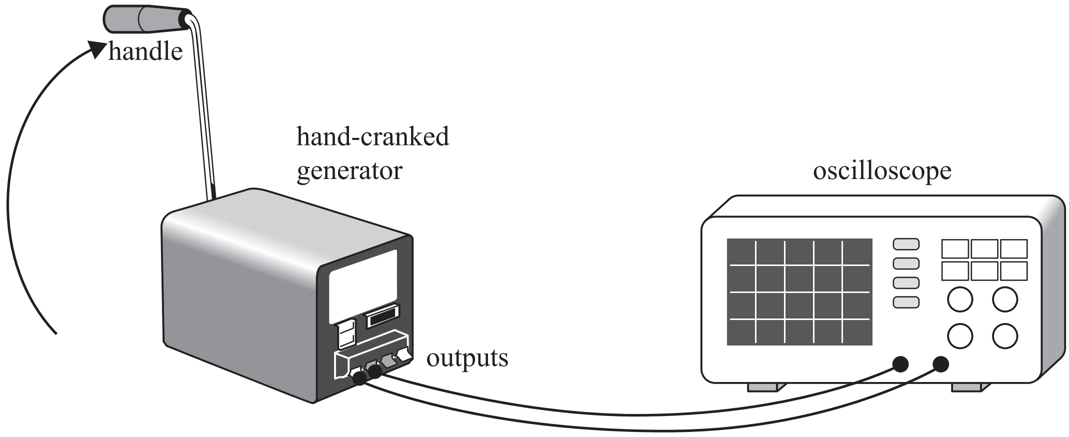


Figure 8

When they rotate the handle at a constant rate, the following trace is observed on the oscilloscope screen, as shown in Figure 9 below.

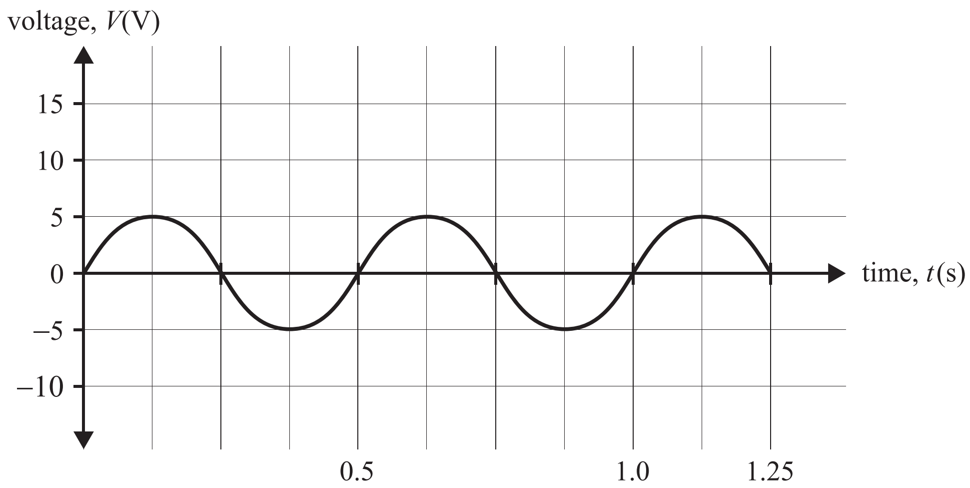


Figure 9

a. Describe the shape and determine the peak voltage, V_{peak}, of this output. 2 marks

V

b. Determine the frequency of the output shown in Figure 9 on the previous page. 1 mark

Hz

c. The students now turn the handle at double the frequency, commencing at the same starting point. On Figure 10 below, draw the trace that would be seen on the oscilloscope screen. The original trace is shown as a dashed line. 2 marks

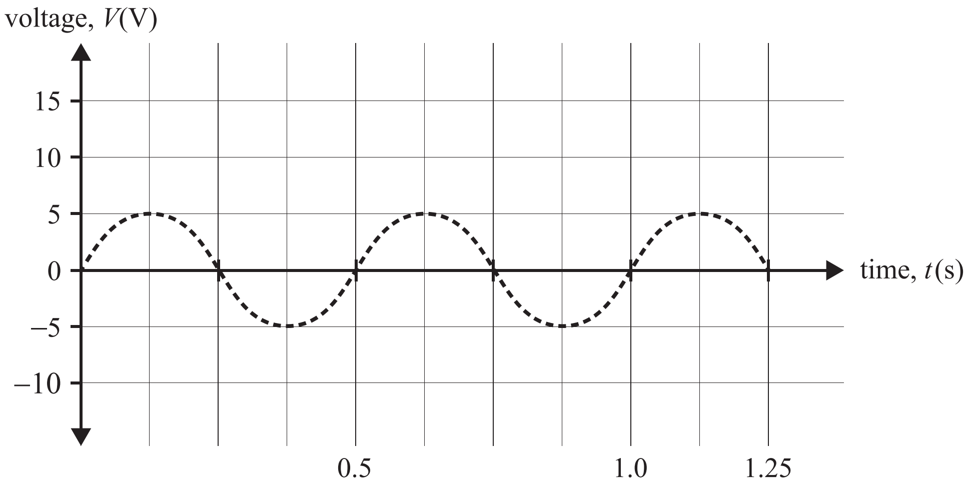


Figure 10

d. Waamil and Emerald's generator can be set to give a constant DC output voltage of 12 V DC.

On Figure 11 below, draw the trace that would be observed on the oscilloscope screen. The original trace is shown as a dashed line. 1 mark

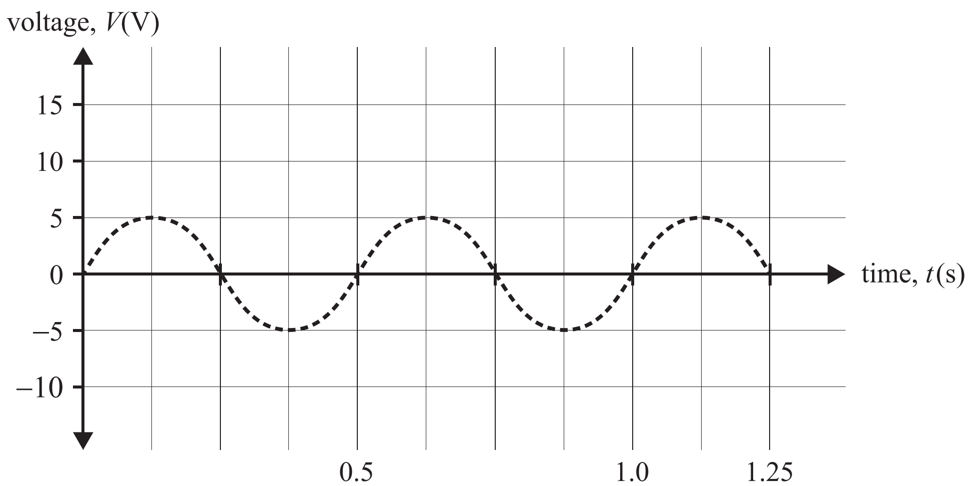


Figure 11

Question 10 (9 marks)

A single square loop of wire of area 1.0×10^{-2} m^2 moves at constant speed from outside left, into, through and out of a magnetic field, as shown in Figure 12a. Assume that the magnetic field outside the poles of the magnets is zero.

The area between the poles of a strong permanent neodymium magnet has a constant uniform magnetic field of magnitude 1.4 T. Figure 12b shows the view from above.

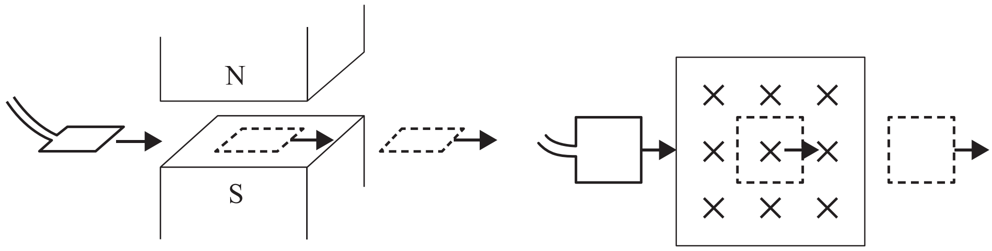


Figure 12a **Figure 12b**

a. On the axes provided below (Figure 13), sketch the magnetic flux, Φ_B, through the loop as it moves into, through and out of the magnetic field. No values are required on the axes. 2 marks

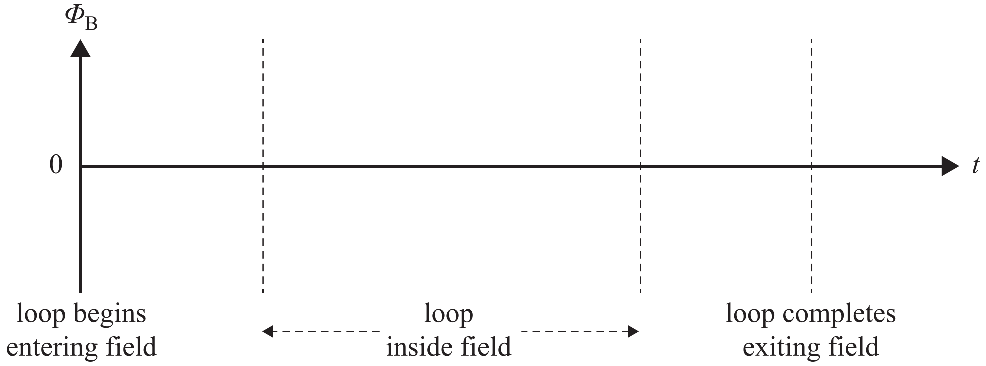


Figure 13

b. On the axes provided below (Figure 14), sketch the EMF induced in the loop as it moves into, through and out of the magnetic field. No values are required on the axes. 2 marks

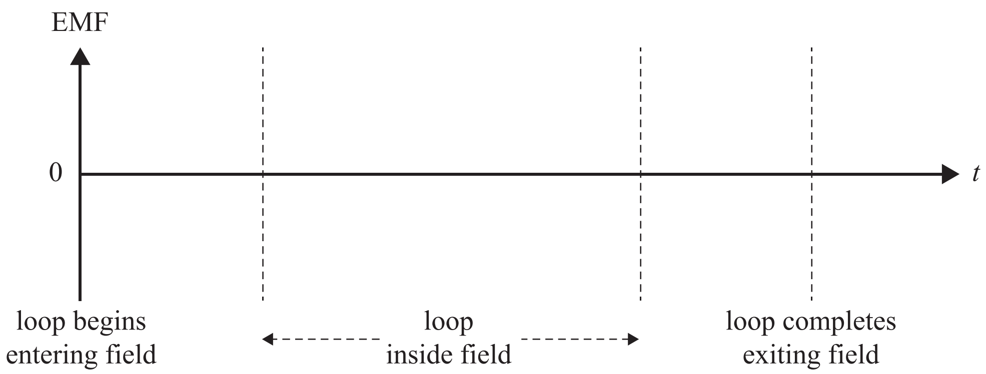


Figure 14

c. It takes 1.5 s from when the front edge of the loop is about to leave the magnetic field until the back edge of the loop just exits the magnetic field.

Calculate the magnitude of the induced EMF. 2 marks

V

d. Determine the direction of the induced current in the loop as it moves out of the magnetic field as viewed from above (clockwise or anticlockwise).

Circle the correct option and justify your answer. 3 marks

clockwise anticlockwise

Question 11 (6 marks)

Mila is studying Young's double-slit experiment, which can also be done using microwave radiation instead of visible light.

The separation of the centres of the slits, S_1 and S_2, is 10 cm and the distance from the slits to the line PQ is 1.5 m.

A microwave detector is moved along the line PQ, and the maxima and minima in microwave intensity are recorded, as shown in Figure 15.

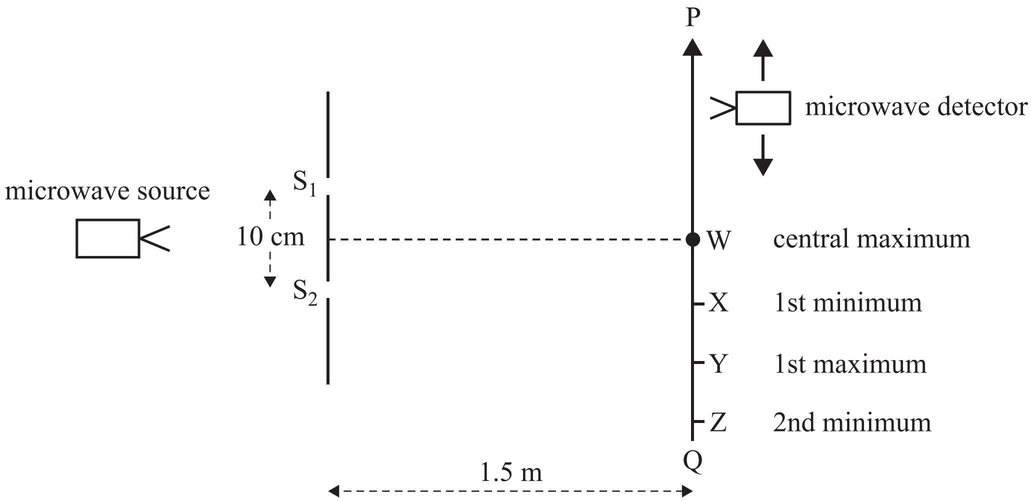


Figure 15

Starting from the central maximum, W, the detector records the first maximum, Y, at 42 cm.

a. What is the wavelength of the microwaves? Give your answer in centimetres. 2 marks

cm

b. Justify why there is a minimum microwave intensity at point Z. 2 marks

c. The microwave frequency is now doubled. Will point Y now be a minimum or a maximum?

Justify your answer. 2 marks

Question 12 (7 marks)

The electron energy level diagram for a hydrogen atom is shown in Figure 16.

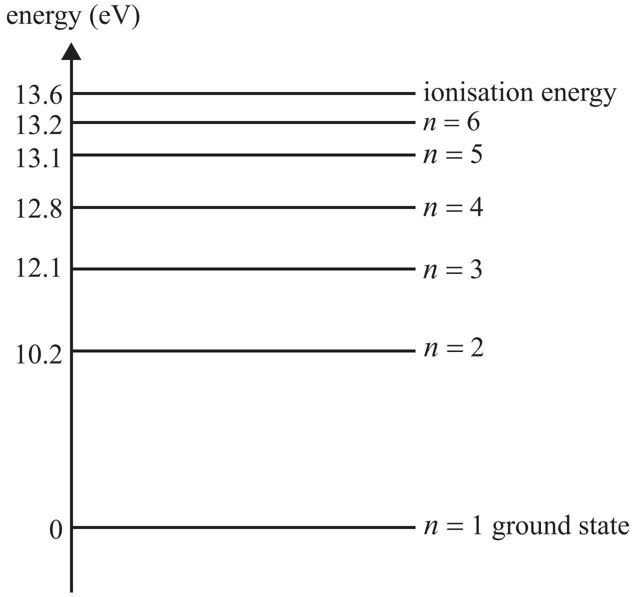


Figure 16

a. Physicists use a laser to change a hydrogen atom from the ground state to the first excited level.

Calculate the wavelength of the laser needed to do this. Give your answer in nanometres. 3 marks

nm

NHT

Do not write in this area.

b. The physicists then use a laser which has a wavelength of 103 nm to raise a hydrogen atom from the $n = 1$ to the $n = 3$ level.

Calculate the momentum of a photon of this wavelength. 2 marks

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

c. On Figure 17 below use arrows to draw all the possible transitions from the $n = 3$ level back to the $n = 1$ level. 2 marks

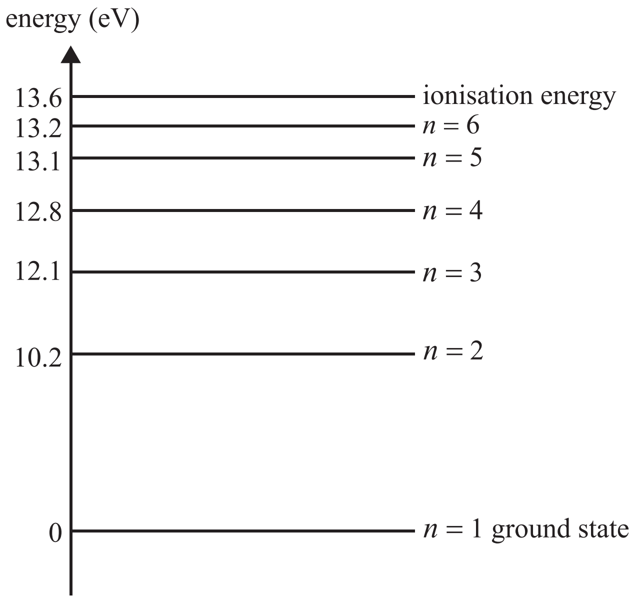


Figure 17

Question 13 (2 marks)

GPS (global positioning system) devices are regularly used to accurately determine the location of an object on Earth. The devices work by receiving timing signals from satellites that carry synchronised atomic clocks. The timing signals must be corrected for the effects of special relativity.

Explain what causes the timing signals to require correction. No calculations or numerical values are required and you need to consider only the effects of special relativity.

Question 14 (4 marks)

The photoelectric effect experiment distinguishes the particle model of light from the wave model of light.

The following observations are made in a photoelectric effect experiment.

Observation 1: The kinetic energy of the electrons emitted depends on the type of metal surface involved.

Observation 2: For a particular frequency, the number of electrons emitted from a given metal depends on the intensity of the incident light.

Observation 3: The kinetic energy of the electrons emitted from a given metal depends only on the frequency of the incident light.

The particle model can account for all three of the above observations; however the wave model can explain only two of these observations.

Select the observation that the wave model **cannot** explain.

Observation number:

Justify why this observation can be satisfactorily explained by the particle model but not the wave model.

Question 15 (2 marks)

Explain how the electron double-slit experiment provides evidence for the wave nature of electrons.

Question 16 (2 marks)

A Sun-like star has a measured power output of 1.52×10^{27} W.

Calculate the rate, in kg s^{-1}, at which the star is reducing its mass.

kg s^{-1}

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Question 17 (15 marks)

The Relativistic Heavy Ion Collider (RHIC), located at Brookhaven National Laboratory in the United States, enables physicists to learn more about the elementary particles that make up protons and neutrons. Gold ions are accelerated to relativistic speeds and then collide.

A gold ion (Au-179) has rest mass 3.27×10^{-25} kg.

Each gold ion is accelerated from rest to a total energy of 1.90 TeV.

a. Show that the total energy, E_{total}, of a gold ion accelerated to 1.90 TeV is 3.04×10^{-7} J. 1 mark

b. Assuming classical (Newtonian) physics, what speed would a gold ion reach if accelerated to a kinetic energy of 1.90 TeV? 2 marks

$\boxed{\quad\quad\quad\quad \text{m s}^{-1}}$

c. Does your answer to **part b** agree with our understanding of physics?

Justify your answer. 2 marks

d. The gold ions are accelerated to a total energy, E_{total}, of 1.90 TeV (3.04×10^{-7} J).

Show that the Lorentz factor, γ, for one of these gold ions is 10.3. 2 marks

e. As part of testing and calibrating the accelerator at the RHIC, scientists vary the accelerating potential for the gold ions (Au-179), providing them with a known total energy, and measuring the corresponding speed.

Table 1 below shows the total relativistic energy (in TeV and J), and the corresponding gold ion speed and speed squared (in units of c and c^2), respectively.

E_{total} (TeV)	E_{total} (J)	v (c)	v^2 (c^2)
0.20	3.2×10^{-8}	0.43	0.18
0.30	4.8×10^{-8}	0.79	0.62
0.40	6.4×10^{-8}	0.89	0.79
0.50	8.0×10^{-8}	0.93	0.86
0.60	9.6×10^{-8}	0.95	0.90
0.70	11×10^{-8}	0.96	0.93
0.80	13×10^{-8}	0.97	0.95
0.90	14×10^{-8}	0.98	0.96
1.0	16×10^{-8}	0.98	0.97

Table 1

Identify the independent and dependent variables in this experiment. Identify one variable that must be controlled.

3 marks

Classification	**Variable**
independent	
dependent	
controlled	

Question 17 continues on the next page.

f. Figure 18 shows a graph of the square of the speed of the gold ions as a function of the total relativistic energy.

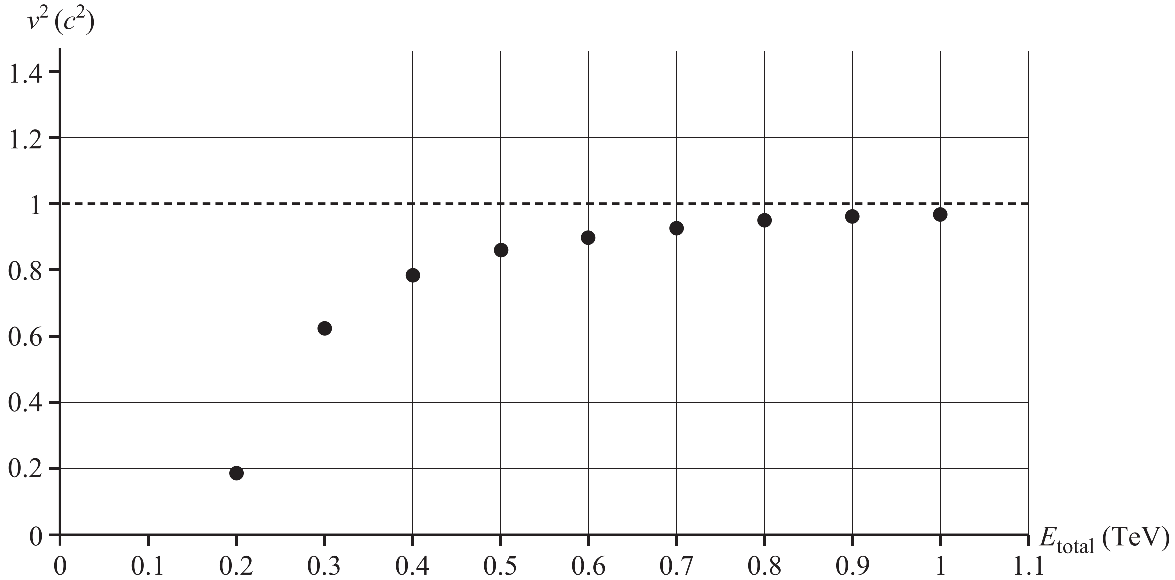

Figure 18

i. Sketch a curve on the graph in Figure 18 above that represents a suitable fit of the data. 2 marks

ii. What is the physical significance of the dashed horizontal line shown on the graph? 1 mark

iii. Estimate the value of the horizontal intercept of the graph. Explain its physical significance. The expected/theoretical value does not need to be calculated. 2 marks

End of examination questions

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2025

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	$E_s = \frac{1}{2}kx^2$
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	$I = \frac{V}{R}$; $P = VI$
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	$E_{\text{k max}} = hf - \phi$
photon energy	$E = hf = \dfrac{hc}{\lambda}$
photon momentum	$p = \dfrac{h}{\lambda}$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$

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 $\quad h = 4.14 \times 10^{-15}$ 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 Physics Formula Sheet