VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2021

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER											Letter

PHYSICS
Written examination

Wednesday 26 May 2021

Reading time: 10.00 am to 10.15 am (15 minutes)
Writing time: 10.15 am to 12.45 pm (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	18	18	110
			Total 130

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers, pre-written notes (one folded A3 sheet or two A4 sheets bound together by tape) and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 33 pages
- Formula sheet
- Answer sheet for multiple-choice questions

Instructions
- Write your student number in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the formula sheet.

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

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

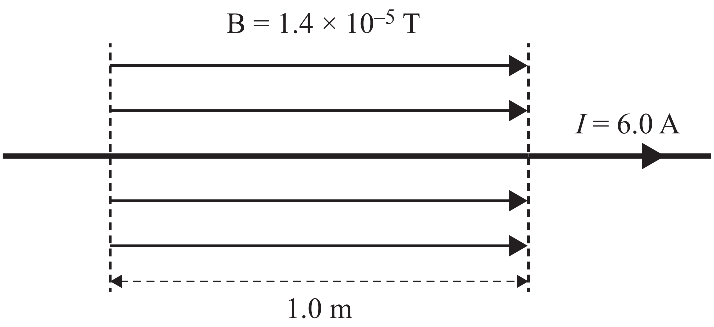
No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Take the value of g to be 9.8 m s^{-2}.

Question 1

A wire carrying a current, I, of 6.0 A passes through a magnetic field, B, of strength 1.4×10^{-5} T, as shown below. The magnetic field is exactly 1.0 m wide.



The magnitude of the force on the wire is closest to

A. 0 N

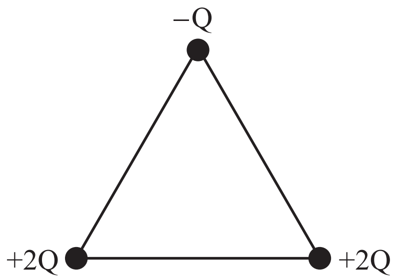
B. 2.3×10^{-6} N

C. 8.4×10^{-5} N

D. 4.3×10^{5} N

Question 2

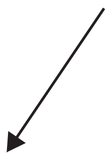
Three charges, –Q, +2Q and +2Q, are placed at the vertices of an equilateral triangle, as shown below.

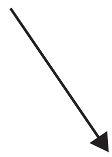


Which one of the following arrows best represents the direction of the net force on the charge –Q?

A. 

B. 

C. 

D. 

Question 3

A 45 g golf ball, initially at rest, is hit by a golf club. The contact time between the club and the ball is 0.50 ms. The magnitude of the final velocity of the ball is 41 m s^{-1}.

Which one of the following is closest to the average force experienced by the golf ball?

A. 0.18 kN

B. 0.37 kN

C. 1.8 kN

D. 3.7 kN

Question 4

A person has a mass of 60.0 kg.

Which one of the following is closest to the weight of this person on Earth's surface?

A. 60.0 kg

B. 60.0 N

C. 588 kg

D. 588 N

Question 5

When a spacecraft orbits Earth, its orbital period is **not** a function of the

A. mass of Earth.

B. mass of the spacecraft.

C. velocity of the spacecraft.

D. height of the spacecraft above Earth.

Question 6

The mains voltage in a particular part of Australia is AC with a voltage of 240 V_{RMS}.

Which one of the following is closest to the peak-to-peak voltage, V_{p-p}, for this mains voltage?

A. 170 V

B. 340 V

C. 480 V

D. 680 V

Question 7

Electrical power stations are often situated far from the cities that require the power that they generate.

Which one of the following best describes the reason for the high-voltage transmission of electrical energy?

A. Transformers can be used to increase the voltage in the cities.

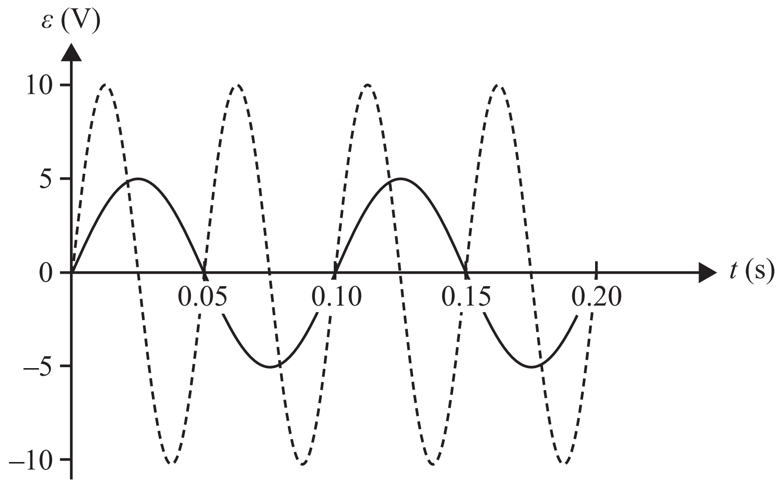
B. High voltages reduce the energy losses in the transmission lines.

C. High voltages provide the large currents needed for efficient transmission.

D. High voltages can reduce the overall total resistance in the transmission lines.

Question 8

In the diagram below, the solid line represents the graph of output EMF, ε, versus time produced by an AC generator. A single change is made to the AC generator and its operation, and the new graph of output EMF, ε, versus time is shown as a dashed line.



Which one of the following best describes the change made to the AC generator?

A. The area of the coil was doubled.

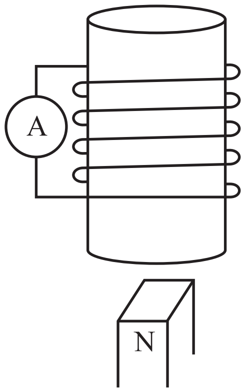
B. The speed of rotation was halved.

C. The speed of rotation was doubled.

D. The number of turns of the wire in the coil was doubled.

Question 9

The diagram below shows a bar magnet moving upward into a coil.

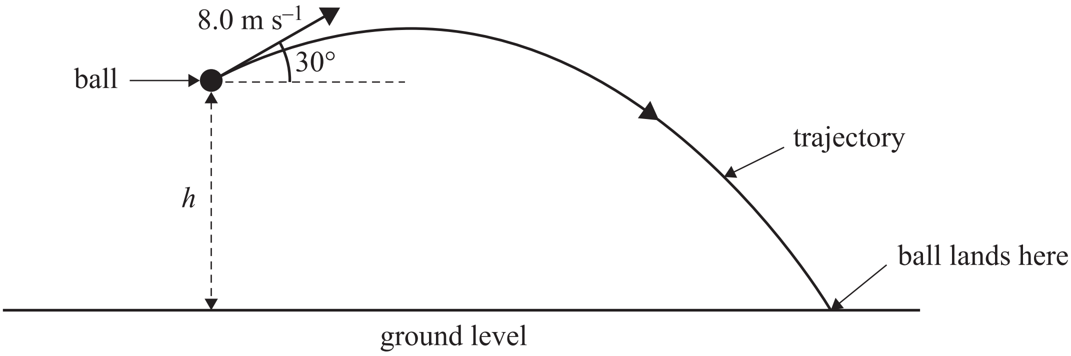


Which of the following correctly identifies the direction of the induced current, as viewed from the **top** of the coil, and the direction of the magnetic field produced by the induced current inside the coil?

	Current direction	Magnetic field direction
A.	clockwise	↓
B.	clockwise	↑
C.	anticlockwise	↑
D.	anticlockwise	↓

Use the following information to answer Questions 10 and 11.

Melissa launches a ball from height h above the ground at a speed of 8.0 m s^{-1} and at an angle of 30° above the horizontal. The time of the ball's flight is 1.0 s. The diagram below shows the trajectory of the ball.



Question 10

Ignoring air resistance, which one of the following is closest to the horizontal distance that the ball landed from Melissa?

A. 4.6 m

B. 5.0 m

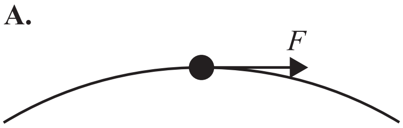
C. 6.9 m

D. 8.0 m

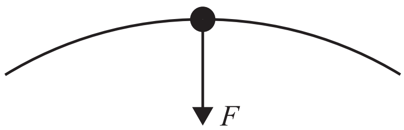
Question 11

Which one of the following diagrams best shows the direction of the resultant force, F, on the ball at the position of maximum height in the real situation where air resistance is **not** ignored?

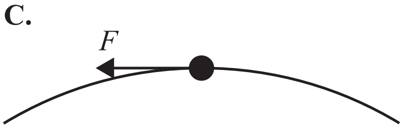
A.



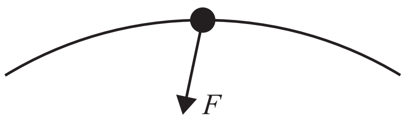
B.



C.

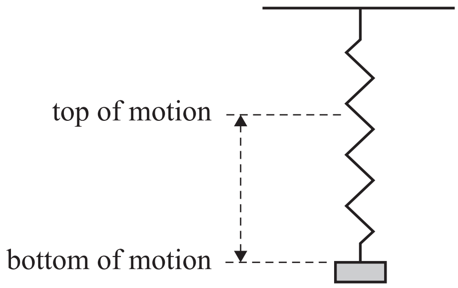


D.



Question 12

A mass at the end of an ideal spring is oscillating freely up and down.



Which one of the following best describes the motion of this oscillating mass?

A. Its speed is a minimum only at the top of the motion.

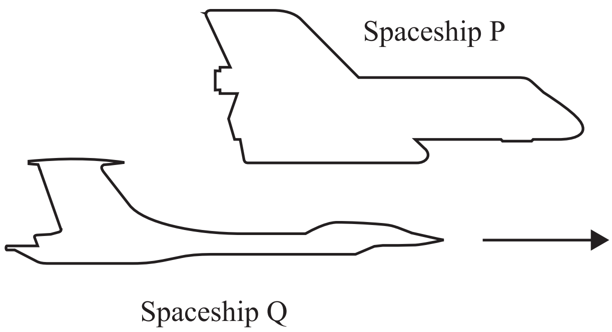
B. Its speed is a maximum when its acceleration is a maximum.

C. Its acceleration has a minimum value at both the top and the bottom of the motion.

D. Its acceleration has a maximum value upward when the mass is stationary at the bottom.

Question 13

Joanna is an observer in Spaceship P and is watching Spaceship Q fly past at a relative speed of $0.943c$ ($\gamma = 3.00$). She observes a stationary clock measuring a time interval of 75.0 s between two events in Spaceship Q. This is a proper time interval.



Which one of the following is closest to the time interval observed between the two events in Spaceship P's frame of reference?

A. 15.0 s

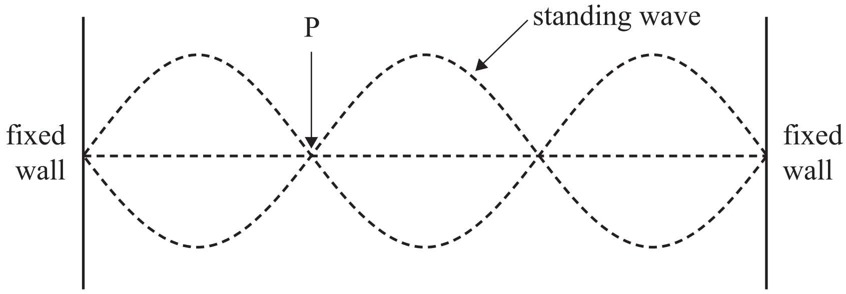
B. 25.0 s

C. 125 s

D. 225 s

Question 14

The diagram below represents a standing wave.



The point P on the standing wave is

A. a node resulting from destructive interference.

B. a node resulting from constructive interference.

C. an antinode resulting from destructive interference.

D. an antinode resulting from constructive interference.

Question 15

The polarisation of light supports

A. the wave model of light.

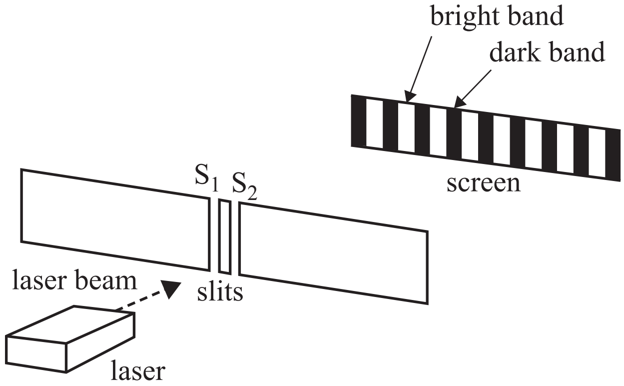
B. the particle model of light.

C. both the wave model and the particle model of light.

D. neither the wave model nor the particle model of light.

Question 16

A red laser used in a double-slit experiment creates an interference pattern on a screen, as shown below.



The red laser is replaced with a green laser.

Which one of the following best explains what happens to the spacing between adjacent bright bands when the green laser is used?

A. The spacing increases.

B. The spacing decreases.

C. The spacing stays the same.

D. The spacing cannot be determined from the information given.

DO NOT WRITE IN THIS AREA

Question 17

Protons of mass 1.67×10^{-27} kg are accelerated to a speed of 2.0×10^{3} m s^{-1}.

The best estimate of the de Broglie wavelength of these protons is

A. 1.2×10^{-10} m

B. 2.0×10^{-10} m

C. 1.2×10^{-7} m

D. 2.0×10^{-7} m

Question 18

Experiments on the photoelectric effect involve shining light onto a metal surface. Measurements are made of the number of emitted electrons and their maximum kinetic energy from the metal surface. This is done for different frequencies and intensities of light.

Which one of the following statements would **not** be one of the experimental findings?

A. The ability to eject electrons from this metal depended only on the frequency of light.

B. The stopping potential for the photoelectrons was independent of the light intensity.

C. The maximum kinetic energy of the photoelectrons depended only on the light intensity.

D. At frequencies below the threshold frequency, no electrons were ejected from this metal no matter how high the light intensity was.

Question 19

In an experimental investigation, an independent variable is one that is

A. independent of the investigator's control.

B. a value selected by the investigator.

C. fixed throughout the experiment.

D. the key variable to be measured.

Question 20

A nucleus in an excited energy state emits a gamma ray of energy 3.6×10^{-13} J as it decays to its ground state. The initial mass of the excited nucleus is M_i.

The final mass of the nucleus after decay is closest to

A. $M_i - 4 \times 10^{-30}$ kg

B. $M_i - 8 \times 10^{-30}$ kg

C. M_i kg

D. $M_i + 4 \times 10^{-30}$ kg

END OF SECTION A
TURN OVER

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (3 marks)

A small sphere carrying a charge of –2.7 μC is placed between charged parallel plates, as shown in Figure 1. The potential difference between the plates is set at 15.5 V, which just holds the sphere stationary. The electric field between the plates is uniform.

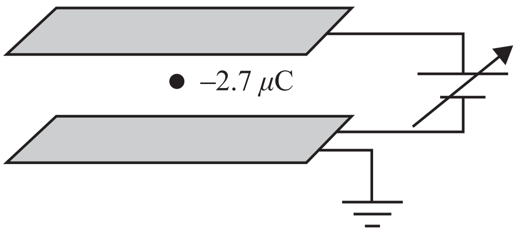


Figure 1

a. In which direction (up, down, right, left) will the sphere move if the voltage is increased? 1 mark

b. Calculate the value of the electric force that is holding the sphere stationary if the plates are 2.0 mm apart. Show your working. 2 marks

N

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DO NOT WRITE IN THIS AREA

Question 2 (8 marks)

An electron is accelerated from rest by a potential difference of V_0. It emerges at a speed of 2.0×10^7 m s^{-1} into a magnetic field, B, of strength 2.5×10^{-3} T and follows a circular arc, as shown in Figure 2.

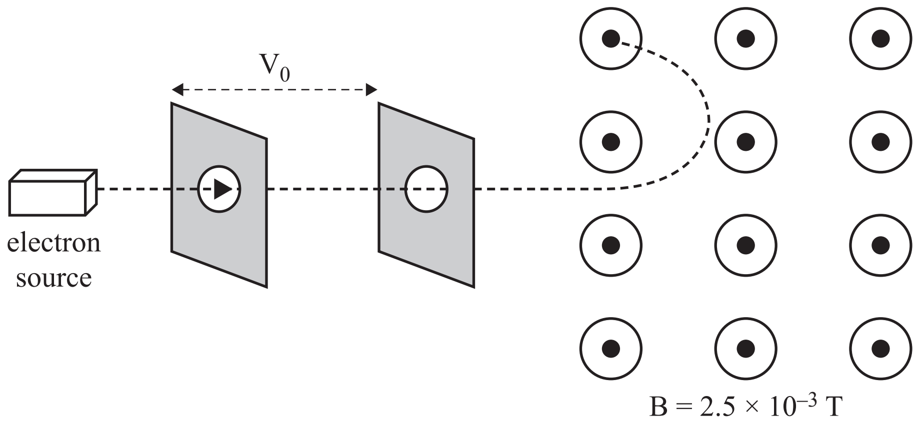


Figure 2

a. Calculate the value of the accelerating voltage, V_0. Show your working. 3 marks

kV

b. Explain why the path of the electron in the magnetic field follows a circular arc. 2 marks

c. Calculate the radius of the path travelled by the electron. Show your working. 3 marks

m

Question 3 (6 marks)

The motion of Earth's moon can be modelled as a circular orbit around Earth, as shown in Figure 3.

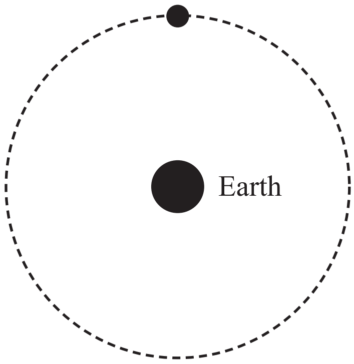


Figure 3

Data

mass of Earth	5.98×10^{24} kg
mass of the moon	7.35×10^{22} kg
radius of the moon's orbit around Earth	3.84×10^{8} m
universal gravitational constant (G)	6.67×10^{-11} N m^2 kg^{-2}

a. Calculate the magnitude of the gravitational force that Earth exerts on the orbiting moon. Give your answer correct to three significant figures. Show your working. 3 marks

N

b. The average orbital period of Earth's moon is 27.32 days. The moon is moving slightly further away from Earth at an average rate of 4 cm per year.

Given this information, will the average orbital period of Earth's moon decrease, stay the same or increase? Explain your answer. 3 marks

Question 4 (3 marks)

Figure 4 shows a schematic diagram of a simple one-coil DC motor. A current is flowing through the coil.

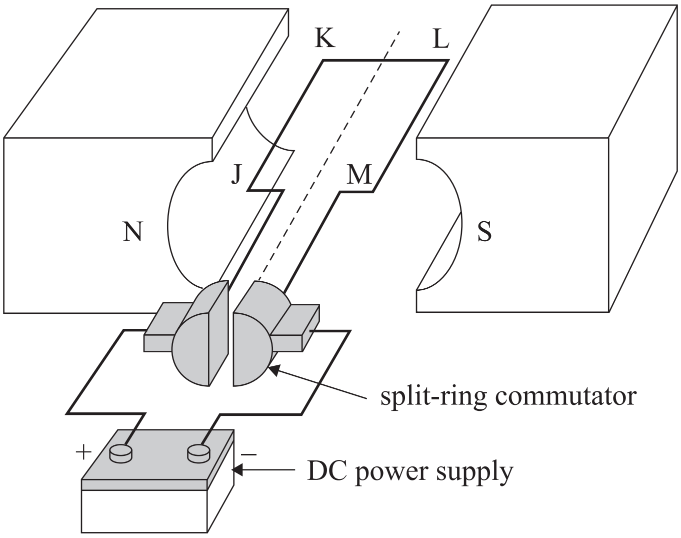


Figure 4

a. Draw an arrow on Figure 4 to indicate the direction of the force acting on the side JK of the coil. 1 mark

b. Explain the purpose of the split-ring commutator. 2 marks

Question 5 (3 marks)

Physics students who are investigating the generation of electricity spin a coil at a constant 10 rotations per second in a uniform magnetic field. They observe the output on an oscilloscope. The experimental set-up is shown in Figure 5. The peak voltage produced by the coil is 5 mV.

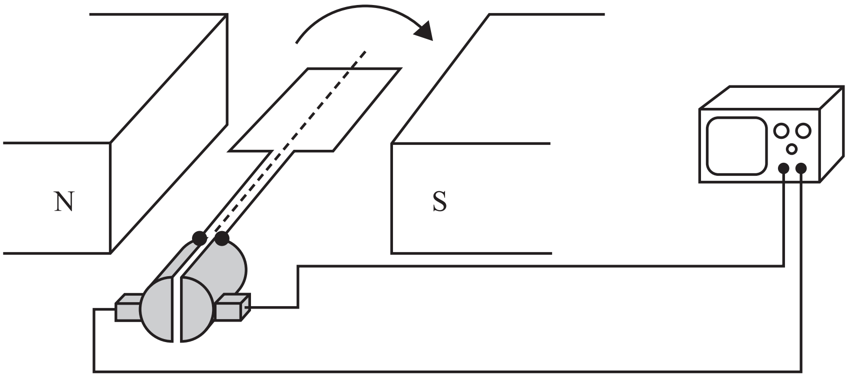
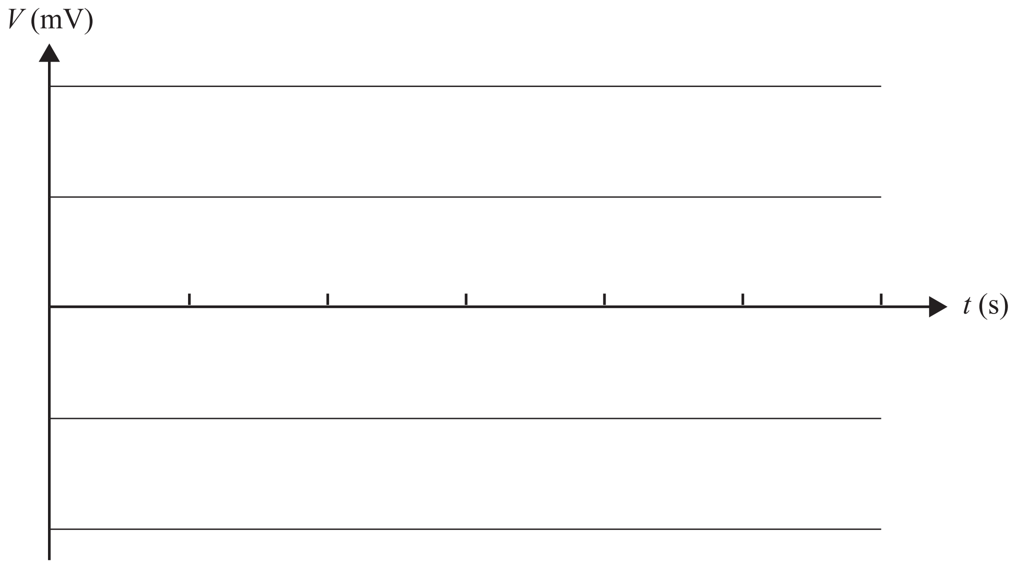


Figure 5

On the axes below, sketch the voltage versus time graph observed on the screen of the oscilloscope for one complete rotation of the coil from the position shown in Figure 5. Include appropriate scales on each axis.



Question 6 (7 marks)

Gir and Kau are investigating electromagnetic induction. They have a single wire loop of dimensions XY = 0.030 m long and YZ = 0.020 m wide, which is placed in a uniform magnetic field of strength 0.20 T. The loop is rotated clockwise about an axis, as shown in Figure 6.

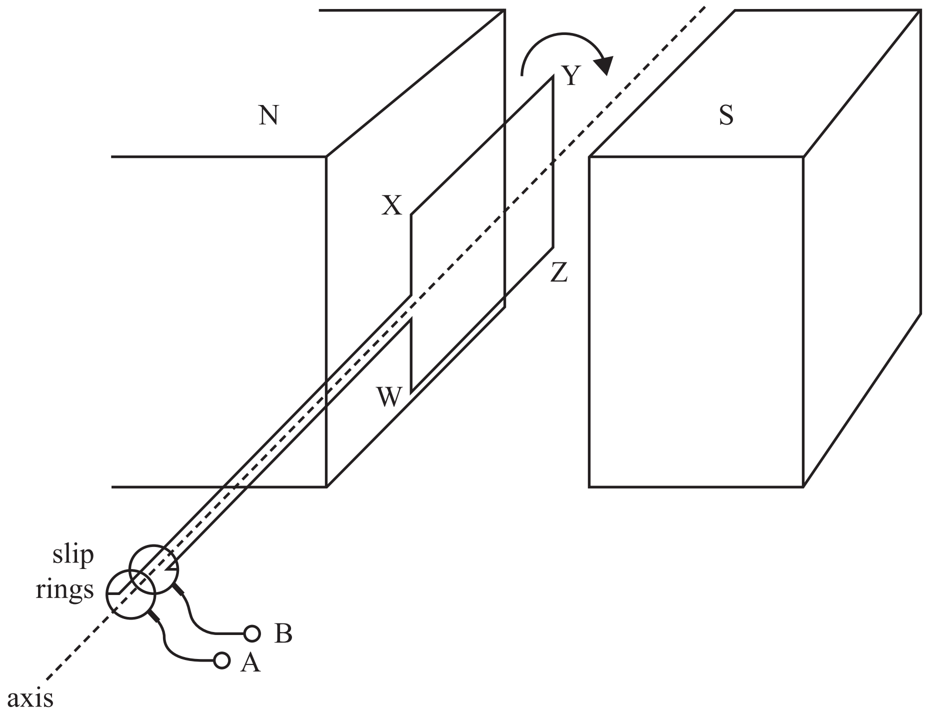


Figure 6

a. Explain the purpose of the slip rings in the apparatus shown in Figure 6. 2 marks

b. Calculate the size of the magnetic flux through the loop when it is oriented as shown in Figure 6. Show your working. 2 marks

Wb

The loop is rotated by Kau at a constant frequency, f, and an EMF, ε, is generated. Figure 7 shows the generated EMF versus time trace observed on the screen of an oscilloscope.

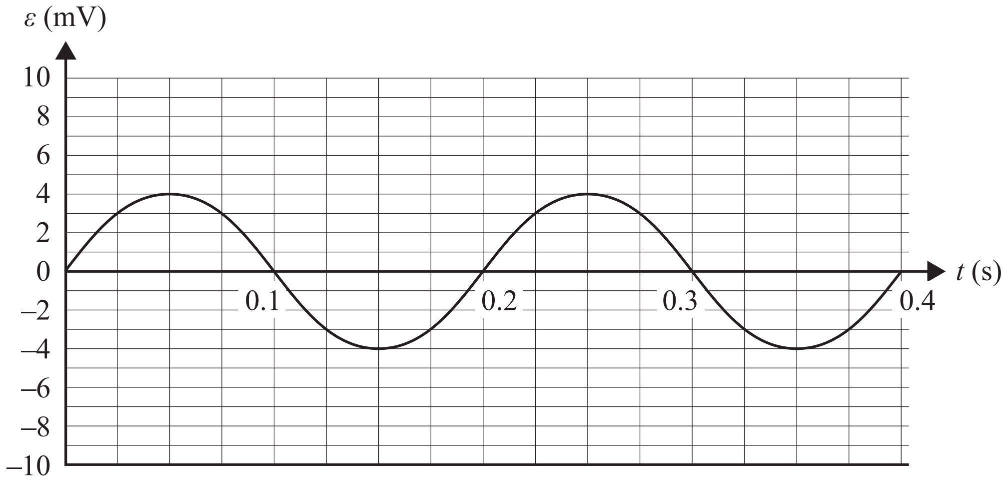


Figure 7

c. Calculate the frequency of the rotation from the oscilloscope trace shown in Figure 7. 1 mark

Hz

d. Gir now doubles the number of turns in the loop from one turn to two turns, creating two loops. The loops are again rotated at the same constant frequency, f.

On Figure 8 below, sketch a graph that shows the resulting variation of the EMF with time between points A and B, as labelled in Figure 6. The original output is shown as a dashed line. 2 marks

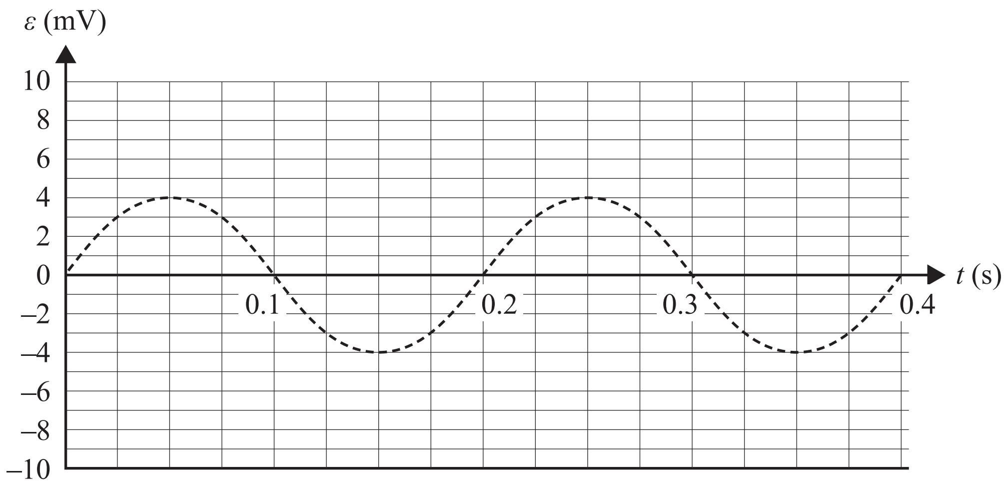


Figure 8

Question 7 (10 marks)

Angela and Janek are installing two low-voltage lights in their outdoor garden. They have a 240 V_{RMS} AC transformer with an output voltage of 12 V_{RMS} AC. Each light has a constant resistance of 6.0 Ω. For the purposes of calculations, assume that the transformer is ideal.

a. Describe what is meant by an ideal transformer in terms of the input power and the output power. 1 mark

b. Calculate the ratio of the number of turns of the primary coil to the number of turns of the secondary coil. 1 mark

c. Each light is designed to operate at 12 V_{RMS}.

Calculate the power dissipated in one light when it is operated at 12 V_{RMS}. Show your working. 2 marks

W

Angela and Janek now connect the first light, Light 1, to the transformer using two wires, each 12.0 m long, as shown in Figure 9. Each wire has a resistance of 0.05 Ω per metre.

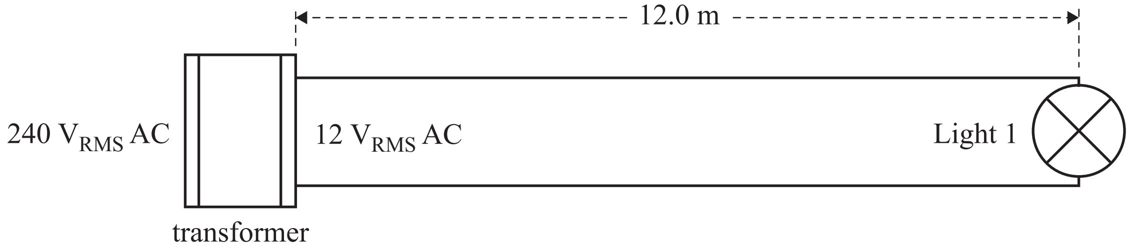


Figure 9

d. Calculate the RMS voltage across Light 1. Show your working. 3 marks

V

e. Angela and Janek now connect the second light, Light 2, directly across the secondary of the transformer, as shown in Figure 10.

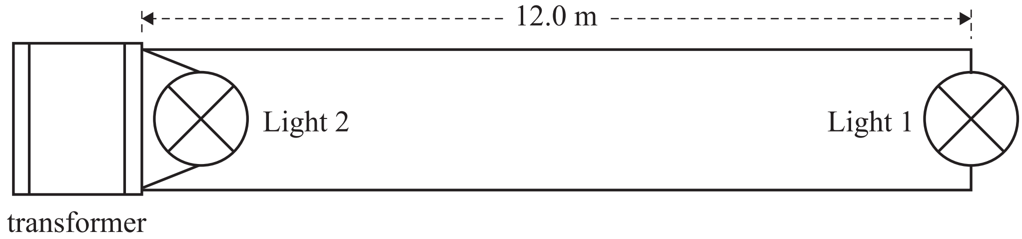


Figure 10

They thought that with the circuit shown in Figure 10, Light 1 and Light 2 would be equally bright. However, they observed that Light 2 was brighter than Light 1.

Explain why Light 2 was observed to be brighter than Light 1. 3 marks

Question 8 (8 marks)

A car is driving up a uniform slope with a trailer attached, as shown in Figure 11. The slope is angled at 15° to the horizontal. The trailer has a mass of 200 kg and the car has a mass of 750 kg. Ignore all retarding friction forces down the slope.

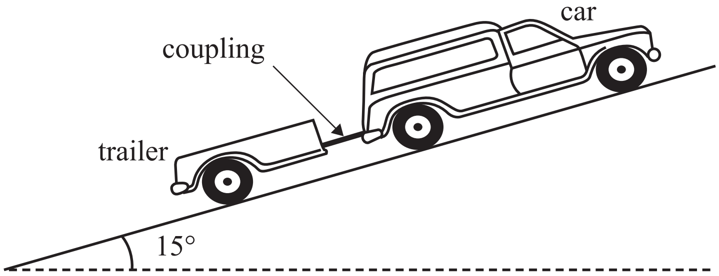


Figure 11

a. On Figure 12 below, draw labelled arrows to indicate the direction of the forces acting on the trailer. The labels should also indicate the kind of force that each arrow represents. 3 marks

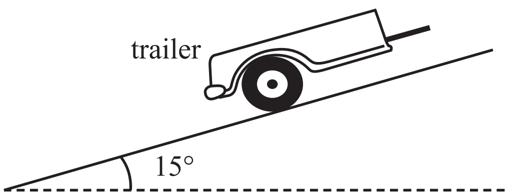


Figure 12

b. The car and trailer are travelling at a constant speed of 8 m s^{-1} up the slope.

Calculate the magnitude of the force that the car exerts on the trailer. Show your working. 2 marks

N

c. Calculate the gravitational potential energy gained by the car and trailer when they have travelled 100 m along the slope. Show your working. 3 marks

kJ

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Question 9 (10 marks)

In a model of a proposed ride at a theme park, a 5.0 kg smooth block slides down a ramp from point W and into an ideal spring bumper without any friction or air resistance, as shown in Figure 13. The final section of the ramp, between points X and Y, is horizontal. The block comes to an instantaneous stop at point Y.

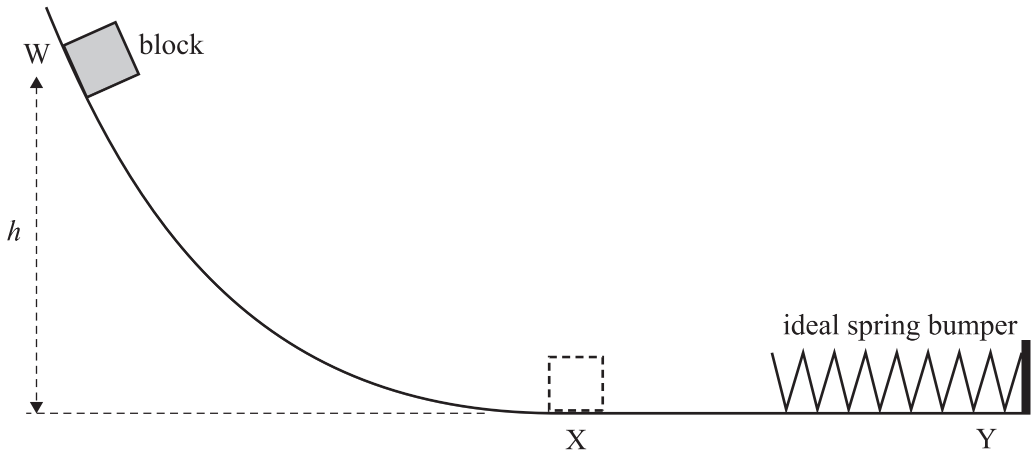

Figure 13

a. Describe the acceleration of the block at points W, X and Y. 4 marks

b. The maximum compression of the spring is measured as 3.0 m and its spring constant, k, is 100 N m^{-1}.

Calculate the release height, h. Show your working. 3 marks

m

c. Calculate the magnitude of the maximum momentum of the block. Show your working. 2 marks

kg m s^{-1}

d. When the block comes to rest, its momentum is zero.

In terms of the principle of conservation of momentum, state what has happened to the momentum of the block as it comes to rest. 1 mark

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Question 10 (4 marks)

Jacinta is standing still while observing a spaceship passing Earth at a speed of 0.984*c*.

a. Calculate γ for this speed, correct to three significant figures. Show your working. 2 marks

b. The spaceship is travelling to the Alpha Centauri star system in a straight line at this speed. In Jacinta's frame of reference, this distance is measured to be 4.37 light-years (that is, it would take light 4.37 years to travel this distance).

Calculate the time that would be measured by Jacinta for the spaceship's journey, correct to three significant figures. Show your working. 2 marks

years

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Question 11 (4 marks)

A transverse wave is travelling through a medium, as shown in Figure 14. The frequency of the source producing the wave is 40 Hz and the wave travels at a speed of 35 m s^{-1}. The amplitude of the wave is 0.50 m.

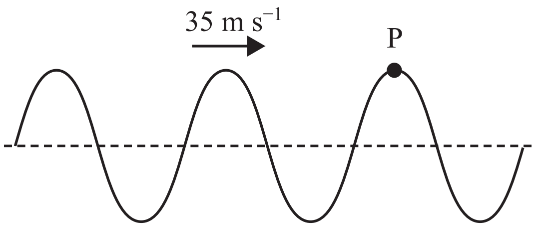
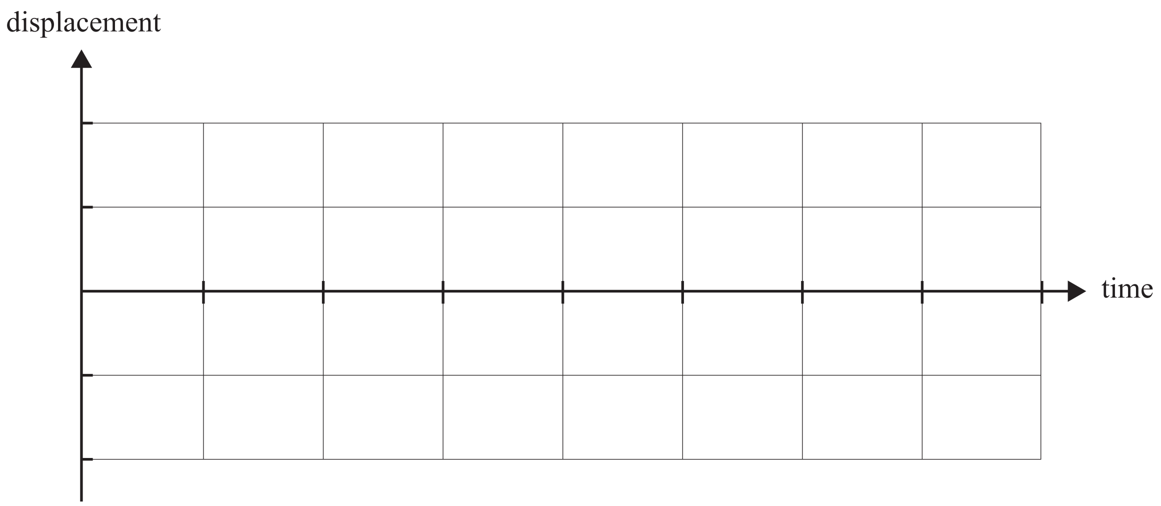


Figure 14

a. What is the period of oscillation for point P in Figure 14? 1 mark

ms

b. On the axes below, sketch the displacement versus time graph for the point P of this transverse wave, showing at least **two** complete cycles. Include scales and units on each axis. 3 marks



Question 12 (5 marks)

Students are testing two identical radio transmitters, R1 and R2, on a football field. The transmitters are positioned 24 m apart, as shown in Figure 15. The transmitters are in phase, both emitting crests simultaneously, and emit waves of wavelength 18 m in all directions. The students are standing at point X, which is located 72 m away from the nearest transmitter, R1.

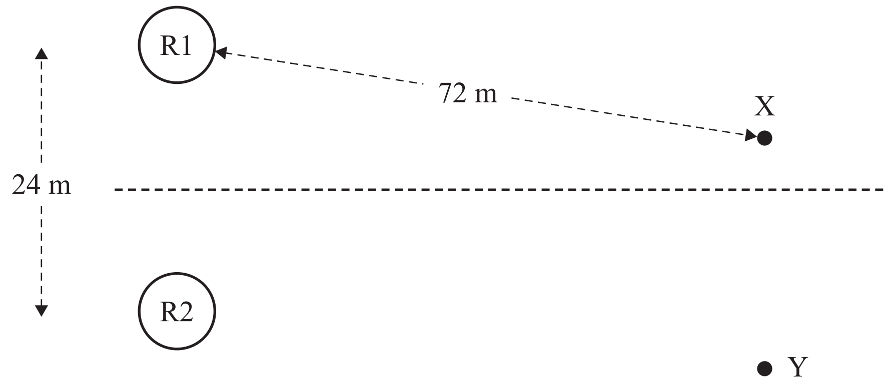


Figure 15

a. During testing, the radio signal received at point X is detected to be a minimum.

Calculate the shortest distance that point X could be from R2. Show your working. 2 marks

m

b. At another location on the football field, point Y, the students detect a maximum.

Explain why the two observations at points X and Y would support the wave model of light. 3 marks

Question 13 (4 marks)

The boundary between two transparent materials, Medium 1 and Medium 2, each having different refractive indices, is shown in Figure 16. An incident ray at an angle θ_i is also shown.

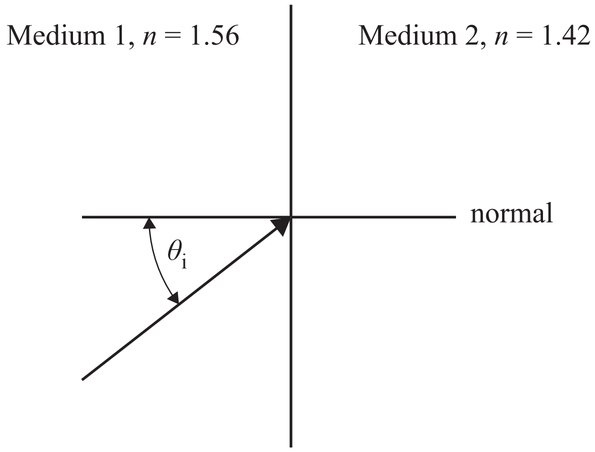


Figure 16

a. The refracted ray appears in Medium 2.

Sketch the approximate direction of the refracted ray in Medium 2 on Figure 16. 1 mark

b. What range of incident angles, θ_i, would result in a light ray emerging in Medium 2? Show your working. 3 marks

Question 14 (2 marks)

To explain different aspects of mechanical waves, a Physics teacher sets up a demonstration in a Physics laboratory using a 0.80 m wide loudspeaker and a microphone. The microphone measures the sound intensity at different positions on a circle around the speaker from position A to position B, as shown in Figure 17.

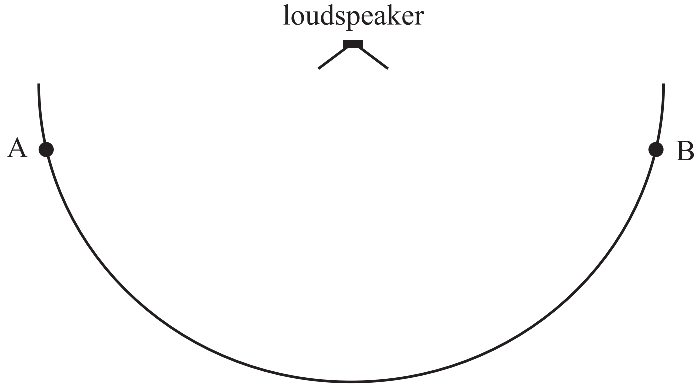


Figure 17

The speed of sound in the Physics laboratory is 334 m s^{-1}. Measurements are made at frequencies of 100 Hz and 10 000 Hz. The loudspeaker emits the 100 Hz and 10 000 Hz frequencies with equal intensity. Figure 18 shows the intensity, *I*, measured for each frequency at positions on the semicircular line shown in Figure 17 between positions A and B.

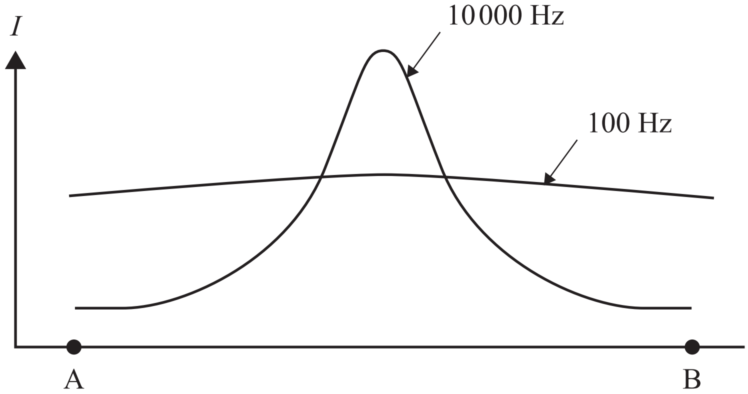


Figure 18

Explain why the response at 10 000 Hz has a greater intensity directly in front of the loudspeaker, while the response at 100 Hz is nearly the same at all positions.

DO NOT WRITE IN THIS AREA

Question 15 (7 marks)

The apparatus shown in Figure 19 is used to investigate the photoelectric effect. Light of various wavelengths is shone onto a silver plate (cathode). The work function of silver is 4.9 eV.

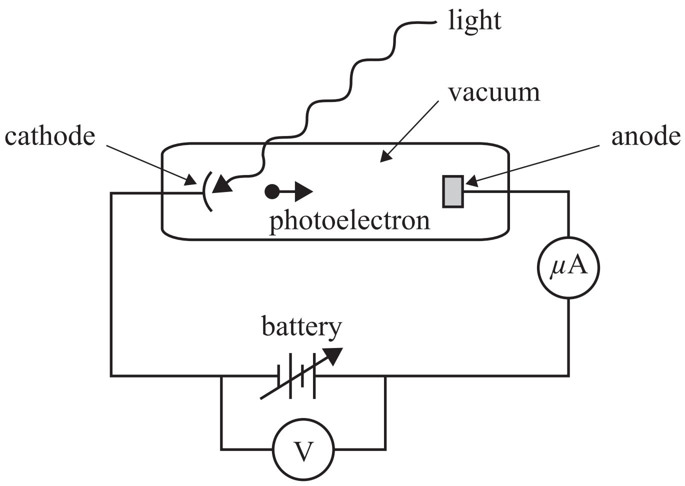


Figure 19

a. Explain what happens when light of wavelength 400 nm hits the silver plate. Use calculations to support your answer. 2 marks

b. Explain what happens when light with a photon energy of 5.4 eV hits the silver plate. 2 marks

c. Which model of light does this photoelectric investigation support? Give two reasons to justify your answer. 3 marks

Model of light ______

1. ______

2. ______

Question 16 (6 marks)

X-rays of wavelength 2.0 nm are emitted from an X-ray source.

a. Calculate the energy of **one** photon of these X-rays. Show your working. 3 marks

eV

b. The 2.0 nm X-rays are incident on a single narrow slit of width 5×10^{-8} m.

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

DO NOT WRITE IN THIS AREA

Question 17 (5 marks)

Light from a mercury vapour lamp shows a line spectrum related to discrete energy levels. Some of the energy levels for the mercury atom are shown in Figure 20.

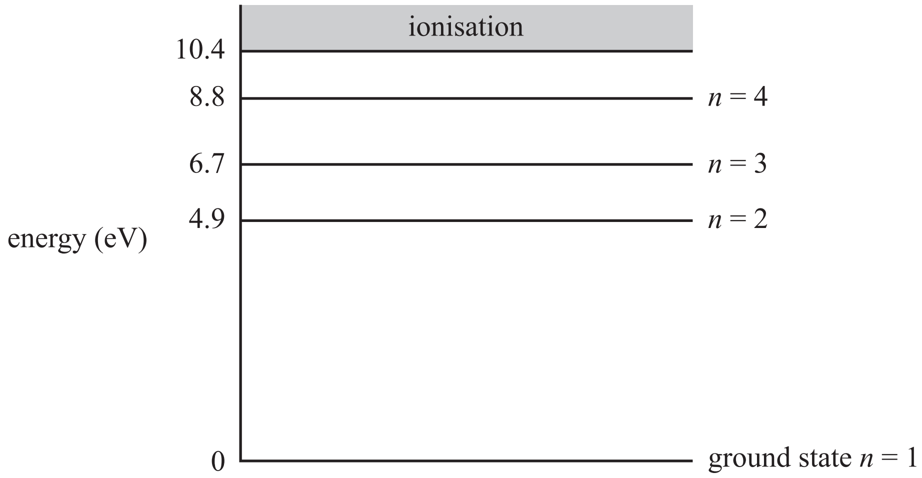


Figure 20

a. Draw an arrow on Figure 20 to indicate the transition between the listed energy states that would produce the lowest frequency of an emitted photon. 1 mark

b. Calculate the energy of the light emitted when the mercury atom makes a transition from the third energy level ($n = 3$) to its ground state ($n = 1$). Show your working. 2 marks

J

c. Explain what happens to a mercury atom in its ground state if a photon of energy 2.1 eV is incident on it. 2 marks

Question 18 (15 marks)

A small rubber ball of mass 50 g falls vertically from a given height and rebounds from a hard floor. The ball's speed immediately before impact is 3.6 m s^{-1}. The ball rebounds upward at a speed of 3.3 m s^{-1} immediately after it leaves the floor. The ball is in contact with the floor for 40 ms.

a. Calculate the magnitude and direction of the net average force acting on the 50 g ball while it is in contact with the floor. Show your working. 4 marks

N	

b. Just before the ball hits the floor, it has a certain amount of kinetic energy, E_k. At one instant when the ball is in contact with the floor, it is stationary before it rebounds.

Explain what has happened to the kinetic energy, E_k, of the ball when it is stationary. 2 marks

c. Just before the ball hits the floor, it has a certain amount of vertical momentum, p. At one instant when the ball is in contact with the floor, it is stationary before it rebounds.

What has happened to the vertical momentum, p, of the ball when it is stationary? 1 mark

During their practical investigation, some Physics students investigate the movement of a small rubber ball. The ball falls from a height of 1.00 m and rebounds to a height of 0.78 m. The students record the ball's vertical position versus time by using a smartphone's video feature and a metre rule scale.

The uncertainty in the ball's vertical position is ± 0.03 m. The results from the students' recorded data are plotted on the graph in Figure 21.

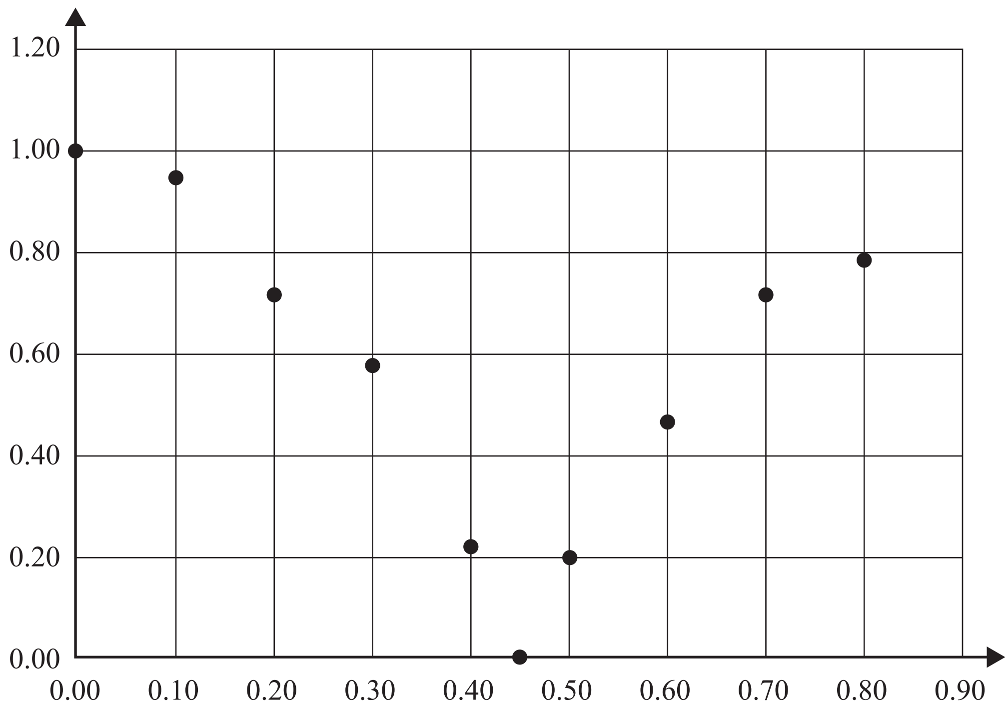


Figure 21

d. On the graph in Figure 21:

- label each axis and include units on each axis
- insert appropriate uncertainty bars for the height values on the graph, for the readings for the first four data points after the ball is released
- draw smooth curves of best fit. 5 marks

e. Estimate the speed of the ball at the instant of impact using an appropriate gradient of the graph in Figure 21. Use calculations to support your answer. 3 marks

m s^{-1}

END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2021

PHYSICS

Written examination

FORMULA SHEET

Instructions

This formula sheet is provided for your reference. A question and answer book is provided with this formula sheet.

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

Physics formulas

Motion and related energy transformations

velocity; acceleration	$v = \frac{\Delta s}{\Delta t}; \quad a = \frac{\Delta v}{\Delta t}$
equations for constant acceleration	$v = u + at$ $s = ut + \frac{1}{2}at^2$ $s = vt - \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(v + u)t$
Newton's second law	$\Sigma F = ma$
circular motion	$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
Hooke's law	$F = -k\Delta x$
elastic potential energy	$\frac{1}{2}k(\Delta x)^2$
gravitational potential energy near the surface of Earth	$mg\Delta h$
kinetic energy	$\frac{1}{2}mv^2$
Newton's law of universal gravitation	$F = G\frac{m_1 m_2}{r^2}$
gravitational field	$g = G\frac{M}{r^2}$
impulse	$F\Delta t$
momentum	mv
Lorentz factor	$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
time dilation	$t = t_o\gamma$
length contraction	$L = \frac{L_o}{\gamma}$
rest energy	$E_{rest} = mc^2$
relativistic total energy	$E_{total} = \gamma mc^2$
relativistic kinetic energy	$E_k = (\gamma - 1)mc^2$

Fields and application of field concepts

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	$E = \frac{kq}{r^2}$
force on an electric charge	$F = qE$
Coulomb's law	$F = \frac{kq_1q_2}{r^2}$
magnetic force on a moving charge	$F = qvB$
magnetic force on a current carrying conductor	$F = nIlB$
radius of a charged particle in a magnetic field	$r = \frac{mv}{qB}$

Generation and transmission of electricity

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

Wave concepts

wave equation	$v = f\lambda$
constructive interference	path difference $= n\lambda$
destructive interference	path difference $= \left(n - \frac{1}{2}\right)\lambda$
fringe spacing	$\Delta x = \frac{\lambda L}{d}$
Snell's law	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
refractive index and wave speed	$n_1 v_1 = n_2 v_2$

The nature of light and matter

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

Data

acceleration due to gravity at Earth's surface	$g = 9.8\ \mathrm{m\ s^{-2}}$
mass of the electron	$m_e = 9.1 \times 10^{-31}\ \mathrm{kg}$
magnitude of the charge of the electron	$e = 1.6 \times 10^{-19}\ \mathrm{C}$
Planck's constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$ $\quad h = 4.14 \times 10^{-15}\ \mathrm{eV\ s}$
speed of light in a vacuum	$c = 3.0 \times 10^{8}\ \mathrm{m\ s^{-1}}$
universal gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$
mass of Earth	$M_E = 5.98 \times 10^{24}\ \mathrm{kg}$
radius of Earth	$R_E = 6.37 \times 10^{6}\ \mathrm{m}$
Coulomb constant	$k = 8.99 \times 10^{9}\ \mathrm{N\ m^2\ C^{-2}}$

Prefixes/Units

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 = tonne = 10^{3} kg

END OF FORMULA SHEET