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 $-2.7\ \mu$C 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.

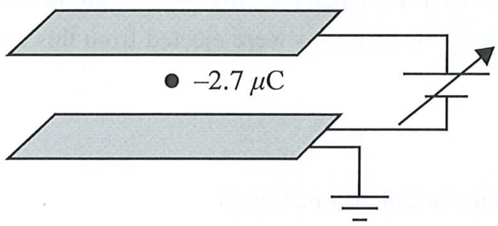


Figure 1

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

Up

Negative charge is attracted to positive plate. When V↑, electric force > gravity

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

$F = qE \quad E = \frac{V}{d}$

$F = \frac{2.7\times10^{-6} \times 15.5}{0.002}$

0.021 N

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.

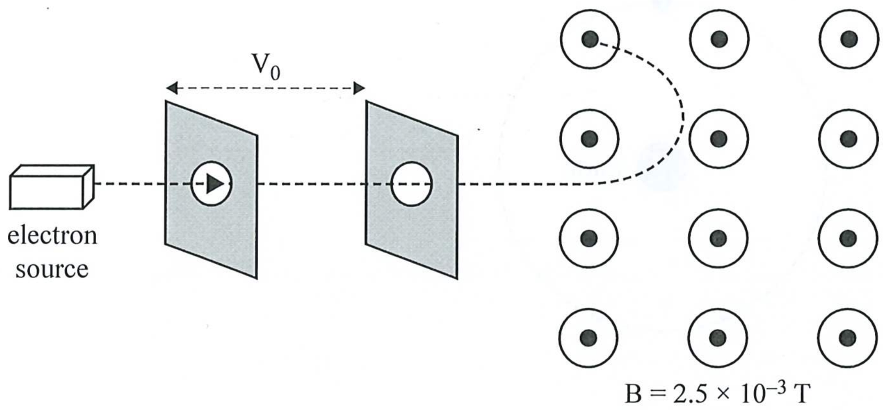


Figure 2

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

$qV = \frac{1}{2} mv^2$

$V = \frac{9.1 \times 10^{-31} \times (2 \times 10^7)^2}{2 \times 1.6 \times 10^{-19}}$

1.1 kV

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

Magnetic force on the electron is always at the right angle to their velocity and constant in magnitude.

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

$qvB = \frac{mv^2}{r}$ $r = \frac{mv}{qB}$

$r = \frac{9.1 \times 10^{-31} \times 2 \times 10^7}{1.6 \times 10^{-19} \times 2.5 \times 10^{-3}}$

0.046 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.

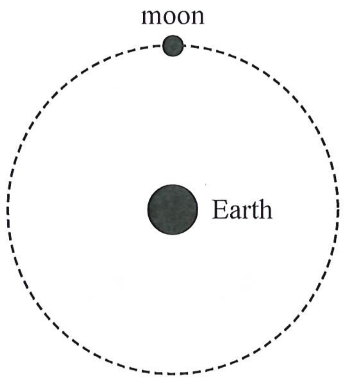


Figure 3

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

$F = \frac{GMm}{r^2}$ $F = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 7.35 \times 10^{22}}{(3.84 \times 10^{8})^2}$

1.99×10^{20} 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

$\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$ Right hand side is constant

so if R ↑, T ↑.

Period will increase

Question 4 (3 marks)

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

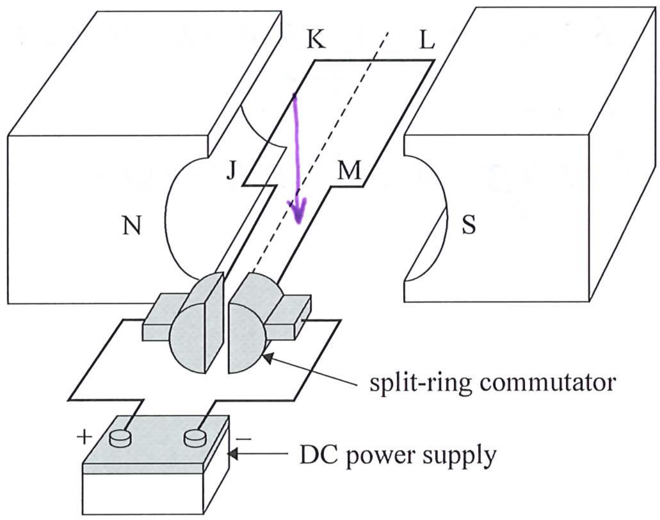


Figure 4

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

To reverse direction of the current every half turn to maintain constant rotation.

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.

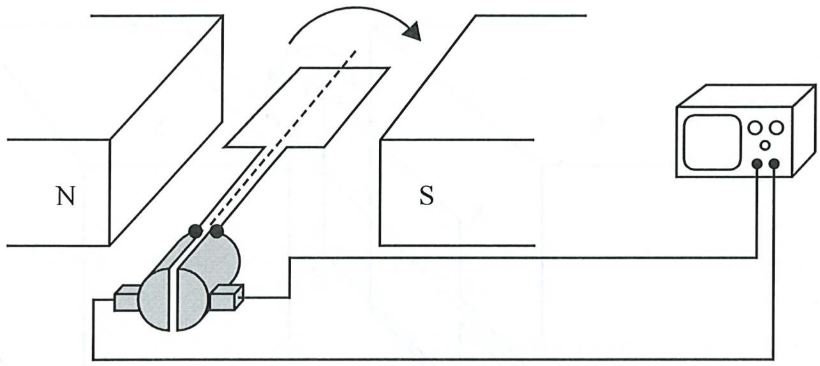
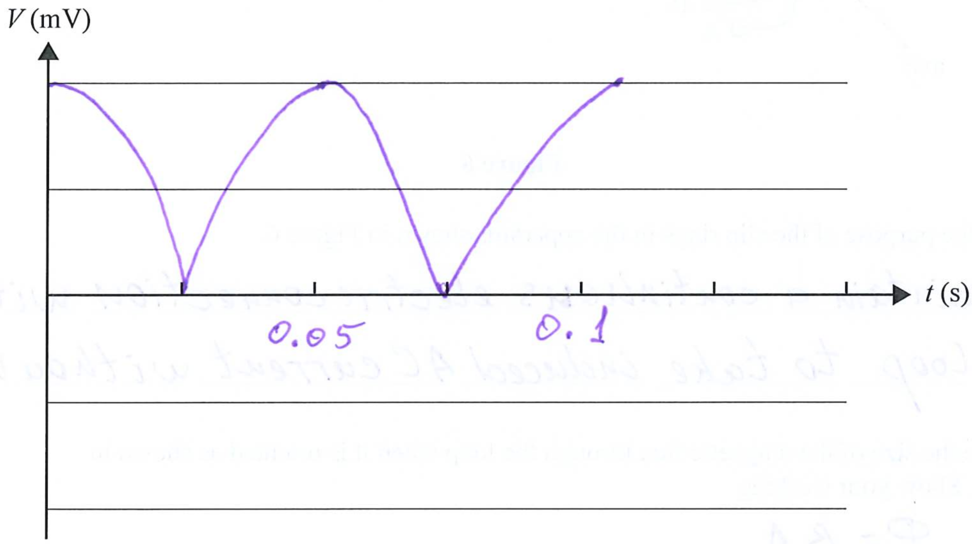


Figure 5

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.

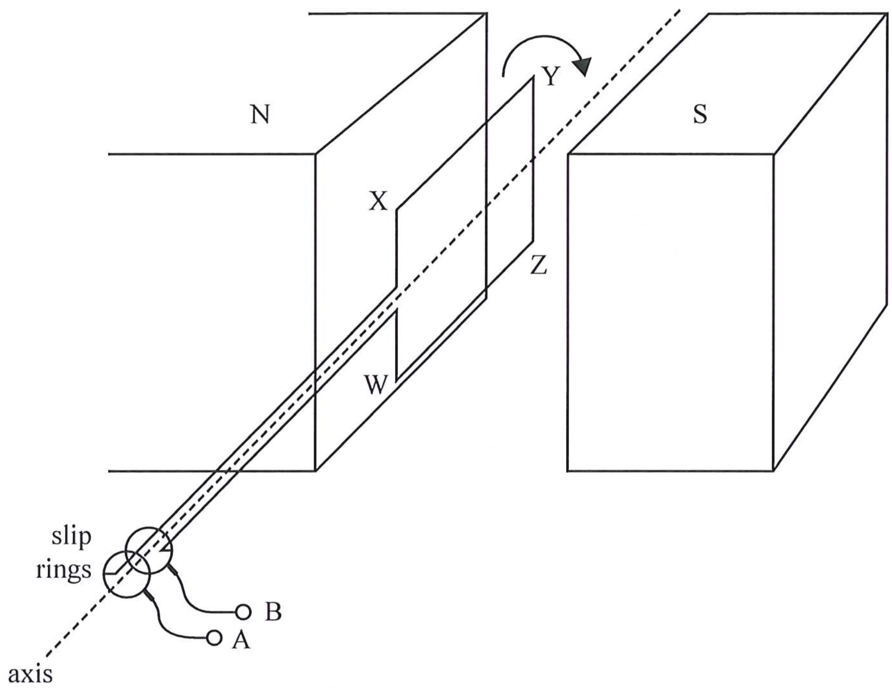


Figure 6

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

To maintain a continuous electric connection with the loop to take induced AC current without change.

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

$\Phi = BA$

$\Phi = 0.2 \times 0.02 \times 0.03$

1.2×10^{-4} 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.

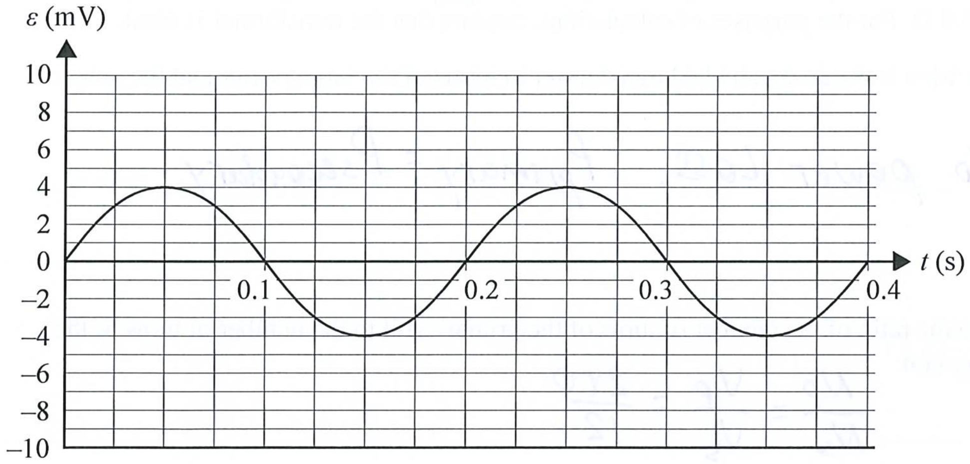


Figure 7

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

5 Hz

$f = \frac{1}{T} = \frac{1}{0.2}$

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

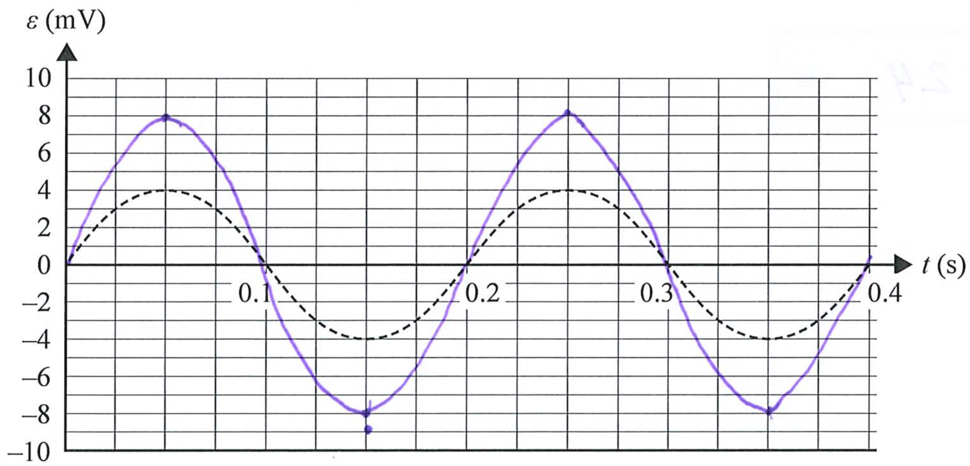


Figure 8

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

No power Loss. $P_{primary} = P_{secondary}$

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

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{240}{12}$

20 : 1

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

$P = \frac{V^2}{R}$

$P = \frac{12^2}{6}$

24 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.

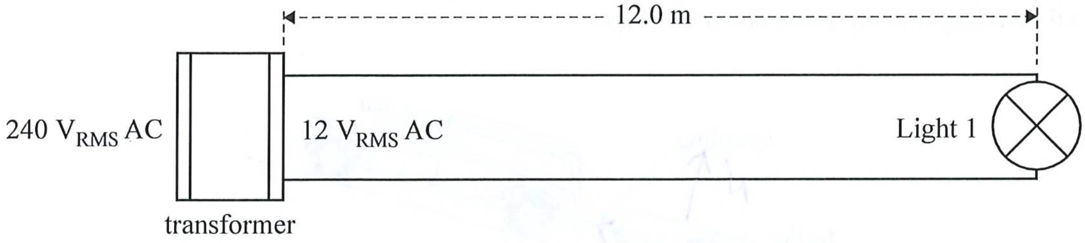


Figure 9

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

$R_{wire} = 2 \times 12 \times 0.05 = 1.2\ \Omega$

$R_{total} = 6 + 1.2 = 7.2\ \Omega$

$I = \frac{V}{R} = \frac{12}{7.2} = 1.67\ A$

$V_{globe} = 1.67 \times 6$

10 V

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

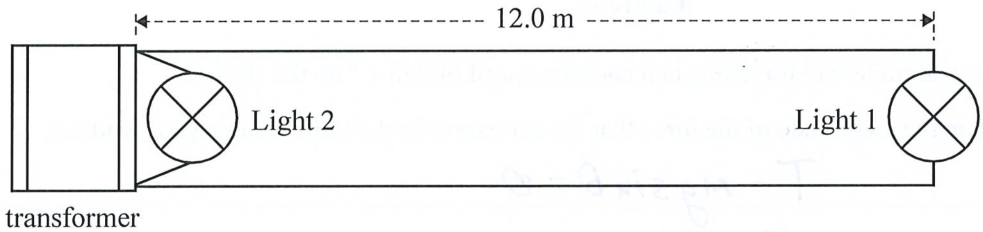


Figure 10

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

Due to the power loss in the wire less power delivered to Light 1 so Light 2 will be brighter

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.

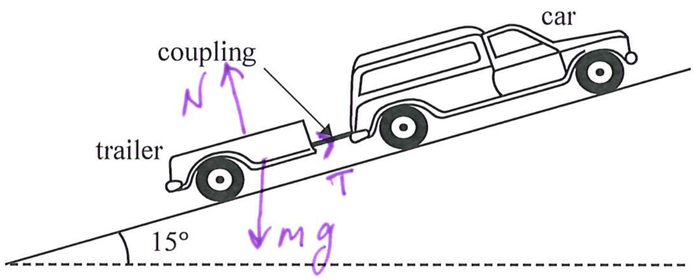


Figure 11

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

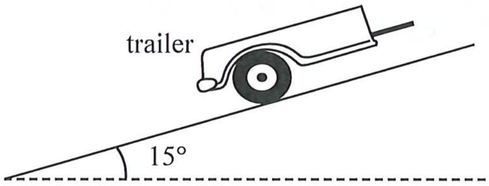


Figure 12

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

$T - mg\sin\theta = 0$

$T = 200 \times 9.8 \times \sin 15$

507 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

$E_{gp} = mgh$ $h = 100 \times \sin 15°$

$E_{gp} = 950 \times 9.8 \times 100 \sin 15°$

241 kJ

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.

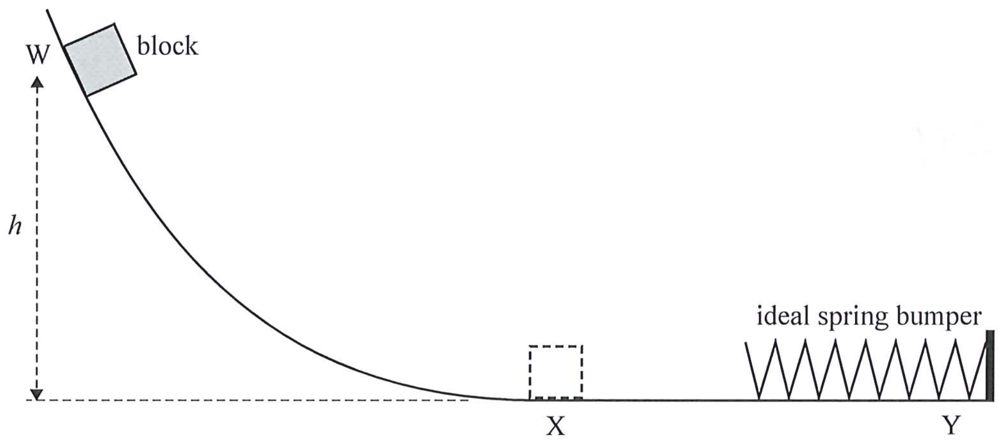


Figure 13

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

W: Acceleration down the slope and less than g

X: zero

Y: Maximum acceleration to the left

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

$mgh = \frac{kx^2}{2}$

$h = \frac{100 \times 3^2}{2 \times 5 \times 9.8}$

9.2 m

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

$\frac{kx^2}{2} = \frac{mv^2}{2}$

$v = \sqrt{\frac{100}{5}} \times 3 = 13.4 \text{ ms}^{-1}$

$p = mv$

67 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

The momentum is transfered to the earth.

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

$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$ $\gamma = \frac{1}{\sqrt{1-0.984^2}}$

5.61

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

$t = \frac{d}{v} = \frac{4.37}{0.984}$

4.44 years

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.

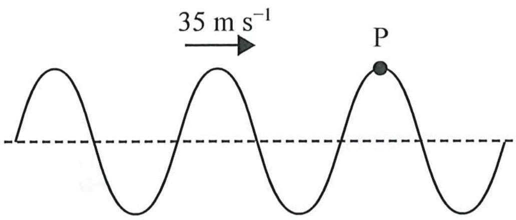


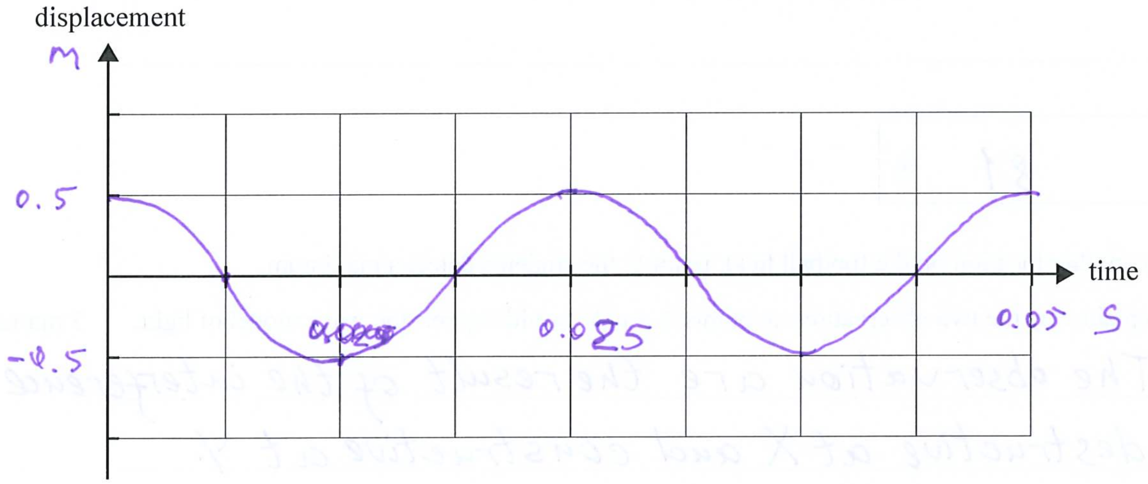
Figure 14

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

$T = \frac{1}{f} = \frac{1}{40}$

25 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.

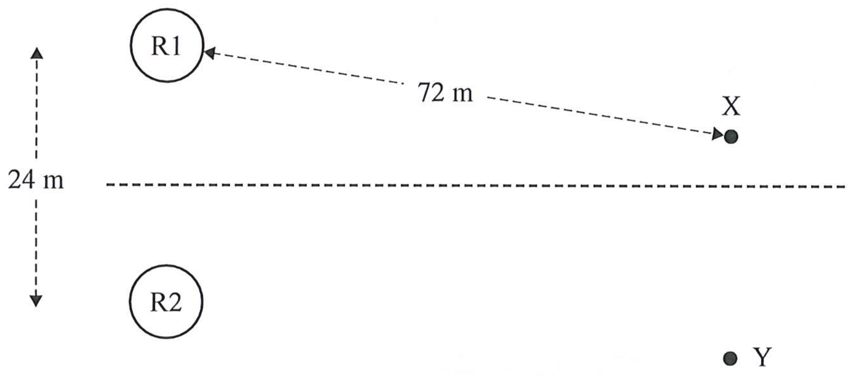


Figure 15

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

Path difference $= \frac{1}{2}\lambda = 9$ m

$72 + 9 = 81$

81 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

The observation are the result of the interference – destructive at X and constructive at Y. Interference is a wave phenomenon.

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.

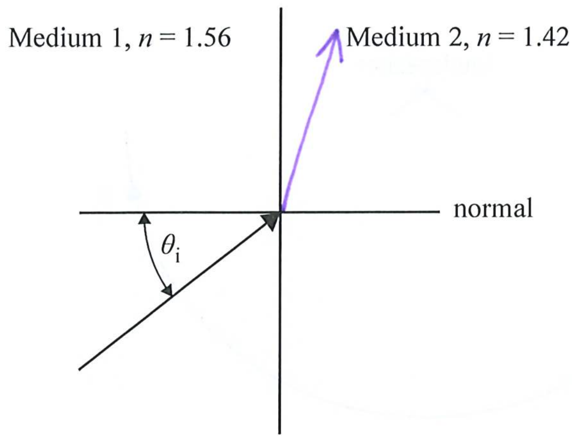


Figure 16

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

$\theta_{critical} = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1.42}{1.56}\right) = 65.5°$

$0 \leq \theta < 65.5°$

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.

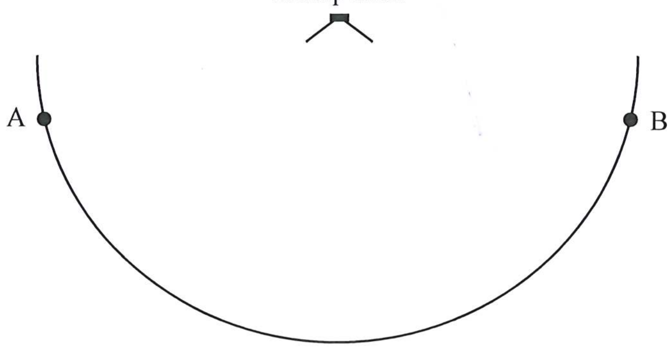


Figure 17

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.

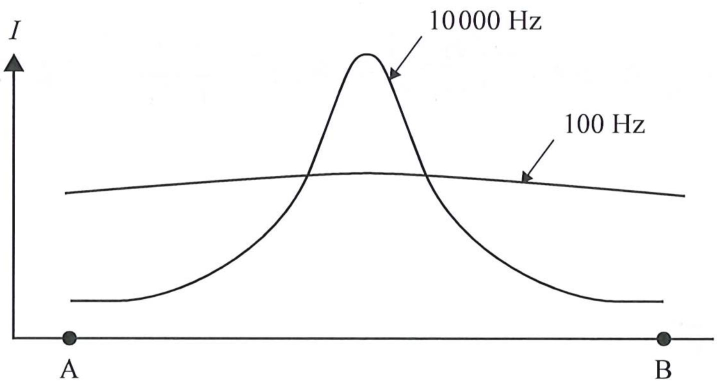


Figure 18

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.

Diffraction depends on the ratio $\frac{\lambda}{w}$. $\lambda = \frac{v}{f}$

At 10 000 Hz $\frac{\lambda}{w} = \frac{0.03}{0.8} = 3.75 \times 10^{-2}$ Very little diffraction

At 100 Hz $\frac{\lambda}{w} = \frac{3.34}{0.8} = 4.18$ Diffraction significant.

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.

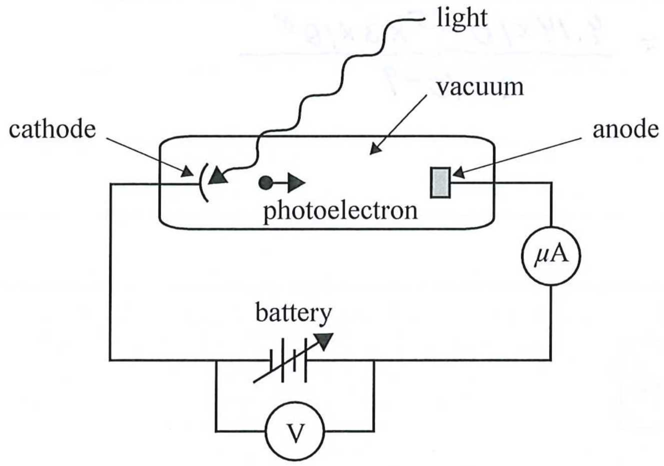


Figure 19

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

$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{400 \times 10^{-9}} = 3.1 eV$

$3.1 < 4.9$

No electrons emitted.

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

$E_{K_{max}} = hf - W = 5.4 - 4.9 = 0.5 eV$

Electron emitted with kinetic energy 0.5eV

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

Model of light particle

1. Existence of threshold frequency according to the particle model. No electrons emitted by 400 nm light

2. Model suggest that energy of the photon depends on frequency so higher frequency light produce photoelectrons.

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

$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2 \times 10^{-9}}$

621 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

$\frac{\lambda}{w} = \frac{2 \times 10^{-9}}{5 \times 10^{-8}} = 4 \times 10^{-2}$

No diffraction will be observed

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.

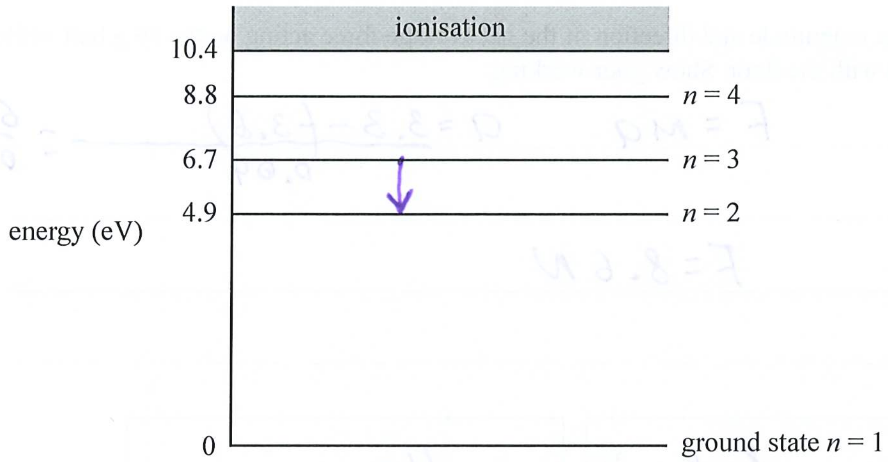


Figure 20

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

Smallest energy change

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

$E = 6.7 eV = 6.7 \times 1.6 \times 10^{-19}$

1.07×10^{-18} 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

Nothing

There is no energy level at 2.1 eV so transition will not take place

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

3.3↑ ↓3.6

$F = ma \quad a = \frac{3.3-(-3.6)}{0.04} = \frac{6.9}{0.04}$

$F = 8.6$ N

8.6 N	Up

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

It is converted to elastic potential energy. Some lost as sound and heat.

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

Transferred to the earth.

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.

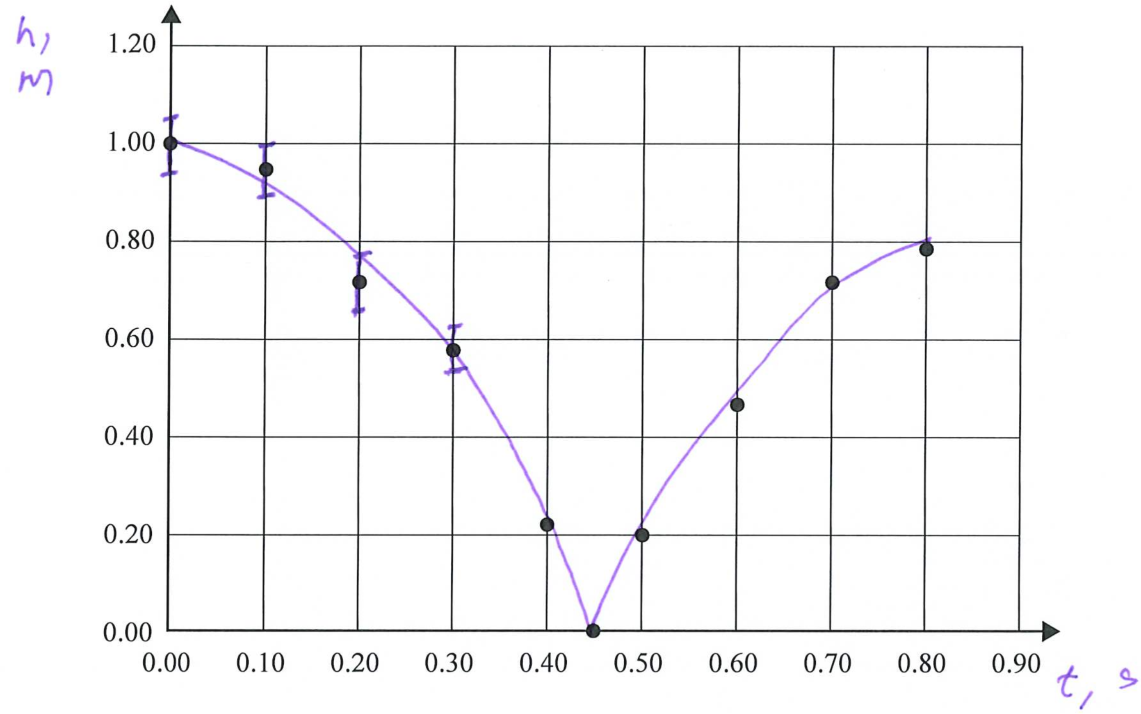


Figure 21

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

$\frac{0.22}{0.05} = 4.4$

4.4 m s^{-1}

END OF QUESTION AND ANSWER BOOK