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STUDENT NUMBER

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Letter

PHYSICS

Written examination

Wednesday 9 November 2022

Reading time: 9.00 am to 9.15 am (15 minutes)

Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	20	20	20
B	17	17	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 42 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.

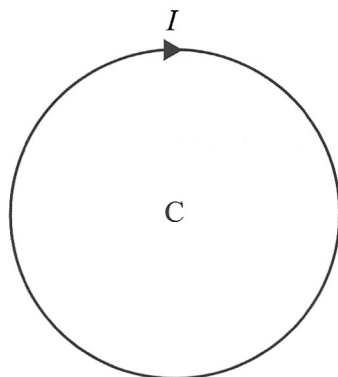
No marks will be given if more than one answer is completed for any question.

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 single loop of wire carries a current, I , as shown in the diagram below.



Right Hand Rule.

Which one of the following best describes the direction of the magnetic field at the centre of the circle, C , which is produced by the current carrying wire?

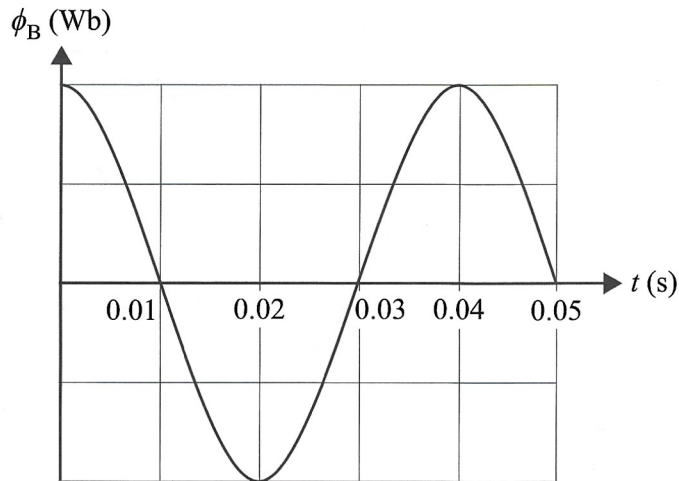
- A. to the left
- B. to the right
- C. into the page**
- D. out of the page

SECTION A – continued



Question 2

The diagram below shows the magnetic flux variation through the coil of an AC generator.



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

$$T = 0.04$$

$$f = \frac{1}{0.04} = 25$$

Which one of the following is closest to the frequency of the magnetic flux variation through the coil of the AC generator?

- A. 0.04 Hz
- B. 10 Hz
- C. 20 Hz
- D. 25 Hz**

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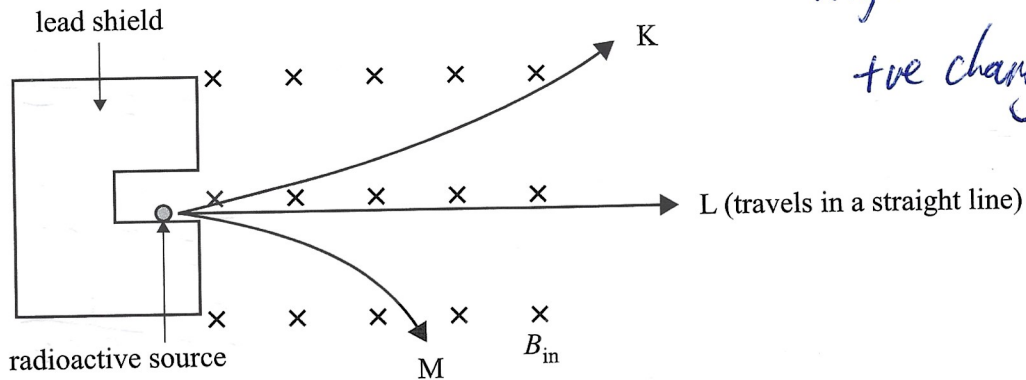
SECTION A – continued
TURN OVER



Question 3

Particles emitted from a radioactive source travel through a magnetic field, B_{in} , directed into the page, as shown schematically in the diagram below.

Three particles, K, L and M, follow the paths indicated by the arrows.



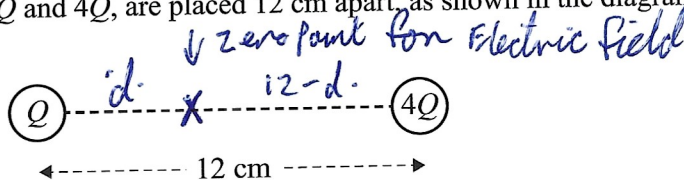
*Right Hand Rule
+ve charge, force
up page.*

Which of the following correctly identifies the charges on particles K, L and M?

	K	L	M
A.	positive ✓	no charge ✓	negative ✓
B.	positive ✓	negative	negative ✓
C.	negative	no charge ✓	positive
D.	no charge	no charge ✓	no charge

Question 4

Two point charges, Q and $4Q$, are placed 12 cm apart, as shown in the diagram below.



On the straight line between the charges Q and $4Q$, the electric field is

- A. non-zero everywhere.
- B. zero at a point 2.4 cm from Q .
- C. zero at a point 3 cm from Q .
- D. zero at a point 4 cm from Q .

$E = \frac{kq}{r^2}$

$\frac{kQ}{d^2} = \frac{k4Q}{(12-d)^2}$

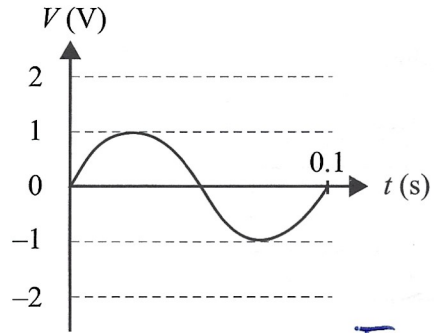
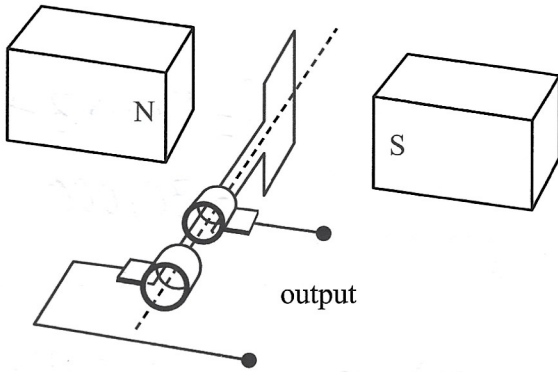
$(12-d)^2 = 4d^2$
 $144 - 24d + d^2 = 4d^2$
 $0 = 3d^2 + 24d - 144$
 $0 = d^2 + 8d - 48$
 $0 = (d+12)(d-4)$

$d = 4 \text{ cm}$



Question 5

A simple electricity generator is shown in the diagram below. When the coil is rotated, the output voltage across the slip rings is measured. The graph shows how the output voltage varies with time.

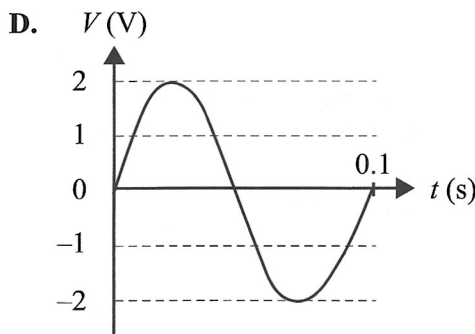
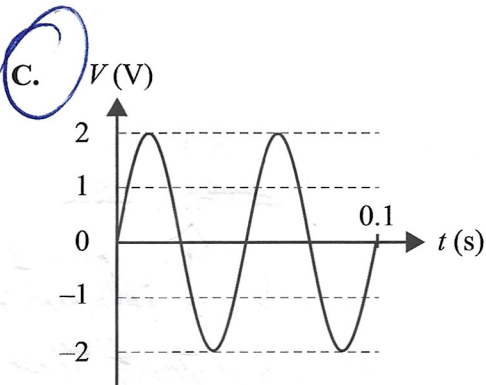
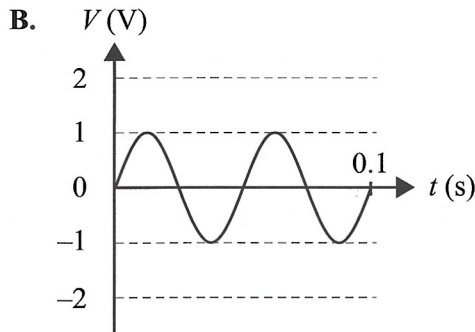
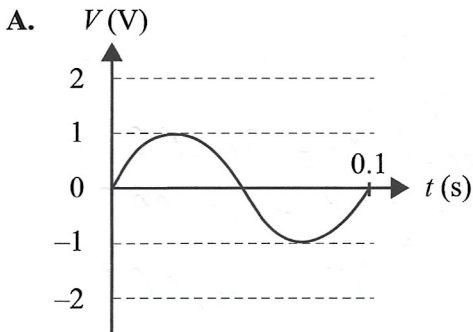


$f \times 2 \rightarrow T \times \frac{1}{2}$
 $\rightarrow \frac{\Delta \Phi}{\Delta t} \times 2$

The frequency of rotation of the generator is now doubled.

Which one of the following graphs best represents the output voltage measured across the slip rings? $\rightarrow \underline{E \times 2}$

$T \text{ Now } 0.05 \text{ s}$
 $E \text{ Now } 2$



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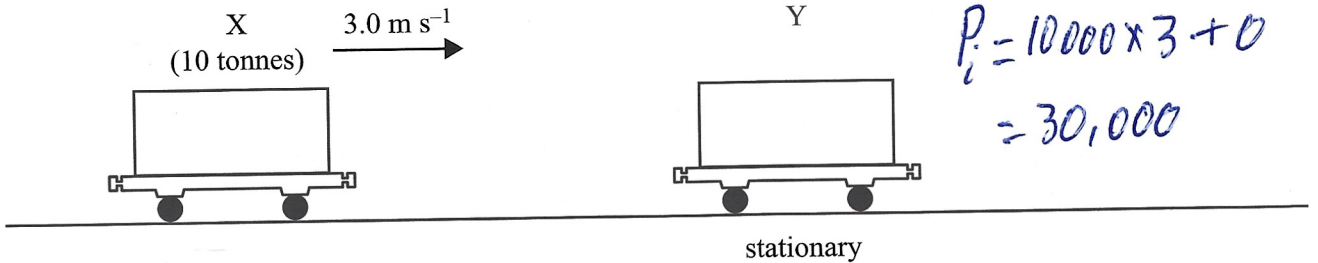


Use the following information to answer Questions 6 and 7.

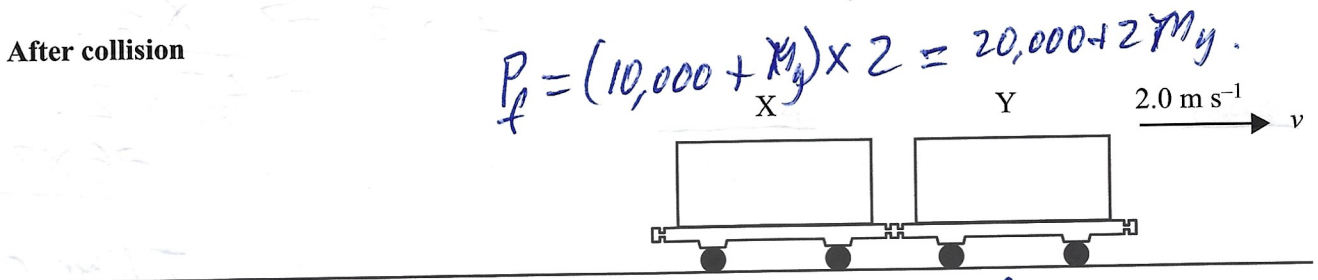
A railway truck (X) of mass 10 tonnes, moving at 3.0 m s^{-1} , collides with a stationary railway truck (Y), as shown in the diagram below.

After the collision, they are joined together and move off at speed $v = 2.0 \text{ m s}^{-1}$.

Before collision



After collision



Question 6

Which one of the following is closest to the mass of railway truck Y?

- A. 3 tonnes
- B. 5 tonnes
- C. 6.7 tonnes
- D. 15 tonnes

$$P_f = P_i$$

$$20,000 + 2M_y = 30,000$$

$$2M_y = 10,000$$

$$M_y = 5,000$$

Question 7

Which one of the following best describes the force exerted by the railway truck X on the railway truck Y ($F_{X \text{ on } Y}$) and the force exerted by the railway truck Y on the railway truck X ($F_{Y \text{ on } X}$) at the instant of collision?

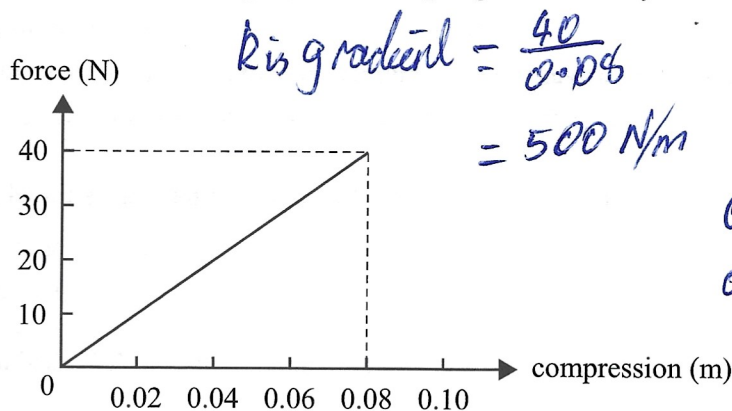
- A. $F_{X \text{ on } Y} < F_{Y \text{ on } X}$
- B. $F_{X \text{ on } Y} = F_{Y \text{ on } X}$
- C. $F_{X \text{ on } Y} = -F_{Y \text{ on } X}$
- D. $F_{X \text{ on } Y} > F_{Y \text{ on } X}$

↑
key information
At this instant:
The trucks are
in contact
∴ Newton's 3rd Law
⇒ $F_{X \text{ on } Y} = -F_{Y \text{ on } X}$



Question 8

The graph below shows force versus compression for a spring used in a Physics investigation.



$$k \text{ is gradient} = \frac{40}{0.08} \\ = 500 \text{ N/m}$$

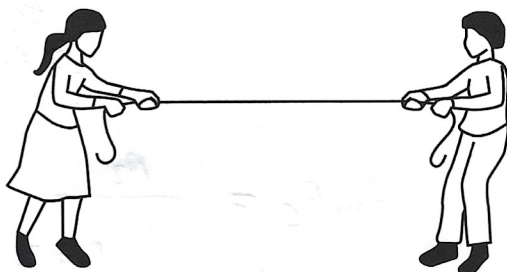
$$U_s = \frac{1}{2} k x^2 \\ 0.9 = \frac{1}{2} \times 500 \times x^2 \\ 0.9 = 250 x^2 \\ x^2 = 0.0036 \\ x = 0.06$$

Which one of the following is closest to the compression required to store 0.9 J of potential energy in the spring?

- A. 0.05 m
- B. 0.06 m**
- C. 0.07 m
- D. 0.08 m

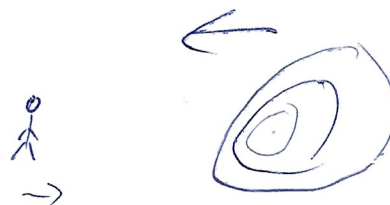
Question 9

Two students pull on opposite ends of a rope, as shown in the diagram below. Each student pulls with a force of 400 N.



Which one of the following is closest to the magnitude of the force of the rope on each student?

- A. 0 N
- B. 400 N**
- C. 600 N
- D. 800 N

**Question 10**

Which one of the following statements best describes an observation of the Doppler effect for sound?

- A. a decrease in frequency received when a source of sound moves towards you
- B. a decrease in frequency received when moving towards a stationary source of sound
- C. an increase in frequency received when moving towards a stationary source of sound**
- D. a decrease in wavelength received when moving away from a stationary source of sound

SECTION A – continued
TURN OVER



Particle \perp to energy

Particle // to energy

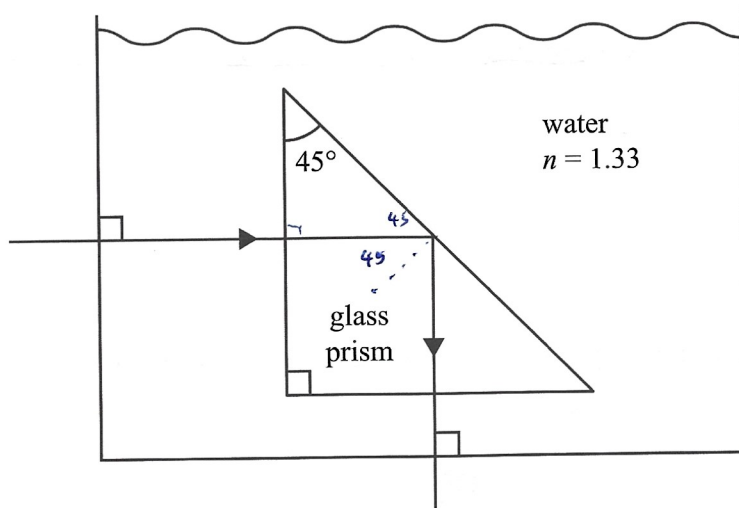
Question 11

Which one of the following statements best describes transverse and longitudinal waves?

- A. Both transverse waves and longitudinal waves travel in a direction parallel to their vibrations.
- B. Both transverse waves and longitudinal waves travel in a direction perpendicular to their vibrations.
- C. Transverse waves travel in a direction perpendicular to their vibrations; longitudinal waves travel parallel to their vibrations.**
- D. Transverse waves travel in a direction parallel to their vibrations; longitudinal waves travel perpendicular to their vibrations.

Question 12

A 45° glass prism is submerged in water and oriented as shown in the diagram below. It is used to reflect a light ray through 90° .



Occurring when
 $\theta_i = 45^\circ$
 $\Rightarrow \theta_c = 45^\circ$

What is the lowest refractive index of the glass prism that will ensure that total internal reflection occurs inside the prism?

- A. 1.00
- B. 1.41
- C. 1.61
- D. 1.88**

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$\sin 45^\circ = \frac{1.33}{n_g}$$

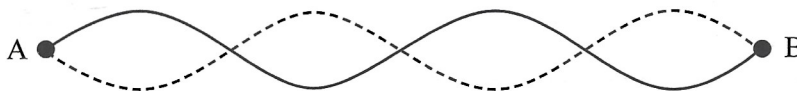
$$n_g = \frac{1.33}{\sin 45}$$

$$= 1.880904$$



Question 13

A travelling wave produced at point A is reflected at point B to produce a standing wave on a rope, as represented in the diagram below.



The distance between points A and B is 2.4 m. The period of vibration of the standing wave is 1.6 s. The speed of the travelling wave along the rope is closest to

- A. 0.75 m s^{-1}
 B. 1.0 m s^{-1}
 C. 1.5 m s^{-1}
 D. 2.0 m s^{-1}

$$A \rightarrow B = 2\lambda$$

$$2\lambda = 2.4$$

$$\lambda = 1.2$$

$$T = 1.6$$

$$f = \frac{1}{1.6}$$

$$= 0.625$$

$$v = \lambda f$$

$$= 1.2 \times 0.625$$

$$= 0.75$$

Question 14

Which one of the following best provides evidence of electrons behaving as waves?

- A. photoelectric effect \leftarrow Particle Behaviour
 B. atomic emission spectra \leftarrow Energy levels of atoms
 C. atomic absorption spectra \leftarrow Energy levels of atoms
 D. diffraction of electrons through a crystal

\nwarrow Wave behaviour of electrons
 \rightarrow Diffraction

Question 15

Which one of the following best provides evidence of light behaving as a particle?

- A. photoelectric effect
 B. white light passing through a prism
 C. diffraction of light through a single slit
 D. interference of light passing through a double slit

Question 16

Which one of the following phenomena best demonstrates that light waves are transverse?

- A. polarisation
 B. interference
 C. dispersion
 D. diffraction

\uparrow Property that Transverse waves have that longitudinal don't.
 \rightarrow Polarisation.

Question 17

Gamma radiation is often used to treat cancerous tumours. The energy of a gamma photon emitted by radioactive cobalt-60 is 1.33 MeV. \leftarrow Use eVs version of Planck's Const.

Which one of the following is closest to the frequency of the gamma radiation?

- A. $1.33 \times 10^6 \text{ Hz}$
 B. $3.21 \times 10^{20} \text{ Hz}$
 C. $3.21 \times 10^{21} \text{ Hz}$
 D. $2.01 \times 10^{30} \text{ Hz}$

$$E = hf$$

$$1.33 \times 10^6 = 4.14 \times 10^{-15} f$$

$$f = 3.2125 \times 10^{20}$$

oops!



Question 18

Which one of the following is an example of an inertial frame of reference?

- A. a bus travelling at constant velocity
- B. an express train that is accelerating
- C. a car turning a corner at a constant speed
- D. a roller-coaster speeding up while heading down a slope

Not accelerating
→ Constant Velocity

Question 19

A particle produced in a linear particle accelerator is travelling at a speed of $2.99 \times 10^8 \text{ m s}^{-1}$.

Take the speed of light to be $3.00 \times 10^8 \text{ m s}^{-1}$.

Which one of the following is closest to the Lorentz factor (γ) of the particle?

- A. 5.51
- B. 7.86
- C. 12.3
- D. 15.1

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1 - \frac{(2.99 \times 10^8)^2}{(3.00 \times 10^8)^2}}}$$

$$= 12.25766$$

Question 20

The experimental uncertainty of a measurement is best understood as

- A. an estimate of the validity of the data.
- B. a mistake in the experimental method used.
- C. a mistake in the recording of a measurement.
- D. an estimate of the maximum likely difference between the measurement and the true value.

Uncertainty is NOT a mistake
is NOT validity

is-related to the True and Measured values
(actual).

- the likely difference between them.

END OF SECTION



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 (5 marks)

Figure 1 shows four positions (1, 2, 3 and 4) of the coil of a single-turn, simple DC motor. The coil is turning in a uniform magnetic field that is parallel to the plane of the coil when the coil is in Position 1, as shown.

When the motor is operating, the coil rotates about the axis through the middle of sides LM and NK in the direction indicated. The coil is attached to a commutator. Current for the motor is passed to the commutator by brushes that are not shown in Figure 1.

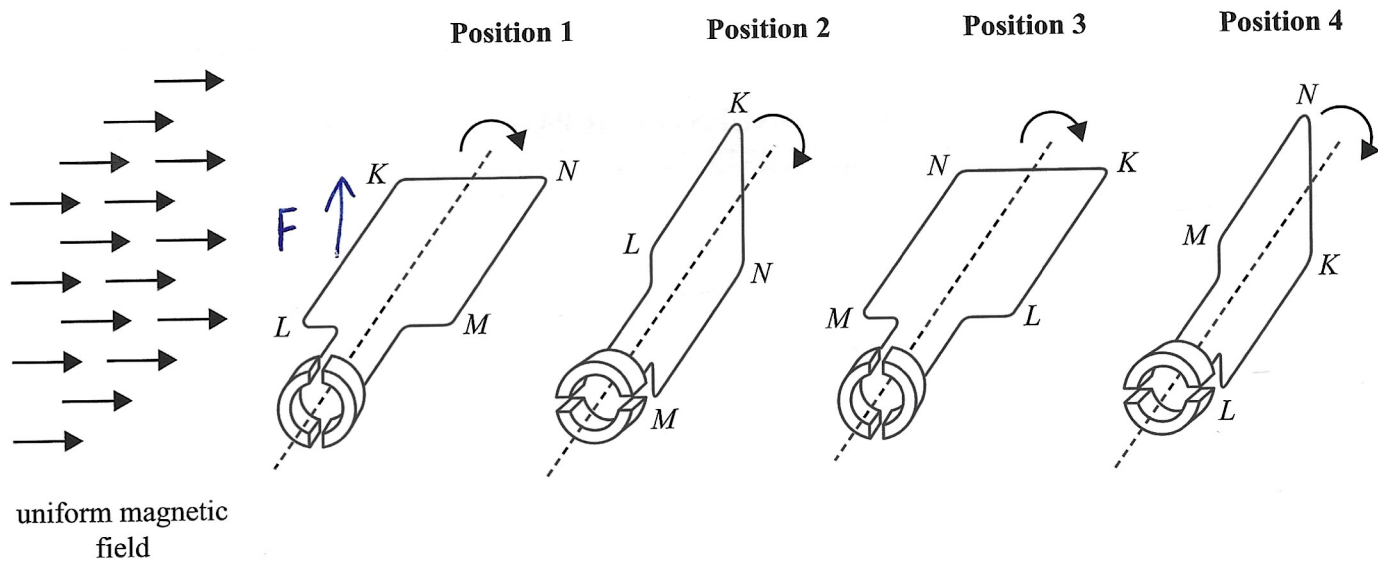


Figure 1

- a. When the coil is in Position 1, in which direction is the current flowing in the side KL – from K to L or from L to K ? Justify your answer. 2 marks

*Force up \rightarrow Using Right Hand Rule, indicates currents K to L
Field to Right. \rightarrow*



- b. When the coil is in Position 3, in which direction is the current flowing in the side KL – from K to L or from L to K ?

1 mark

L to K.

Position 3 \rightarrow split ring commutator has changed the direction of the current.

- c. The side KL of the coil has a length of 0.10 m and experiences a magnetic force of 0.15 N due to the magnetic field, which has a magnitude of 0.5 T.

Calculate the magnitude of the current in the coil.

2 marks

$$F = nILB. \quad F = 0.15 \quad n = 1 \quad L = 0.10 \quad B = 0.5$$

$$0.15 = 1 \times I \times 0.1 \times 0.5$$

$$0.15 = 0.05 I$$

$$I = \frac{0.15}{0.05} = 3.0.$$

3.0

A

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SECTION B – continued
TURN OVER



Question 2 (9 marks)

There are over 400 geostationary satellites above Earth in circular orbits. The period of orbit is one day (86 400 s). Each geostationary satellite remains stationary in relation to a fixed point on the equator. Figure 2 shows an example of a geostationary satellite that is in orbit relative to a fixed point, X, on the equator.

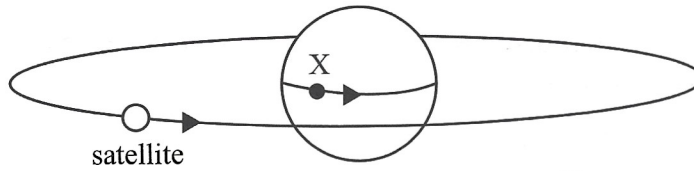


Figure 2

- a. Explain why geostationary satellites must be vertically above the equator to remain stationary relative to Earth's surface. 2 marks

The centripetal force must be directed towards the centre of the Earth. The satellite must orbit in the same plane as the Earth. Thus the satellite is above the same place on the equator.

- b. Using $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$, $M_E = 5.98 \times 10^{24} \text{ kg}$ and $R_E = 6.37 \times 10^6 \text{ m}$, show that the altitude of a geostationary satellite must be equal to $3.59 \times 10^7 \text{ m}$. 4 marks

$$g = G \frac{M_E}{r^2}$$

$$g = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{r^2}$$

$$a = \frac{4\pi^2 r}{T^2}$$

$$a = \frac{4\pi^2 r}{(86400)^2}$$

radius of orbit = R_E .

for satellite $a = g \rightarrow \frac{4\pi^2 r}{(86400)^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{r^2}$

Since the acceleration is provided by the gravitational field.
or Centripetal force = Gravitational force.
 $F_c = F_g$

$$r^3 = 7.54 \times 10^{22}$$

$$r = 42250474.31$$

$$\begin{aligned} \text{Altitude} &= r - R_E = 42250474.31 - 6.37 \times 10^6 \\ &= 35880474.31 \\ &= 3.59 \times 10^7 \text{ m} \end{aligned}$$

Could also use Keplers 3rd Law.

$$\frac{R^3}{T^2} = \text{Constant}$$

The constant is $\frac{GM}{4\pi^2}$.

$$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$

4 Marks \rightarrow Significant Working



- c. Calculate the speed of an orbiting geostationary satellite.

3 marks

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$v^2 = \frac{4\pi^2 r^2}{T^2}$$

$$v^2 = \frac{4\pi^2 \times 4225047.31^2}{86400^2}$$

$$v^2 = 94405$$

$$v = 307.25$$

$$= 3.07 \times 10^3$$

$$3.07 \times 10^3 \text{ m s}^{-1}$$

Note: Could use $v = \frac{2\pi r}{T}$

OR $v = \sqrt{\frac{GM}{r}}$

where r is the radius of the orbit

↑
show
ALL
Working

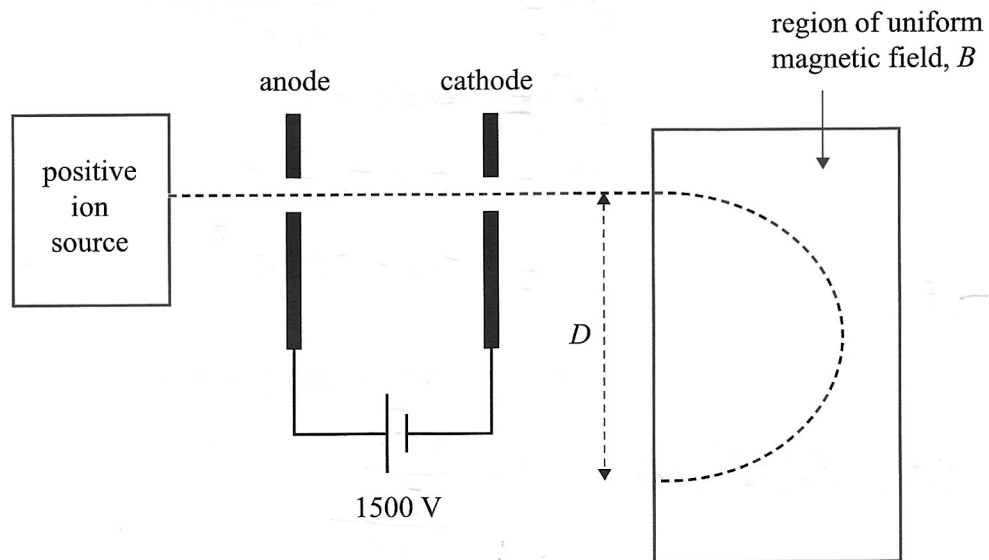
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SECTION B – continued
TURN OVER



Question 3 (7 marks)

A schematic diagram of a mass spectrometer that is used to deflect charged particles to determine their mass is shown in Figure 3. Positive singly charged ions (with a charge of $+1.6 \times 10^{-19} \text{ C}$) are produced at the ion source. These are accelerated between an anode and a cathode. The potential difference between the anode and the cathode is 1500 V. The ions pass into a region of uniform magnetic field, B , and are directed by the field into a semicircular path of diameter D .

**Figure 3**

- a. Calculate the increase in the kinetic energy of each ion as it passes between the anode and the cathode. Give your answer in joules. 2 mark

$$\begin{aligned} \text{Energy} &= qV = 1.6 \times 10^{-19} \times 1500 \\ &= 2.4 \times 10^{-16} \end{aligned}$$

$$2.4 \times 10^{-16} \text{ J}$$



Each ion has a mass of 4.80×10^{-27} kg.

- b. Show that each ion has a speed of 3.16×10^5 m s⁻¹ when it exits the cathode. Assume that the ion leaves the ion source with negligible speed. Show your working.

2 marks

$$k.E. = \frac{1}{2} m v^2$$

$$2.4 \times 10^{-16} = \frac{1}{2} \times 4.80 \times 10^{-27} \times v^2$$

$$1.0 \times 10^{11} = v^2$$

$$v = 316227.766$$

$$= 3.16 \times 10^5 \text{ m s}^{-1}$$

- c. The region of uniform magnetic field, B , in Figure 3 has a magnitude of 0.10 T.

Calculate the diameter, D , of the semicircular path followed by the ions within the magnetic field in Figure 3.

3 marks

$$F_m = q v B$$

$$= 1.6 \times 10^{-19} \times 3.16 \times 10^5 \times 0.10$$

$$= 5.056 \times 10^{-15}$$

$$F_c = \frac{m v^2}{r}$$

$$F_m = F_c$$

$$5.056 \times 10^{-15} = \frac{4.80 \times 10^{-27} \times (3.16 \times 10^5)^2}{r}$$

$$r = \frac{4.80 \times 10^{-27} \times (3.16 \times 10^5)^2}{5.056 \times 10^{-15}}$$

$$= 0.0948 \text{ m}$$

$$\text{Diameter} = 2 \times r$$

$$= 0.1896$$

0.19 m

Note: could use $r = \frac{m v}{B q}$



Question 4 (6 marks)

A square loop of wire connected to a resistor, R , is placed close to a long wire carrying a constant current, I , in the direction shown in Figure 4.

The square loop is moved three times in the following order:

- Movement A – Starting at Position 1 in Figure 4, the square loop rotates one full rotation at a steady speed about the x -axis. The rotation causes the resistor, R , to first move out of the page.
- Movement B – The square loop is then moved at a constant speed, parallel to the current carrying wire, from Position 1 to Position 2 in Figure 4.
- Movement C – The square loop is moved at a constant speed, perpendicular to the current carrying wire, from Position 2 to Position 3 in Figure 4.

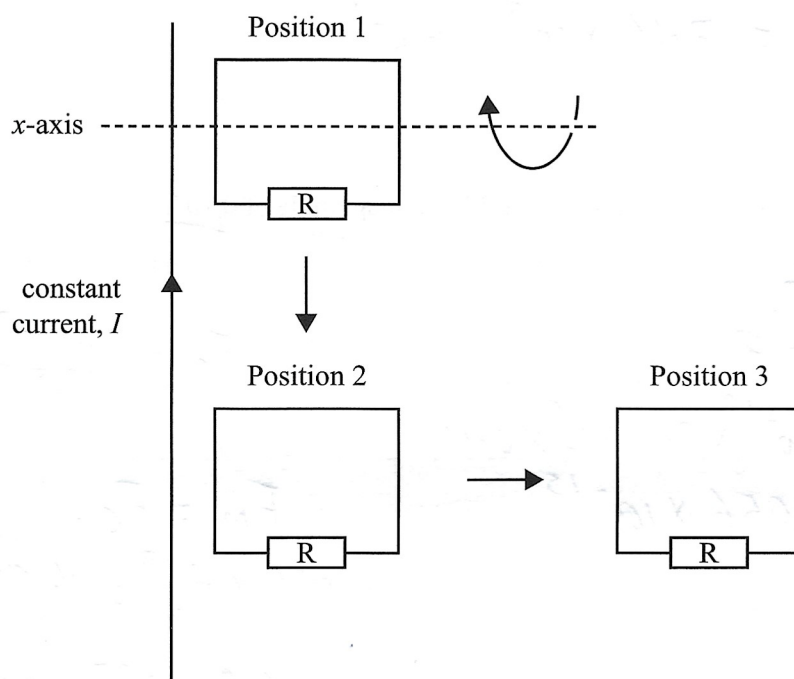
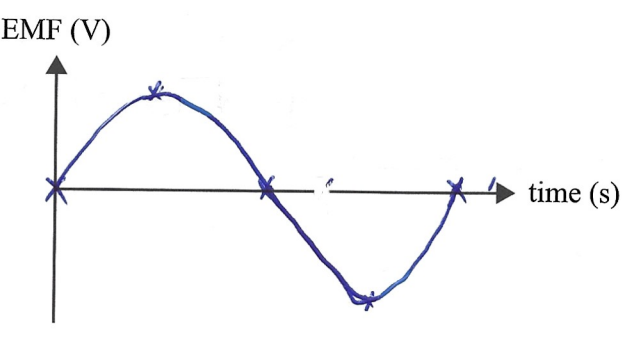

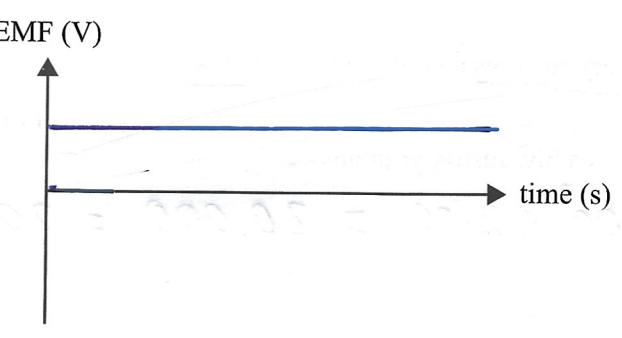


Figure 4



Complete the table below to show the effects of each of the three movements by:

- sketching any EMF generated in the square loop during the motion on the axes provided (scales and values are not required)
- stating whether any induced current in the square loop is 'alternating', 'clockwise', 'anticlockwise' or has 'no current'.

Movement	Possible induced EMF $\mathcal{E} = -N \frac{\Delta \Phi}{\Delta t}$	Direction of any induced current (alternating/clockwise/ anticlockwise/no current)
<p>A</p> <p>rotation about x-axis</p> <p>Flux Change Max $\rightarrow 0 \rightarrow$ Max (opp) $\rightarrow 0 \rightarrow$ Max original</p>	<p>EMF (V)</p>  <p>time (s)</p>	<p>Alternating</p>
<p>B</p> <p>moving from Position 1 to Position 2</p> <p>No Flux change.</p>	<p>EMF (V)</p>  <p>time (s)</p>	<p>No Current</p>
<p>C</p> <p>moving from Position 2 to Position 3</p> <p>Flux Change. Reduces.</p>	<p>EMF (V)</p>  <p>time (s)</p>	<p>Clockwise</p>

Note: for Part C  and  were also accepted

Quantitative understanding of how the strength of the field varies around a current carrying wire is not required.

SECTION B – continued
TURN OVER



Question 5 (7 marks)

A wind generator provides power to a factory located 2.00 km away, as shown in Figure 5.

When there is a moderate wind blowing steadily, the generator produces an RMS voltage of 415 V and an RMS current of 100 A.

The total resistance of the transmission wires between the wind generator and the factory is 2.00 Ω .

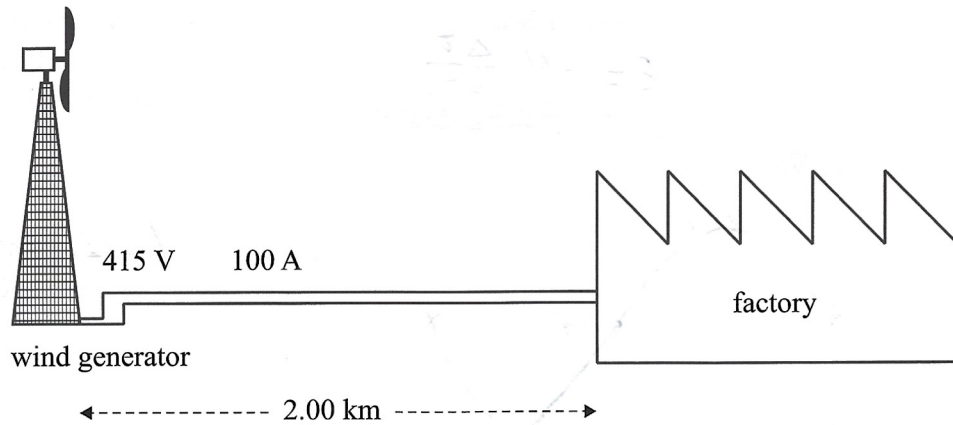


Figure 5

- a. Calculate the power, in kilowatts, produced by the wind generator when there is a moderate wind blowing steadily.

1 mark

$$P = VI = 415 \times 100 = 41,500$$

41.5 kW

To operate correctly, the factory's machinery requires a power supply of 40 kW.

- b. Determine whether the energy supply system, as shown, will be able to supply power to the factory when the moderate wind is blowing steadily. Justify your answer with calculations.

3 marks

$$P_{\text{loss}} = I^2 R = 100^2 \times 2.00 = 20,000 = 20 \text{ kW.}$$

At Factory

$$P_F = P_G - P_{\text{loss}}$$

$$= 41,500 - 20,000$$

$$= 21,500$$

$$= 21.5 \text{ kW.}$$

Not enough power will be supplied to the factory

SECTION B – Question 5 – continue



- c. The factory's owner decides to limit transmission energy loss by installing two transformers: a step-up transformer with a turns ratio of 1:10 at the wind generator and a step-down transformer with a turns ratio of 10:1 at the factory. Each transformer can be considered ideal.

With the installation of the transformers, determine the power, in kilowatts, now supplied to the factory.

$$\frac{1}{10} = \frac{I_2}{100} \quad I_2 = 10 \quad P_{\text{loss}} = 10^2 \times 2.00$$

$$\frac{N_1}{N_2} = \frac{I_2}{I_1} \quad = 200 \text{ W.}$$

$$\begin{aligned} \text{Power available} &= 41,500 - 200 \\ &= 41,300 \\ &= 41.3 \text{ kW.} \end{aligned}$$

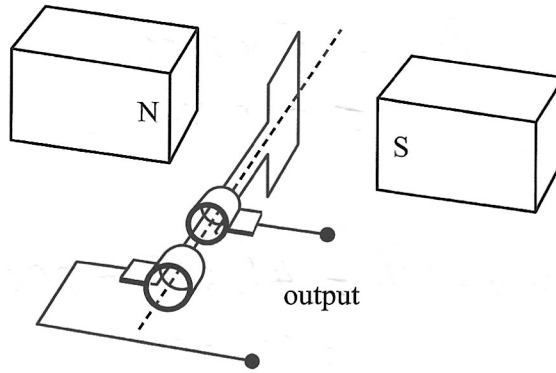
41.3 kW

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Question 6 (5 marks)

Figure 6 shows a simple alternator consisting of a rectangular coil of area 0.060 m^2 and 200 turns, rotating in a uniform magnetic field. The magnetic flux through the coil in the vertical position shown in Figure 6 is $1.2 \times 10^{-3} \text{ Wb}$.

**Figure 6**

- a. Calculate the strength of the magnetic field in Figure 6. Show your working.

2 mark

$$\Phi = B_{\perp} A$$

$$1.2 \times 10^{-3} = B_{\perp} \times 0.060$$

$$B_{\perp} = \frac{1.2 \times 10^{-3}}{0.060}$$

$$2.0 \times 10^{-2} \text{ T}$$

$$= 0.02$$

$$= 2.0 \times 10^{-2}$$



- b. The rectangular coil rotates at a frequency of 2.5 Hz.

$$\Phi_{\text{from}} 1.2 \times 10^{-3} \rightarrow 0$$

Calculate the average induced EMF produced in the first quarter of a turn. Begin the quarter with the coil in the vertical position shown in Figure 6.

3 marks

$$f = 2.5$$

$$T = \frac{1}{2.5}$$

$$T = 0.4$$

$$\frac{1}{4} \text{ turn} \rightarrow t = 0.1$$

$$\begin{aligned} \text{EMF} &= -N \frac{\Delta \Phi}{\Delta t} \\ &= -200 \times \frac{-1.2 \times 10^{-3}}{0.1} \end{aligned}$$

$$= +2.4$$

2.4 V

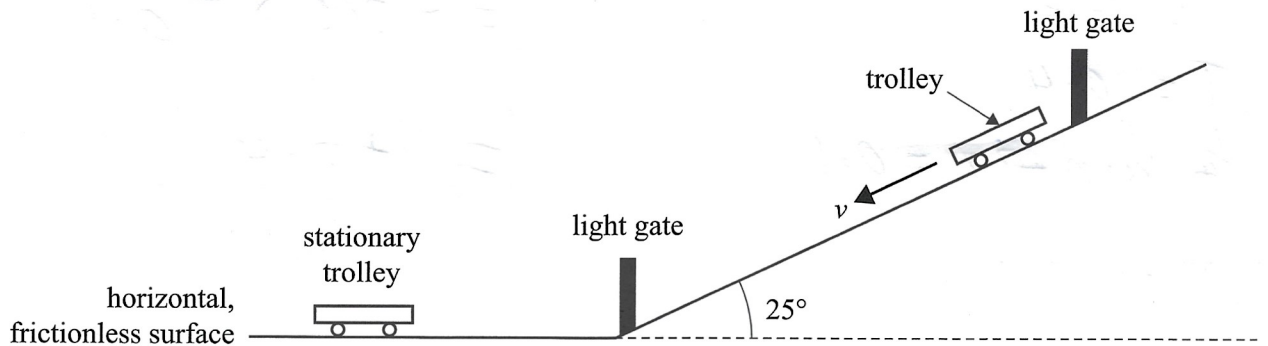
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SECTION B – continued
TURN OVER



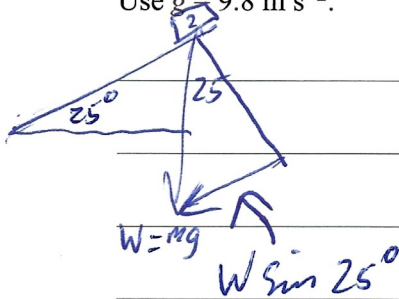
Question 7 (10 marks)

Kym and Kelly are experimenting with trolleys on a ramp inclined at 25° , as shown in Figure 7. They release a trolley with a mass of 2.0 kg from the top of the ramp. The trolley moves down the ramp, through two light gates and onto a horizontal, frictionless surface. Kym and Kelly calculate the acceleration of the trolley to be 3.2 m s^{-2} using the information from the light gates.

**Figure 7**

- a. i. Show that the component of the gravitational force of the trolley down the slope is 8.3 N .
Use $g = 9.8 \text{ m s}^{-2}$.

2 marks



$$\begin{aligned} \text{Component down slope} &= mg \sin 25^\circ \\ &= 2 \times 9.8 \times \sin 25^\circ \\ &= 8.283317 \\ &= 8.3 \text{ N} \end{aligned}$$

- ii. Assume that on the ramp there is a constant frictional force acting on the trolley and opposing its motion.

Calculate the magnitude of the constant frictional force acting on the trolley.

2 marks

$$\begin{aligned} \Sigma F &= ma \\ 8.3 - \text{Friction} &= 2 \times 3.2 \\ 8.3 - \text{Friction} &= 6.4 \\ \text{Friction} &= 8.3 - 6.4 \\ &= 1.9 \end{aligned}$$

1.9 N



b. When it reaches the bottom of the ramp, the trolley travels along the horizontal, frictionless surface at a speed of 4.0 m s^{-1} until it collides with a stationary identical trolley. The two trolleys stick together and continue in the same direction as the first trolley.

- i. Calculate the speed of the two trolleys after the collision. Show your working and clearly state the physics principle that you have used. 3 marks

$$P_i = P_f$$

$$2 \times 4 = 4 \times v$$

$$8 = 4 \times v$$

$$v = 2.0 \text{ m s}^{-1}$$

Using Conservation of Momentum

2.0 m s^{-1}

- ii. Determine, with calculations, whether this collision is an elastic or inelastic collision. Show your working. 3 marks

$$\text{K.E. before} = \frac{1}{2} \times 2 \times 4^2 = 16 \text{ J}$$

$$\text{K.E. After} = \frac{1}{2} \times 4 \times 2^2 = 8 \text{ J}$$

Collision is inelastic since KE after is less than K.E. before collision



Question 8 (5 marks)

A Formula 1 racing car is travelling at a constant speed of 144 km h^{-1} (40 m s^{-1}) around a horizontal corner of radius 80.0 m . The combined mass of the driver and the car is 800 kg . Figure 8a shows a front view and Figure 8b shows a top view.

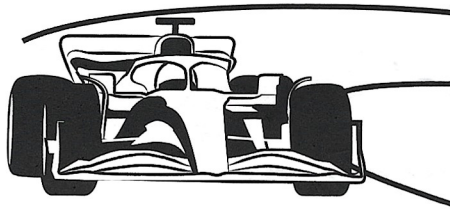


Figure 8a – Front view

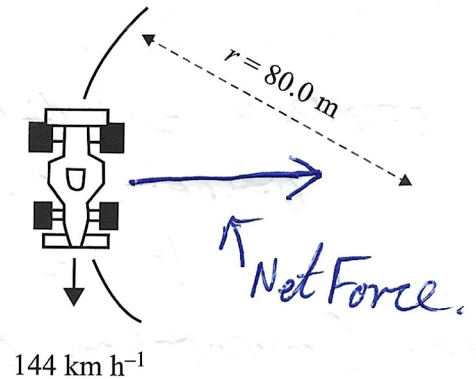


Figure 8b – Top view

- a. Calculate the magnitude of the net force acting on the racing car and driver as they go around the corner. 2 ma

$$F = \frac{mv^2}{r} = \frac{800 \times 40^2}{80} = 16,000$$

$1.6 \times 10^4 \text{ N}$

- b. On Figure 8b, draw the direction of the net force acting on the racing car using an arrow. 1 ma
- c. Explain why the racing car needs a net horizontal force to travel around the corner and state what exerts this horizontal force. 2 ma

Needs net horizontal force to change the direction of travel not the speed, i.e. Circular Motion.

Force provided by friction between the tyres and the road.



Question 9 (2 marks)

A star is transforming energy at a rate of 2.90×10^{25} W.

Explain the type of transformation involved and what effect, if any, the transformation would have on the mass of the star. No calculations are required.

In the star Fusion occurs. Thus Mass - Energy transformation occurs.

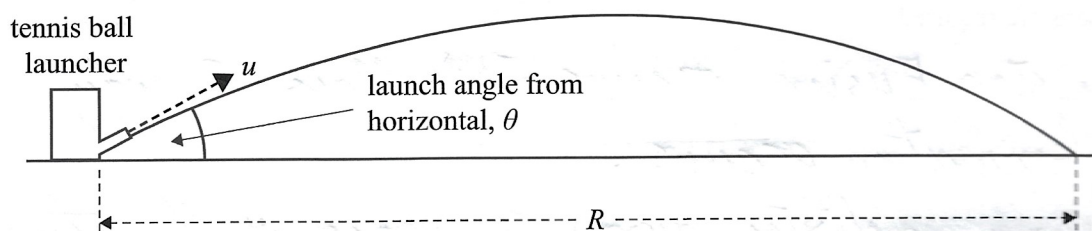
As energy radiates away the mass of the star will decrease.

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Question 10 (16 marks)

Physics students use a tennis ball launcher on a level, outdoor oval on a windless day to investigate projectile motion, as shown in Figure 9. Assume that the tennis balls are launched from ground level.

**Figure 9**

The tennis ball launcher can be set to project tennis balls at speeds, u , between 8 m s^{-1} and 30 m s^{-1} at angles, θ , between 10° and 80° . Standard tennis balls of mass 56 g are used.

The students measure the range, R , of the projected tennis ball at a fixed speed for various angles.

- a. The variables in this experiment can be classified as controlled, dependent or independent.

Complete the table below by providing one variable from the experiment for each classification.

Classification	Variable
controlled	Launch Speed OR Mass
dependent	Range.
independent	Launch Angle. OR Launch Speed

- b. The students set the tennis ball launcher to project tennis balls at a speed of 25 m s^{-1} . They vary angle between 10° and 80° and measure the range, R .

The students repeat each experiment at each angle three times and determine the average range. results are shown in Table 1 below.

Table 1

Angle ($^\circ$)	Average range (m)
10	17
20	30
30	37
40	40
50	40
60	36
70	29
80	15

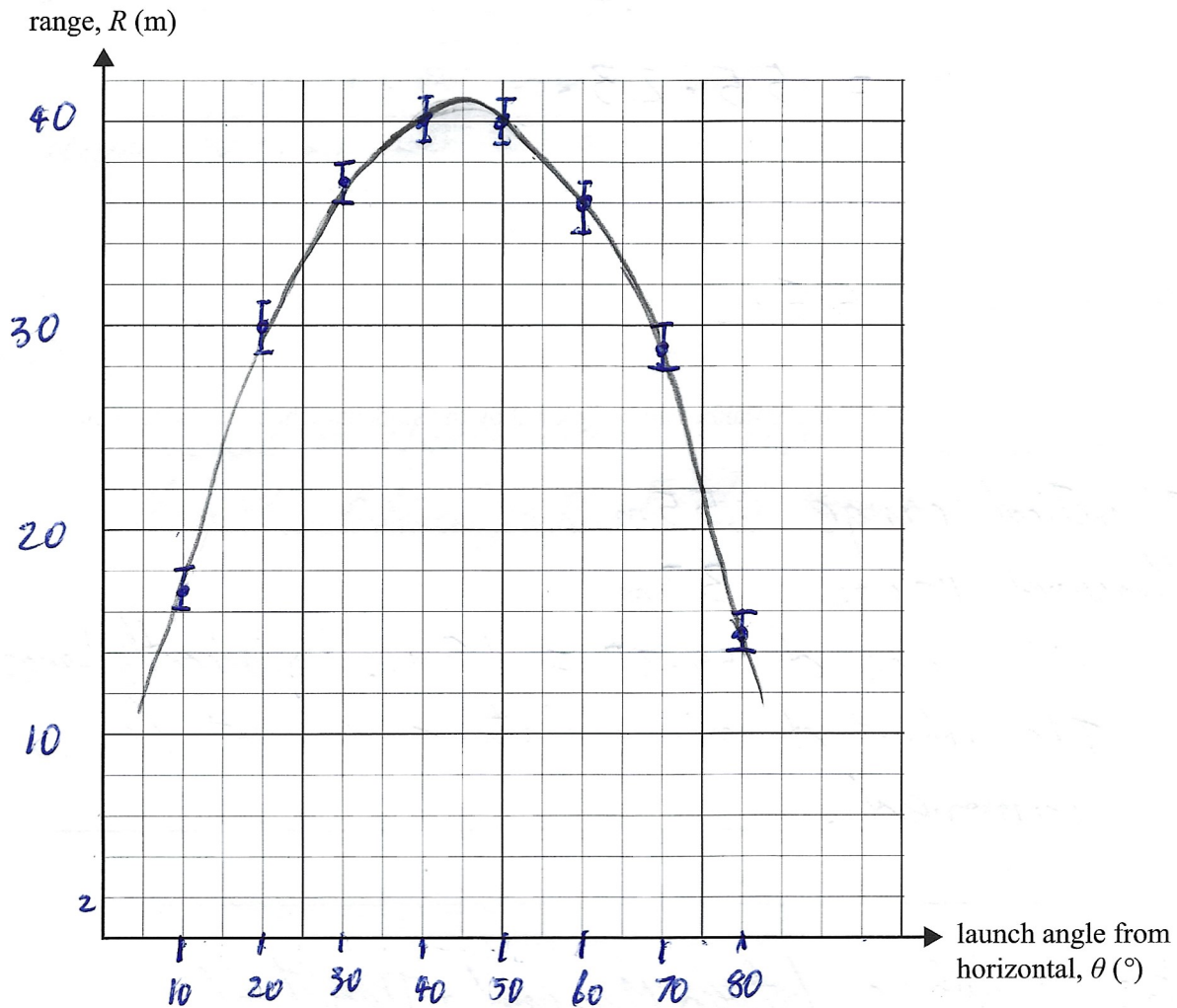


The students determine that the uncertainty in the measurement of the range is ± 1 m.

On the grid provided below:

- plot the data from Table 1
- add a scale to each axis
- insert appropriate uncertainty bars for the range for at least three data points
- draw a smooth curve of best fit.

6 marks



- c. From the graph in **part b.**, estimate the maximum range and the angle that gives the maximum range. 2 marks

Maximum range 41 m

Angle for maximum range 45 $^{\circ}$



- d. The students think that air resistance on the tennis ball may affect the maximum range. They decide to compare their data to the theoretical range achieved when air resistance is ignored.

- i. Using the range formula $R = \frac{u^2 \sin 2\theta}{g}$, calculate the theoretical range of a projectile launched at an initial speed of 25 m s^{-1} and at an angle of 30° . Use $g = 9.8 \text{ m s}^{-2}$. 2 marks

$$R = \frac{25^2 \sin(2 \times 30)}{9.8}$$

$$= 55.23$$

Theoretical range	55.2	m
-------------------	------	---

- ii. Evaluate whether the effect of air resistance can be ignored by the students when analysing their data. Justify your answer. 3 marks

Theoretical range 55m

Measured range 37m.

A difference of $55 - 37 = 18 \text{ m}$. Significantly Large.

The effect of air resistance cannot be ignored.

Note: The difference between Measured + Theoretical is large, greater than the limits of experimental uncertainty. This needs to be mentioned in some way.



Question 11 (2 marks)

Explain why muons formed in the outer atmosphere can reach the surface of Earth even though their half-lives ^{time} indicate that they should decay well before reaching Earth's surface.

Muons are travelling at relativistic speeds.

Due to time-dilatation they are able to reach Earth before decaying.

The half-life in the Earth's frame of reference is greater than the half-life measured in the Muon's frame of reference.

Note: Length Contraction could also be used.

Distance in Muons frame of reference is less than the distance in the Earth's frame of reference.

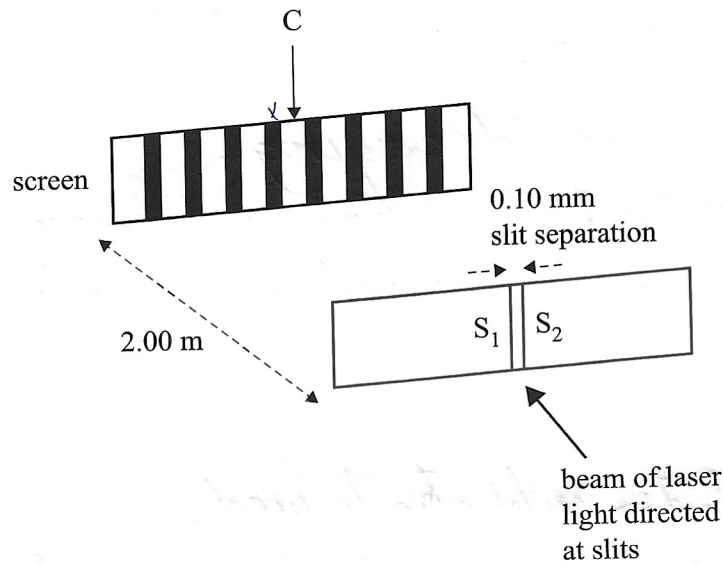
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SECTION B - continue
TURN OVER



Question 12 (8 marks)

Students conduct an experiment in a Physics laboratory using a laser light source, two narrow slits and a screen, as shown in Figure 10.

**Figure 10**

Point C is at the centre of the pattern of light and dark bands on the screen. The slit separation is 0.10 mm and the distance between the two slits and the screen is 2.00 m .

- a. The band at point C is a bright band.

Explain why the band at point C is bright and why there is a dark band to the left of the centre.

2 marks

Point C is in the centre. The distance to each slit is equal. Constructive interference occurs giving a bright band.

To the left, The dark band is $\frac{1}{2}$ wavelength closer to S_1 than it is to S_2 . Destructive interference occurs giving a dark band.



The experiment performed by the students is often described as Young's double-slit experiment.

- b. Explain how this experiment gave support to those who argued that light has a wave-like nature. 2 marks

The light and dark bands, ^{formed.} are due to Constructive and destructive Interference.

Interference is a property of waves, thus this experiment supports the wave model for light.

The frequency of the laser light is 6.00×10^{14} Hz.

- c. Calculate the spacing of the dark bands on the screen. Show your working. 2 marks

$$\Delta x = \frac{\lambda L}{d}$$

$$\Delta x = \frac{5.00 \times 10^{-7} \times 2.00}{(0.1 \times 10^{-3})}$$

$$= 0.01$$

$$v = \lambda f$$

$$3 \times 10^8 = \lambda \times 6 \times 10^{14}$$

$$\lambda = 5 \times 10^{-7}$$

0.01 m

- d. The students decide to safely immerse the entire apparatus in a liquid. The refractive index of the liquid is unknown but it is greater than the refractive index of air. Using the same laser light, they notice that the spacing of the bands changes.

Describe the change observed in the spacing of the bands and explain why this change occurred. 2 marks

Refractive Index increases

⇒ Speed of light decreases

⇒ Wave length decreases

∴ Spacing of bands decreases.

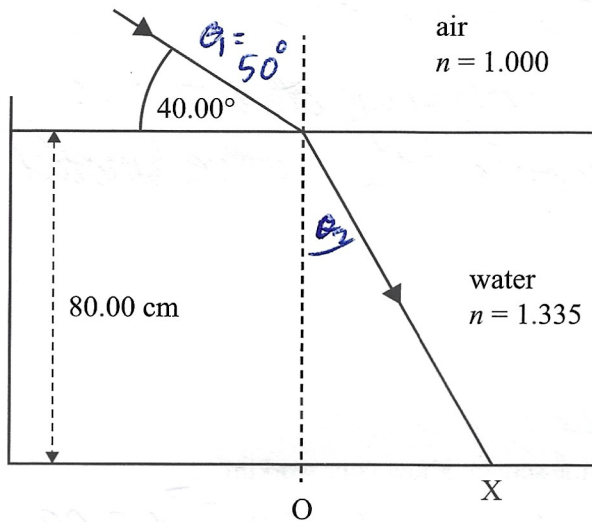
Note: $\Delta x = \frac{\lambda L}{d}$

⇒ $\Delta x \propto \lambda$



Question 13 (7 marks)

A ray of green light from a light-emitting diode (LED) strikes the surface of a tank of water at an angle of 40.00° to the surface of the water, as shown in Figure 11. The ray arrives at the base of the tank at point X. The depth of the water in the tank is 80.00 cm. The refractive index of green LED light in water is 1.335

**Figure 11**

- a. Calculate the distance OX. Outline your reasoning and show all your working. Give your answer in centimetres.

4 marks

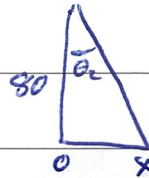
Refraction - Snell's Law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$1 \times \sin 50 = 1.335 \sin \theta_2$$

$$\sin \theta_2 = 0.5738$$

$$\theta_2 = 35.01676^\circ$$



$$\tan \theta_2 = \frac{OX}{80}$$

$$OX = 80 \tan(35.01676)$$

$$= 56.051$$

$$= 56$$

56 cm



- b. The green LED light is replaced with a narrow beam of white sunlight.

Describe the colour of the light that arrives to the left of point X, at point X and to the right of point X. 3 marks

Light to the left of point X	Light at point X	Light to the right of point X
Blue, Indigo & Violet order Violet, Indigo, Blue	GREEN	Red, Orange Yellow. order Yellow, Orange, Red.

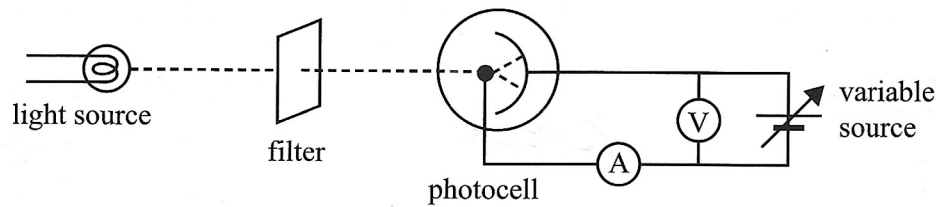
ROY G BIV
 ↑
 LED.
 ← Bends less.
 → Bends More
 ↓
 To right of X.
 To left of X
 Dispersion occurs.

DO NOT WRITE IN THIS AREA

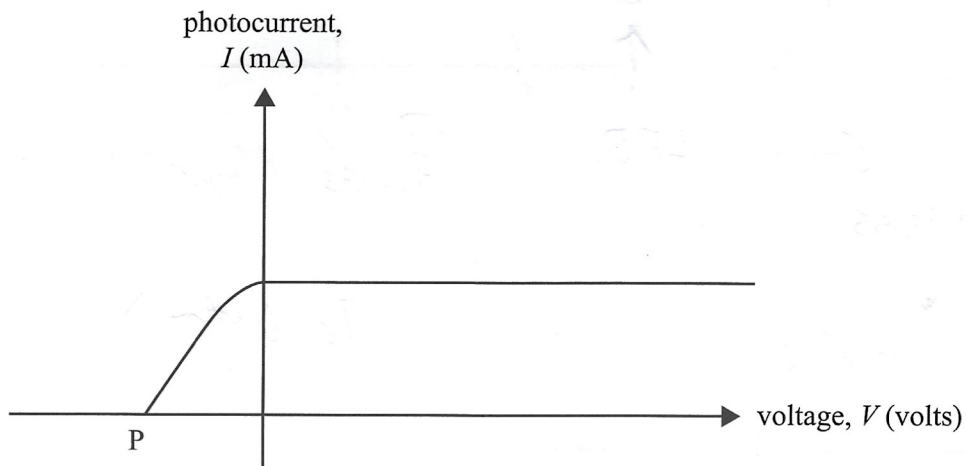


Question 14 (9 marks)

Sam undertakes a photoelectric effect experiment using the apparatus shown in Figure 12. She uses a green filter.

**Figure 12**

Sam produces a graph of photocurrent, I , in milliamperes, versus voltage, V , in volts, as shown in Figure 13.

**Figure 13**

- a. Identify what point P represents on the graph in Figure 13.

1 mark

Stopping Voltage for photoelectrons

Note: cut-off voltage and Stopping potential were accepted.



- b. Sam then significantly increases the intensity of the light.

Sketch the resulting graph on Figure 14. The dashed line in Figure 14 represents the original data. 2 marks

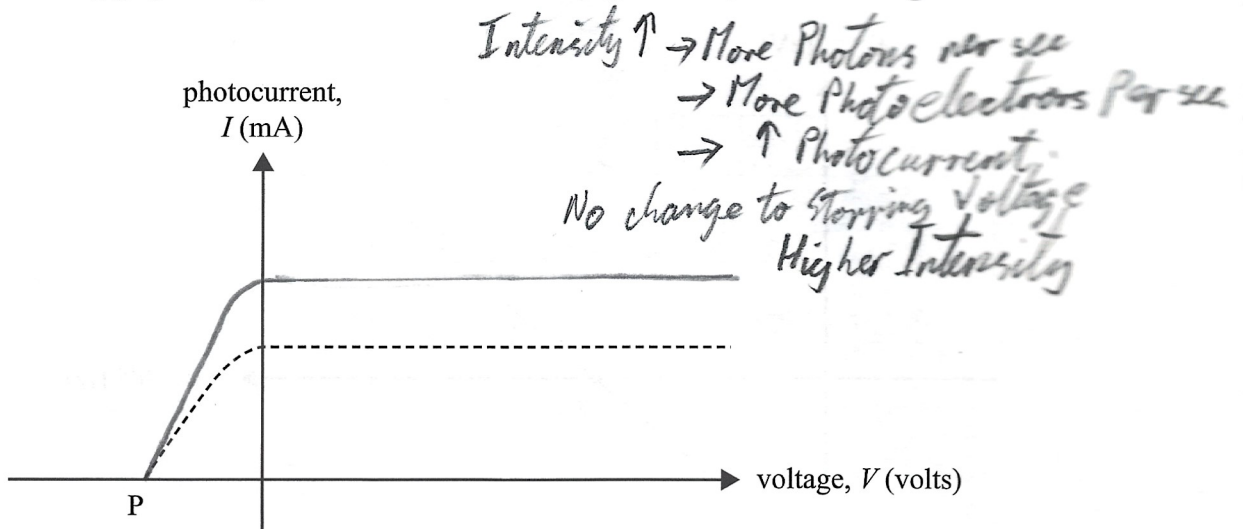


Figure 14

- c. Sam replaces the green filter with a violet filter, keeping the light source at the increased intensity.

Sketch the resulting graph on Figure 15. The dashed line in Figure 15 represents the original data. 2 marks

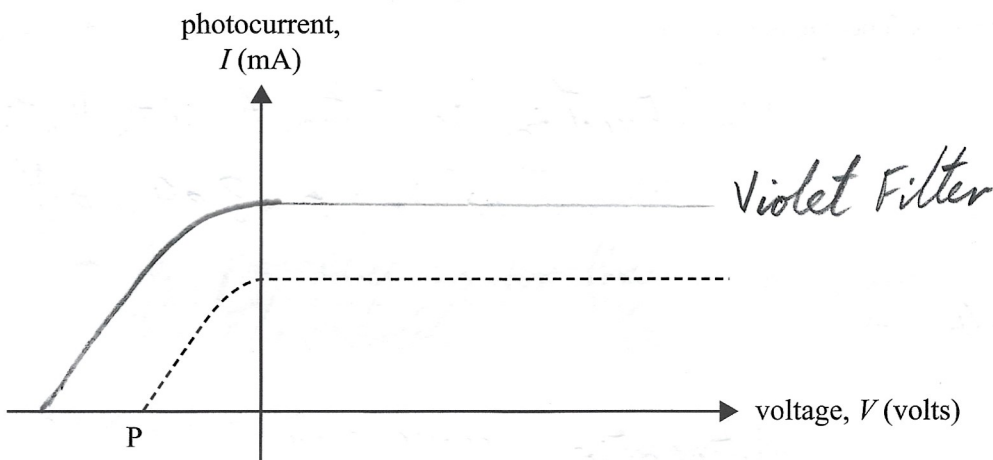


Figure 15

Violet filter → ↑ frequency
 ↑ Photon energy
 ↑ K.E. of Photo electron
 ↑ stopping voltage
 ↑ Intensity → ↑ Photocurrent.

SECTION B – Question 14 – continued

TURN OVER



Further experiments produce Figure 16, a graph of maximum kinetic energy, $E_{k \max}$, of emitted photoelectrons versus frequency, f , of light.

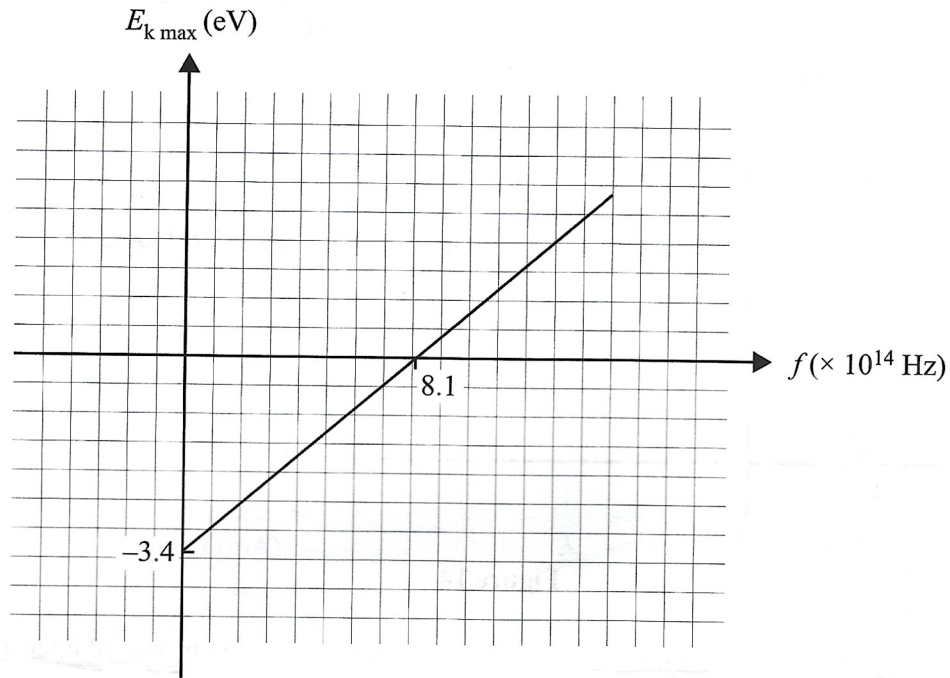


Figure 16

- d. Determine the work function, in electron volts, of the metal surface used in the experiment that produced the data shown in Figure 16.

1 mark

Work Function is intercept with Vertical axis
 Work Function = 3.4 eV

3.4 eV

Alternative (Assumes gradient = 4.14×10^{-15})

$$\text{Work Function} = h f_0$$

$$= 4.14 \times 10^{-15} \times 8.1 \times 10^{14}$$

$$= 3.3534$$

$$= 3.4 \text{ eV}$$

Note: As this is an EXPERIMENT the gradient may not be 4.14×10^{-15} . Safer to use intercept



- e. From the graph shown in Figure 16, calculate, in joule-seconds, the value of Planck's constant. Show your working.

2 marks

Planck's Constant is the gradient = $\frac{\text{Rise}}{\text{Run}}$

$$3.4 \text{ eV} = 3.4 \times 1.6 \times 10^{-19} \text{ J}$$

$$= 5.44 \times 10^{-19} \text{ J}$$

$$h = \text{gradient} = \frac{5.44 \times 10^{-19}}{8.1 \times 10^{14}}$$

$$= 6.716049 \times 10^{-34}$$

$6.7 \times 10^{-34} \text{ J s}$

- f. State one limitation of the wave model in explaining the results of the photoelectric effect.

1 mark

Wave model says energy is delivered over time.
Doesn't explain the immediate ejection of photoelectrons.

Note: *Also doesn't explain

- No photoelectrons for frequencies below the threshold.

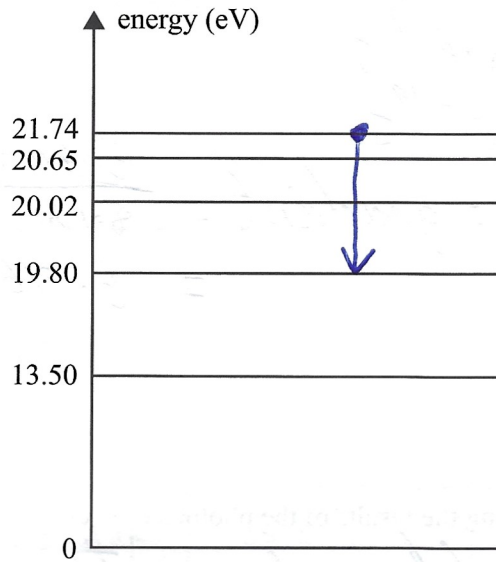
* Wave model says higher intensity \rightarrow higher Energy
doesn't explain that the intensity doesn't effect the Energy of the photoelectrons or the threshold

SECTION B – continued
TURN OVER



Question 15 (2 marks)

Figure 17 shows some of the energy levels of excited neon atoms. These energy levels are not drawn to scale.

**Figure 17**

- a. Show that the energy transition required for an emitted photon of wavelength 640 nm is 1.94 eV . 1 mark

$$E = hf \rightarrow E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{640 \times 10^{-9}}$$

$$= 1.940625$$

$$= 1.94 \text{ eV.}$$

- b. On Figure 17, draw an arrow to show the transition that would emit the photon described in part a. 1 mark

$$21.74 - 20.65 = 1.09 \text{ X}$$

$$21.74 - 20.02 = 1.72 \text{ X}$$

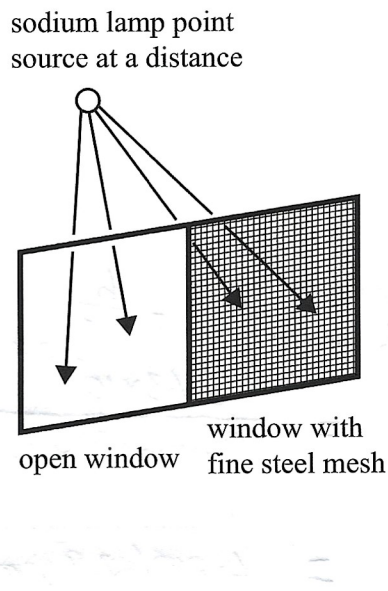
$$21.74 - 19.80 = 1.94 \text{ ✓}$$



Question 16 (3 marks)

A small sodium lamp, emitting light of wavelength 589 nm, is viewed at night through two windows from across a street. The glass of one window has a fine steel mesh covering it and the other window is open, as shown in Figure 18. Assume that the sodium lamp is a point source at a distance.

A Physics student is surprised to see a pattern formed by the light passing through the steel mesh but no pattern for the light passing through the open window. She takes a photograph of the observed pattern to show her teacher, who assures her that it is a diffraction pattern.

**Figure 18**

- a. State the condition that the fine steel mesh must satisfy for a diffraction pattern to form. 2 marks

The holes in the mesh need to be the same order of magnitude as the wavelength of the light. i.e. $\approx 589 \text{ nm}$.

- b. Explain why the condition stated in **part a.** does not apply to the open window. 2 marks

The distance between the edges of the window frame is very large, compared to the wavelength of the light.
Thus the waves pass straight through without being diffracted.



Question 17 (7 marks)

A materials scientist is studying the diffraction of electrons through a thin metal foil. She uses electrons with an energy of 10.0 keV. The resulting diffraction pattern is shown in Figure 19.

Kinetic Energy
 $K.E. = \frac{1}{2}mv^2$

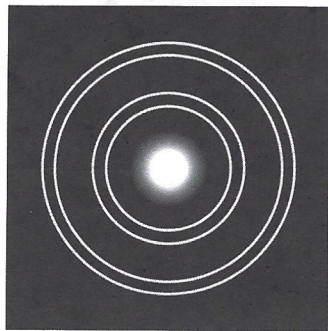


Figure 19

Need to convert to Joules.

Note: could use $\lambda = \frac{h}{\sqrt{2mE_k}}$

Fair bit of Working

- a. Calculate the de Broglie wavelength of the electrons in nanometres.

$$E = 10.0 \text{ keV}$$

$$= 10.0 \times 10^3 \times 1.6 \times 10^{-19}$$

$$= 1.6 \times 10^{-15} \text{ J}$$

$$K.E. = 1.6 \times 10^{-15} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2$$

$$v^2 = 3.51648 \times 10^{15}$$

$$v = 5.93 \times 10^7 \text{ m/s}$$

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 5.93 \times 10^7}$$

$$= 1.2286 \times 10^{-11}$$

$$= 0.0128 \text{ nm}$$

4 marks

0.012 nm

- b. The materials scientist then increases the energy of the electrons by a small amount and hence their speed by a small amount.

Explain what effect this would have on the de Broglie wavelength of the electrons. Justify your answer.

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

Increasing the speed, increases the denominator, which in turn decreases the value of the de Broglie λ

The effect is to decrease the de Broglie wavelength

3 marks

END OF QUESTION AND ANSWER BOOK

