YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME	

CG		INDEX NO	

PHYSICS 9749/03

Paper 3 Longer Structured Questions **15 September 2023**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer any **one** question.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 3	
Section A	
1	**/10**
2	**/10**
3	**/8**
4	**/10**
5	**/10**
6	**/12**
Section B	
7	**/20**
8	**/20**
Penalty	
	/80

This document consists of **23** printed pages and **1** blank page.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	$\rho g h$
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
temperature,	T/K	=	$T/°C + 273.15$
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle C^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{(x_o^2 - x^2)}$
electric current,	I	=	$A n v q$
resistors in series,	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel,	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_o n I$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** questions in the spaces provided.

1 **(a)** State the principle of conservation of momentum.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………… [2]

(b) Two balls, X and Y, move along a horizontal surface frictionless surface, as shown in Fig. 1.1.

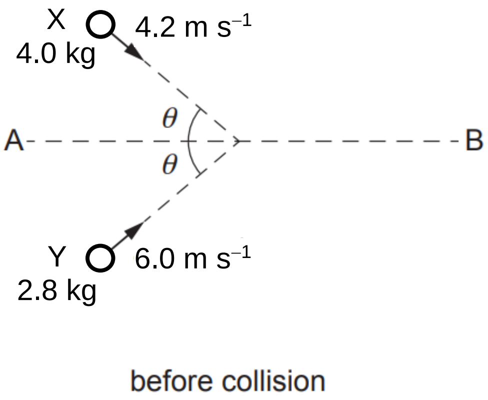

Fig. 1.1

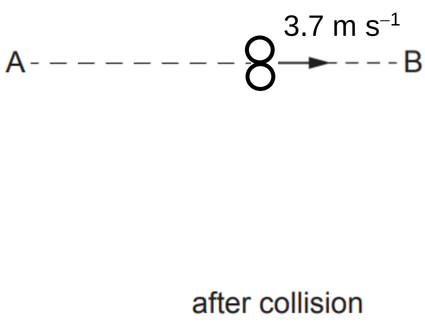

Fig. 1.2

Ball X has a mass of 4.0 kg and a velocity of 4.2 m s^{-1} in a direction at angle θ to a line AB.

Ball Y has a mass of 2.8 kg and a velocity of 6.0 m s^{-1} in a direction at angle θ to a line AB.

The balls collide and stick together. After colliding, the balls have a velocity of 3.7 m s^{-1} along the line AB on the horizontal surface, as shown in Fig. 1.2. The duration of collision is 3.0 ms.

(i) By considering the components of the momenta **along** the line AB, determine θ.

θ = ………………….. ° [2]

(ii) Determine the impulse experienced by ball X along the direction **perpendicular** to line AB.

impulse = ………………….. N s [2]

(iii) Given that balls X and Y moves along line AB after collision, explain why the value of the angle θ for ball X and Y must be the same.

……………………………………………………………..……..…….……………..

…………………………………………………………..……………..…………….

……………………………………………………………..……..…….……………..

…………………………………………………………..……………..……………. [2]

(iv) With calculations, state and explain whether the collision of the balls is elastic or inelastic collision.

[2]

[Total: 10]

2 **(a)** **(i)** State 2 assumptions that the kinetic theory of gases makes about any ideal gas.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(ii) A fixed mass of gas can be compressed into a smaller volume, such as when an inflated balloon is squeezed.

Using the kinetic theory of gases, explain why the pressure exerted by the gas on its container wall increases when its volume is reduced at constant temperature.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [2]

(b) The $p - V$ diagram in Fig. 2.1 shows one cycle of changes applied to a fixed mass of gas in a petrol engine.

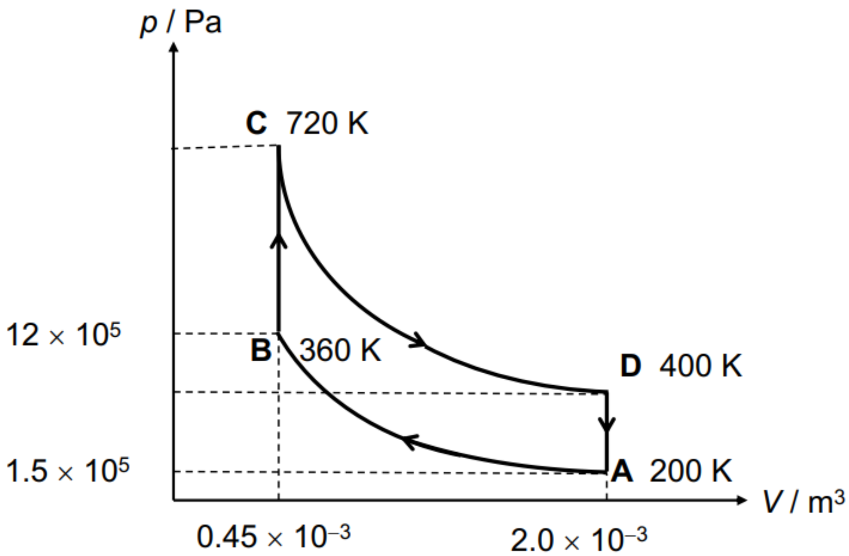

Fig. 2.1

The cycle starts at A with the gas at a volume of 2.0×10^{-3} m^3, temperature of 200 K and pressure of 1.5×10^5 Pa. From A to B, when it is compressed to a volume of 0.45×10^{-3} m^3, the pressure and temperature rises to 12×10^5 Pa and 360 K respectively.

(i) Assuming that the gas is an ideal gas, determine the number of moles in the fixed mass of gas.

number of moles = ………………….. mol [1]

(ii) Given that the mass of one gas molecule is 40u, calculate the r.m.s. speed of the gas molecules at state A.

r.m.s. speed = ………………….. m s^{-1} [2]

(iii) From C to D, the gas expands to its original volume and 50 J of heat is lost. The temperature of the gas at D is 400 K. Calculate the work done in this process, stating clearly whether work is done on or by the gas.

work done = ………………….. J

work is done ……………….(on/by) the gas [3]

[Total: 10]

3 **(a)** Define *simple harmonic motion*.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(b) A needle-carrier is used in a sewing machine to constrain the movement of the needle to a vertical line only. Low friction guides are used to achieve this. The simple harmonic motion of the needle-carrier is produced by a rotating disc carrying a peg which moves in a circle and engages with a slot attached to the needle carrier, as shown in Fig. 3.1 below.

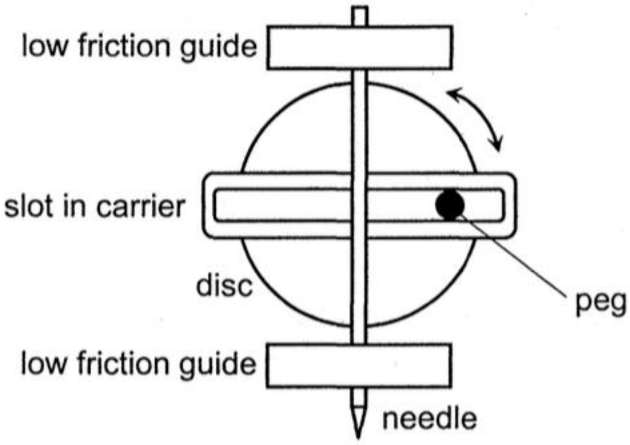

Fig. 3.1

(i) Show that the angular speed of the disc's circular motion that results in the peg having an oscillation frequency of 12 Hz is 75 rad s^{-1}.

[1]

(ii) The carrier and needle have a combined mass of 25 g and the needle's tip moves a distance of 32 mm from its highest point to its lowest.

Calculate the maximum speed of the needle.

maximum speed = ………………….. m s^{-1} [2]

(iii) Assuming that the needle requires negligible force to penetrate the fabric being sewn, calculate the maximum contact force acting on the peg by the slot.

maximum contact force = ………………….. N [2]

(iv) Draw on Fig. 3.2 below the position of the peg at which the:

1. needle is at its maximum speed (label as **1**), and

2. the peg experiences the maximum contact force by the slot (label as **2**)

Front view of disc

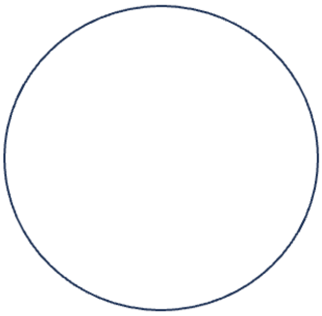

Fig. 3.2

[2]

[Total: 8]

4 **(a)** Two isolated point charges A and B are separated by a distance of 30.0 cm, as shown in Fig. 4.1.

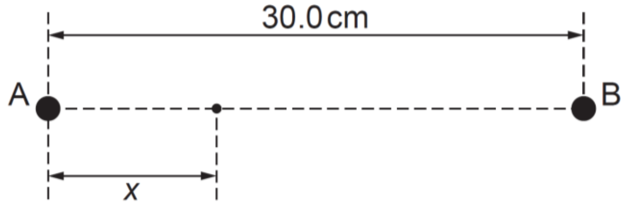

Fig. 4.1

The charge at A is + 3.6×10^{-9} C.
The variation with distance x from A along AB of the potential V is shown in Fig. 4.2.

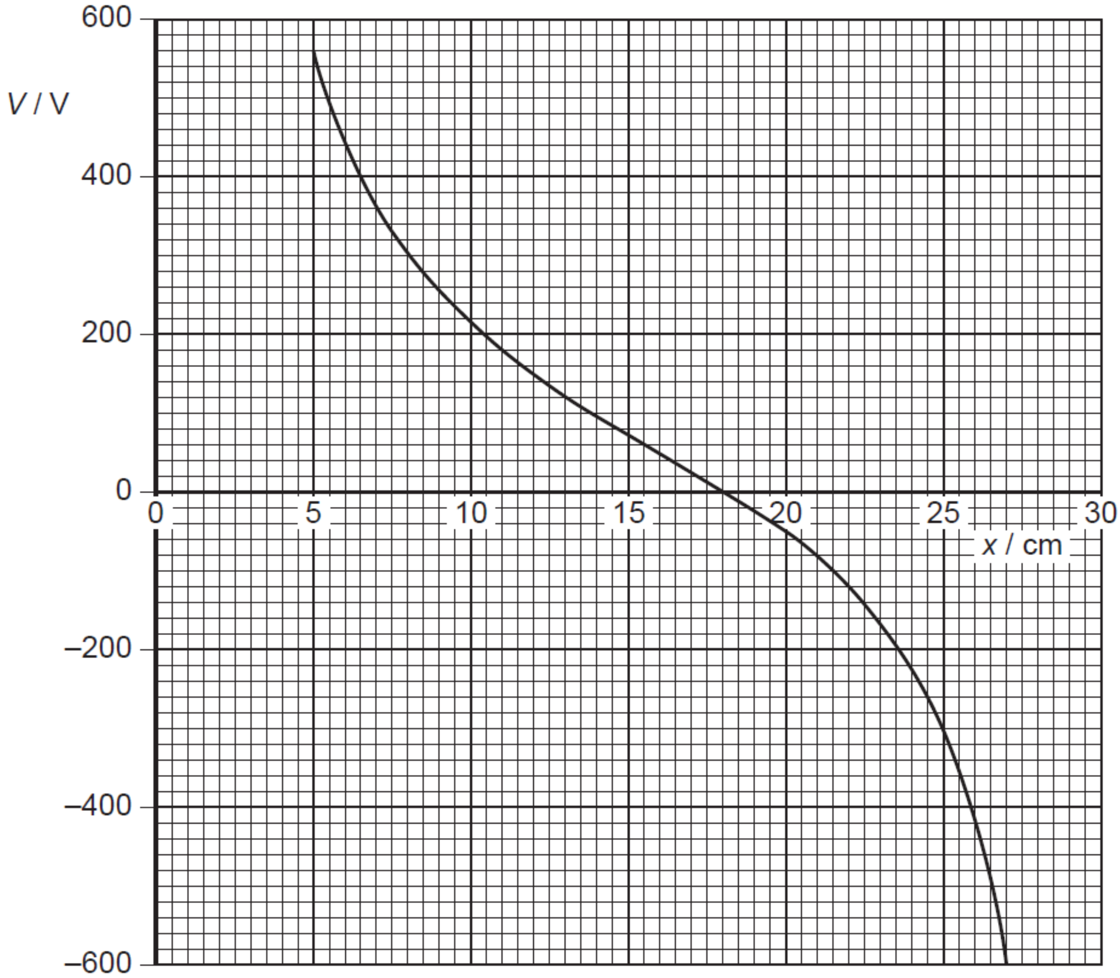

Fig. 4.2

(i) State the value of x at which the potential is zero.

x = ………………….. cm [1]

(ii) Use your answer in **(i)** to determine the charge at B.

charge = ………………….. C [3]

(b) An electron is projected along the line AB in **(a)** from x = 5.0 cm to 27.0 cm so that the electron is just able to reach the position x = 27.0 cm.

Determine the projection speed of this electron.

speed = ………………….. m s^{-1} [3]

(c) A small test charge is now moved along the line AB in **(a)** from x = 5.0 cm to 27.0 cm.

State and explain the value of x at which the force on the test charge will be maximum.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [3]

[Total: 10]

5 **(a)** A metal wire has length L and cross-sectional area A, as shown in Fig. 5.1.

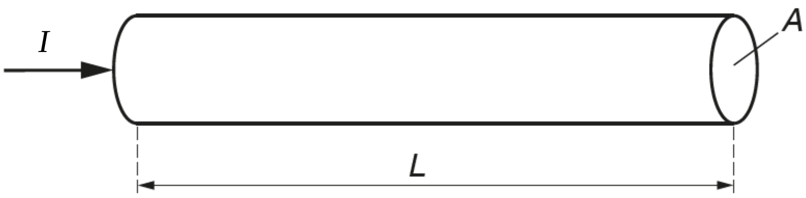

Fig. 5.1

I is the current in the wire,
n is the number of free electrons per unit volume in the wire,
v is the average drift speed of a free electron and
e is the charge of an electron.

(i) State, in terms of A, e, L and n, an expression for the total charge of the free electrons in the wire.

.... [1]

(ii) Use your answer in **(i)** to show that the current I is given by the equation

$$I = nAve$$

[1]

(b) A metal wire in a circuit is damaged. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a length of 3.0 mm, as shown in Fig. 5.2.

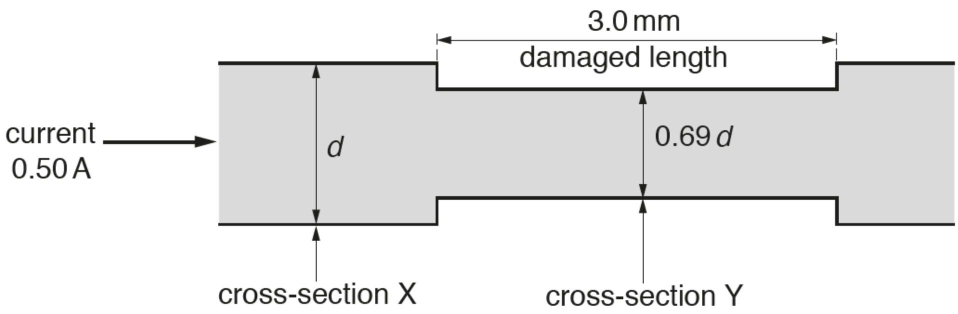

Fig. 5.2

The wire has diameter d at cross-section X and diameter $0.69d$ at cross-section Y.
The current in the wire is 0.50 A.

Determine the ratio

$$\frac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}}.$$

ratio = ………………….. [2]

(c) A uniform resistance wire AB has length 50 cm and diameter 0.36 mm. The resistivity of the metal of the wire is 5.1×10^{-7} Ω m.

(i) Show that the resistance of the wire AB is 2.5 Ω.

[1]

(ii) The wire AB is connected in series with a power supply E and a resistor R as shown in Fig. 5.3.

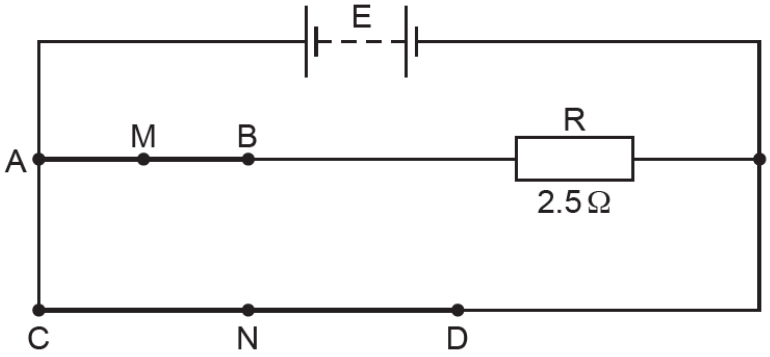

Fig. 5.3

The electromotive force (e.m.f.) of E is 6.0 V and its internal resistance is negligible.

The resistance of R is 2.5 Ω.

A second uniform wire CD is connected across the terminals of E. The wire CD has length 100 cm, diameter 0.18 mm, and is made of the same metal as wire AB.

Calculate

1. the current supplied by E,

current = ………………….. A [3]

2. the potential difference (p.d.) between the midpoint M of wire AB and the midpoint N of wire CD.

p.d. = ………………….. V [2]

[Total: 10]

6 A uranium-238 nucleus, ${}^{238}_{92}\mathrm{U}$, originally at rest, spontaneously decays to form a thorium (Th) nucleus and an alpha particle. A gamma ray is not emitted.

(a) Using the ${}^{A}_{Z}X$ notation, write down a nuclear equation representing the above decay.

[2]

(b) **(i)** This alpha particle travelled 25 mm in a cloud chamber. On average, an alpha particle creates 5.0×10^{3} ion pairs per mm of track in the chamber and the energy required to produce an ion pair is 5.2×10^{-18} J.

Show that the kinetic energy with which the alpha particle was emitted during the decay is 6.5×10^{-13} J. State one assumption made in the calculations.

…………………………………………………………………………………………………..

………………………………………………………………………………………………….. [2]

(ii) Calculate the initial speeds of the

1. alpha particle, and

speed = ……………… m s^{-1} [2]

2. the thorium nucleus.

speed = ……………… m s^{-1} [2]

(c) The thorium nucleus produced by the α-decay of uranium-238 is also radioactive, with a half-life of 24.1 days. For a 5.0 g sample of thorium, determine

(i) the probability per unit time that a thorium nucleus will decay, and

probability per unit time = ………………. s^{-1} [2]

(ii) the activity of the sample.

activity = ………………. Bq [2]

[Total: 12]

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** A source of sound has frequency *f*. Sound of wavelength λ is produced by the source.

(i) State

1. what is meant by the frequency of the source,

……………………………………………………………………………………………………..

…………………………………………………………………………………………………… [1]

2. the distance moved, in terms of λ, by a wavefront during *n* oscillations of the source.

distance = ………………….. [1]

(ii) Use your answers in **(i)** to deduce an expression for the speed *v* of the wave in terms of *f* and λ.

[2]

(b) An arrangement that can be used to determine the speed of sound in air is shown in Fig. 7.1.

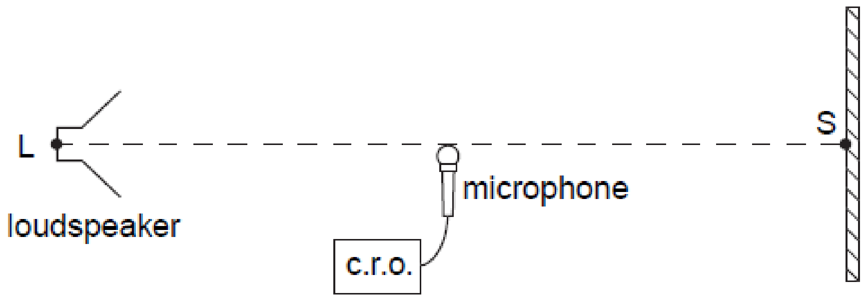

Fig. 7.1

A loudspeaker L is positioned to face a hard surface. Sound waves of constant frequency are emitted from the loudspeaker L. The loudspeaker is then moved away from a point S on the hard surface until a stationary wave is produced.

The variation with distance x of the intensity I of a stationary sound wave is shown in Fig. 7.2.

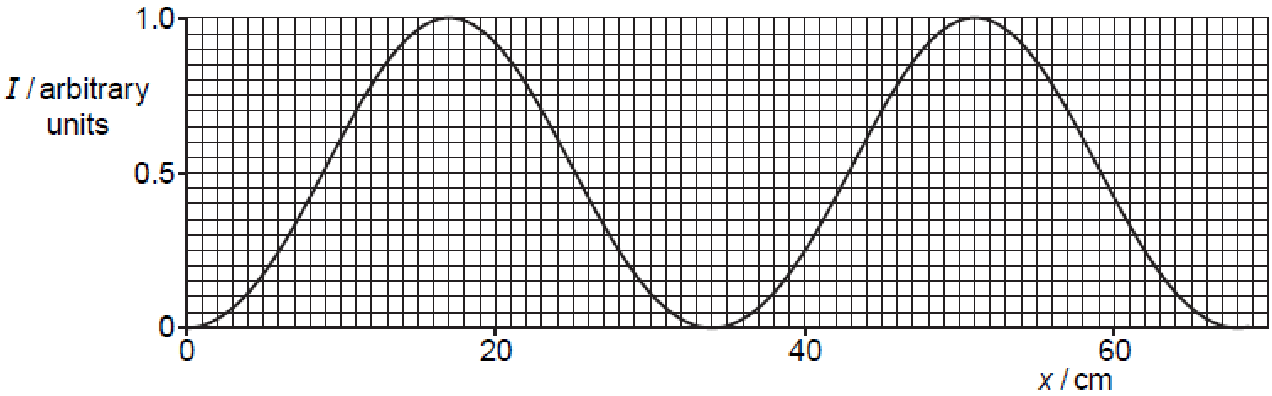

Fig. 7.2

(i) Explain how sound waves from L give rise to a stationary wave between L and S.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(ii) On the x–axis of Fig 7.2, indicate the positions of all nodes and antinodes of the stationary wave. Label the nodes **N** and the antinodes **A**. [1]

(iii) The speed of sound in air is 330 m s^{-1}.

Use Fig. 7.2 to determine the frequency of the sound wave.

frequency = ………………….. Hz [2]

(iv) Determine the ratio of

$$\frac{\text{the amplitude of the wave when } x = 20 \text{ cm}}{\text{the amplitude of the wave when } x = 40 \text{ cm}}.$$

ratio = ………………….. [3]

(c) White light is incident on a diffraction grating, as shown in Fig. 7.3.

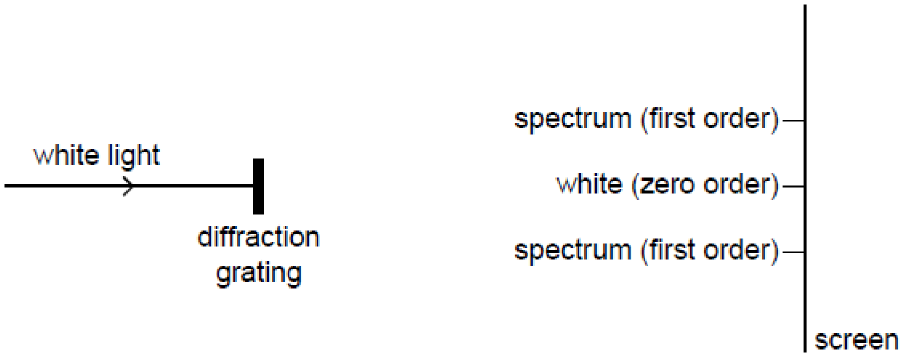

Fig. 7.3 (not to scale)

The diffraction pattern formed on the screen has white, called zero order and coloured spectra in other orders.

(i) Explain

1. the white light at the zero order,

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [2]

2. the relative difference in position of red and blue light in the first-order spectrum.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [2]

(ii) Light of wavelength 625 nm produces a second-order maximum at an angle of 61.0° to the incident direction.

Determine the number of lines per metre of the diffraction grating.

number of lines = ………………….. m^{-1} [2]

(iii) Calculate the wavelength of another part of the visible spectrum that gives a maximum for a different order at the same angle as in **(ii)**.

wavelength = ………………….. nm [2]

[Total: 20]

8 **(a)** In Fig. 8.1 below, a negatively charged sphere of mass *m* of 6.0 g and charge *q* of -5.0×10^{-2} C performs uniform circular motion horizontally in a clockwise direction on a smooth insulated board. The plane of the board is kept parallel to the ground. This motion takes place in a region with a uniform magnetic field that is perpendicular to the plane of the board.

The magnitude of the mass' instantaneous velocity is *v* and its direction is shown in Fig. 8.1.

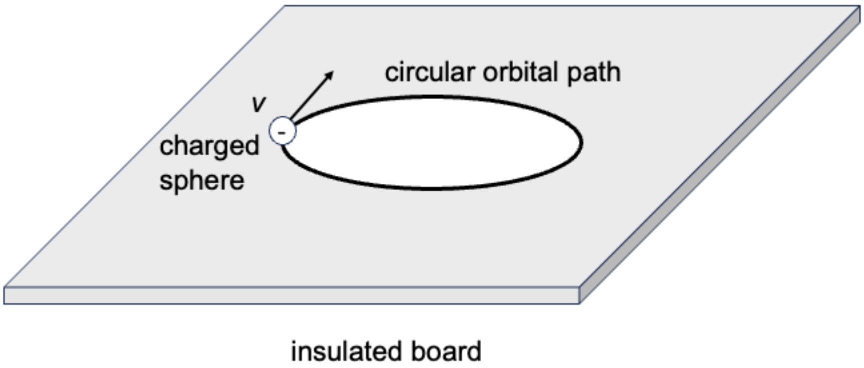

Fig 8.1

(i) Figure 8.2 below shows the frontal view of the charged sphere and the insulated board. The position of the centre of the circular path is indicated.

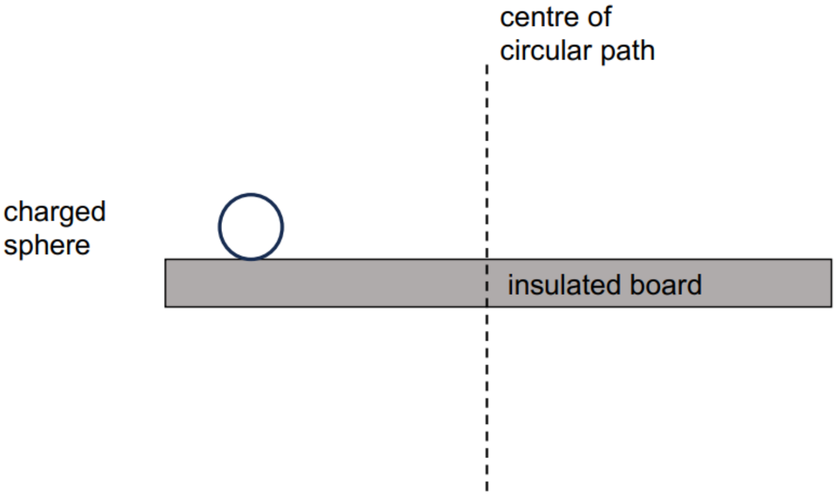

Fig. 8.2

Draw and label on Fig. 8.2 the forces acting on the charged sphere during its circular motion.

[3]

(ii) State the direction of the magnetic field.

.... [1]

(iii) Given that the magnetic field has magnetic flux density B of 0.50 T, determine the period T of the charge's revolution.

T = ………………….. s [3]

(iv) A downward uniform electric field is now added. State and explain the effect on the path of the charged particle.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [3]

(b) A metal rod PQ of mass 0.200 kg is placed on a pair of conducting rails which are separated by a distance of 50.0 cm and are parallel to the horizontal. The two rails are electrically connected at their right end. A uniform magnetic field of flux density 8.00 T is applied perpendicularly to the plane of the rails. The rod has a resistance of 10.0 Ω, and the rails and their connection have negligible resistances. Fig. 8.3 show the top view of the setup.

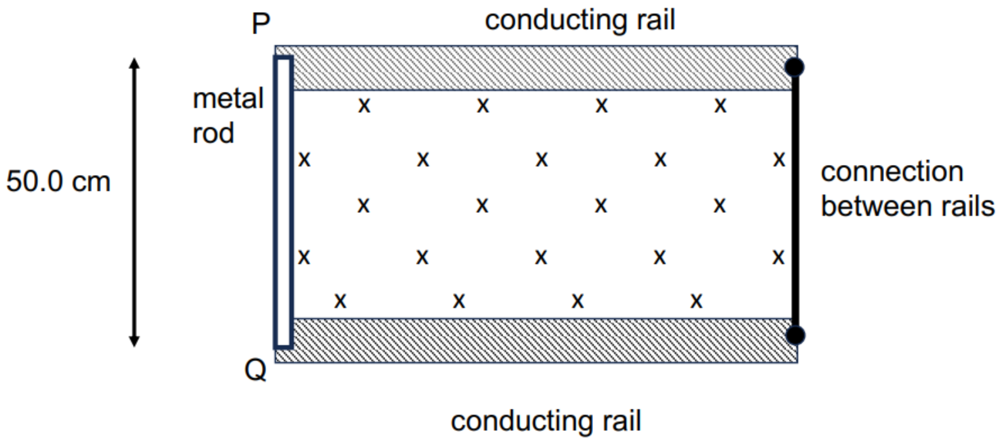

Fig 8.3

(i) State Lenz's law.

……..

……. [1]

(ii) The rod is given a slight rightward push and it slides rightwards on the conducting rails at an initial velocity of 2.00 m s^{-1}. Explain why this results in an induced current in the metal rod.

……..

…….

……..

……. [2]

(iii) Calculate the induced current when the rod has an initial velocity of 2.00 m s^{-1}.

induced current = ………………….. A [2]

(iv) The rod will eventually slow down and come to a complete stop, but it does not move leftwards.

Explain why this is so.

……..

…….

…….

…….

……..

……. [3]

(v) An additional rightward force F_{ext} is applied on the rod, as shown in Fig. 8.4.

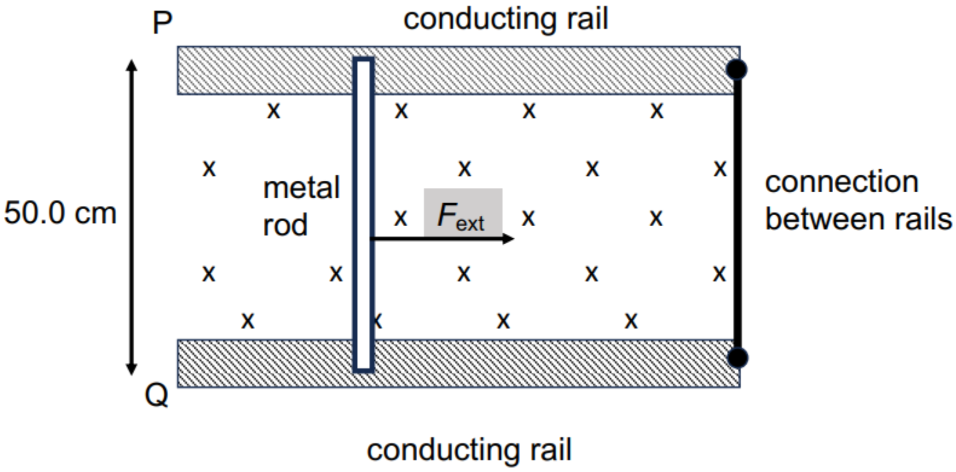

Fig. 8.4

Calculate the magnitude of F_{ext} that is required to keep the metal rod at a constant rightward velocity of 2.00 m s^{-1}.

magnitude of F_{ext} = ………………….. N [2]

[Total: 20]

End of Paper

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