Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS
9749/03

Paper 3 Longer Structured Questions

10 September 2024

2 hours

Candidates answer on the Question Paper.

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, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINER'S USE	
SECTION A	
Q1	/ 8
Q2	/ 9
Q3	/ 8
Q4	/ 12
Q5	/ 7
Q6	/ 8
Q7	/ 8
SECTION B	
Q8	/ 20
Q9	/ 20
PAPER 3	/ 80
PAPER 2	/ 80
PAPER 1	/ 30
PAPER 4	/ 55
TOTAL (WEIGHTED)	%

This document consists of **27** printed pages and **one** blank page.

[Turn over

DATA

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	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} mol^{-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	$s = u t + \frac{1}{2} a t^2$ $v^2 = u^2 + 2as$	
work done on / by a gas	$W = p \Delta V$	
hydrostatic pressure	$p = \rho g h$	
gravitational potential	$\phi = -\frac{Gm}{r}$	
temperature	$T / K = T / {}^\circ C + 273.15$	
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.	$x = x_0 \sin \omega t$	
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$	
electric current	$I = Anvq$	
resistors in series	$R = R_1 + R_2 + ...$	
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$	
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$	
alternating current / voltage	$x = x_0 \sin \omega t$	
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	$x = x_0 \exp(-\lambda t)$	
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$	

[Turn over

Section A

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

1 **(a)** An object Q of weight 30.0 N is supported by two ropes A and B as shown in Fig. 1.1.

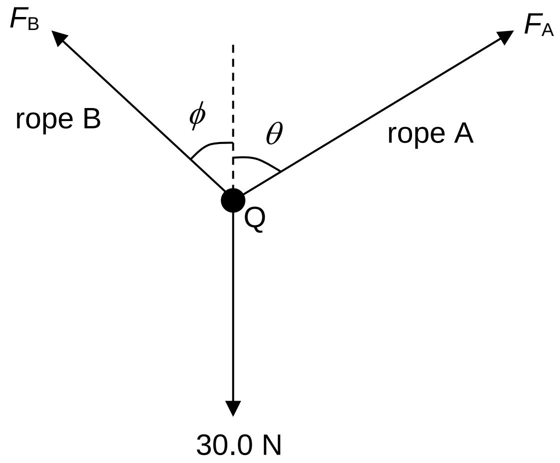

Fig. 1.1

Rope A is at an angle θ to the vertical and exerts force F_A on Q. Rope B is at an angle ϕ to the vertical and exerts a force F_B on Q.

The angle ϕ of rope B is varied from 0° to 90°. The force F_A is varied in magnitude and direction to keep Q in equilibrium.

(i) Determine the magnitude of force F_A when the angle ϕ is 35° and F_B is 20.0 N.

magnitude of F_A = ... N [3]

(ii) Explain why angles ϕ and θ cannot be 90° at the same time.

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(b) A uniform metal rod AB is freely pivoted at end A as illustrated in Fig. 1.2. The end B is suspended by a light spring. The other end of the spring is supported at Z.

The rod is in equilibrium.

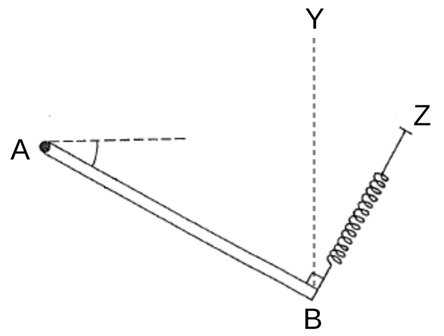

Fig. 1.2

The spring is now aligned vertically along YB so that the angle between the rod and the spring is no longer 90°. The rod remains in equilibrium in the same position.

Explain why the spring force increases.

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[Total: 8]

2 Two spheres A and B approach each other as illustrated in Fig. 2.1.

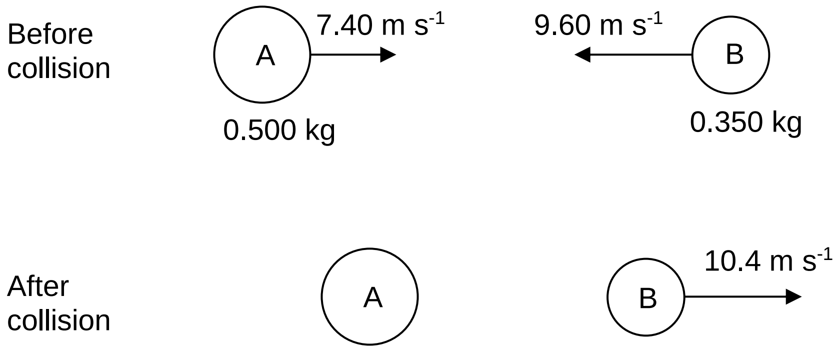

Fig. 2.1

Sphere A has a mass of 0.500 kg and moves to the right with a speed of 7.40 m s^{-1}.
Sphere B has a mass of 0.350 kg and moves to the left with a speed of 9.60 m s^{-1}.

The spheres collide and are in contact for a time of 0.400 s.

Sphere B reverses its direction of motion and moves off with a speed of 10.4 m s^{-1}.

(a) Using momentum consideration, explain quantitatively why spheres A and B cannot be at rest at the same instant.

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(b) For the time during the collision, calculate the average force between the spheres.

average force = ……………………………… N [2]

(c) Use your answer in **(b)** to determine the magnitude of the velocity of sphere A after the collision. Explain your working.

magnitude of velocity = …………………………… m s^{-1} [3]

(d) By considering quantitatively the relative speeds of approach and of separation of the two spheres, deduce whether the collision is elastic or inelastic.

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[Total: 9]

3 **(a)** Copper has one conduction electron per atom. The density of copper is 8960 kg m^{-3}. The mass of one mole of copper is 63.5 g.

Show that the number density of charge carriers in copper is 8.49×10^{28} m^{-3}.

[3]

(b) A composite wire XYZ is made by connecting in series two uniform wires, each of length L and made of copper but having different diameters as shown in Fig. 3.1. One wire has diameter d and the other wire has diameter $2d$.

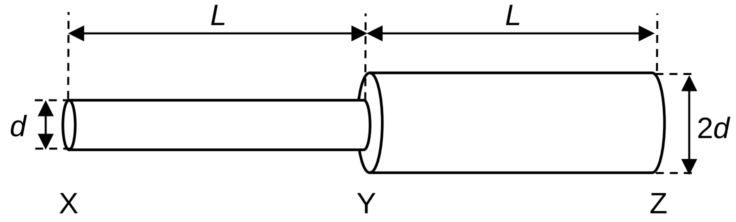

Fig. 3.1

A potential difference is then applied across X and Z of the wire and a current flows through the wire.

On Fig. 3.2, sketch a graph to show how the drift velocity v_d of electrons through the composite wire varies with distance along the wire from end X to end Z.

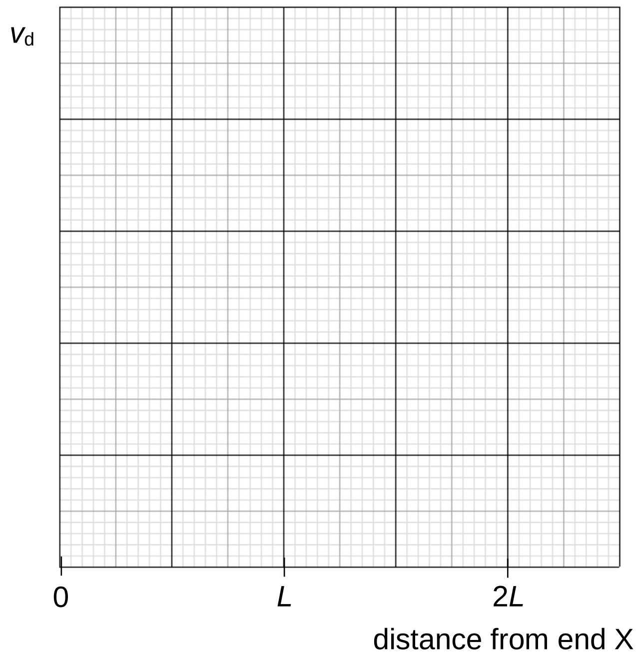

Fig. 3.2 [3]

(c) The mean speed of a conduction electron in the wire is very much greater than the drift velocity of the conduction electrons in the wire.

Explain this observation.

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.... [2]

[Total: 8]

[Turn over

4 A mass *m* is suspended from a vertical spring of spring constant *k* attached to a fixed support. The mass is pulled down and held at a vertical displacement of 0.16 m from its equilibrium position, as shown in Fig. 4.1.

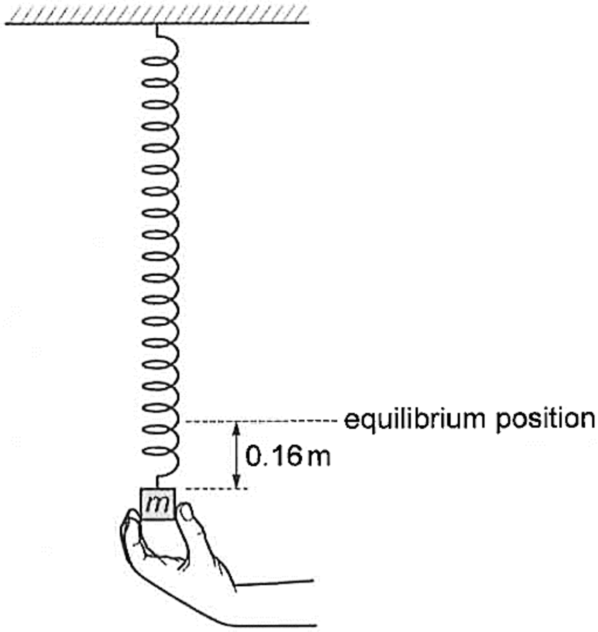

Fig. 4.1

The mass is released.

(a) Show that the mass's acceleration *a* is related to its displacement *x* from the equilibrium position by the equation:

$$a = -\frac{k}{m}x .$$

Explain your working.

[3]

(b) The mass undergoes simple harmonic oscillations described by the equation in **(a)**.

Show that the period T of the oscillations of the mass is given by:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

[2]

(c) Ten oscillations are timed using a stopwatch. The data for the mass and the time, together with their uncertainties, are shown in Table 4.1.

Table 4.1

time for 10 oscillations / s	7.2 $\pm$ 0.2
m / g	120 $\pm$ 1%

Determine the value of k together with its actual uncertainty. Give your answer to an appropriate number of significant figures.

k = ……………. $\pm$ ……………. N m^{-1} [3]

(d) Calculate the total energy of oscillations of the spring-mass system.

total energy = ………………………………….. J [2]

(e) On Fig. 4.2, sketch a graph to show the variation with time of the kinetic energy of the mass for one complete oscillation, starting from the time of release. Label the axes with values obtained from **(c)** and **(d)**.

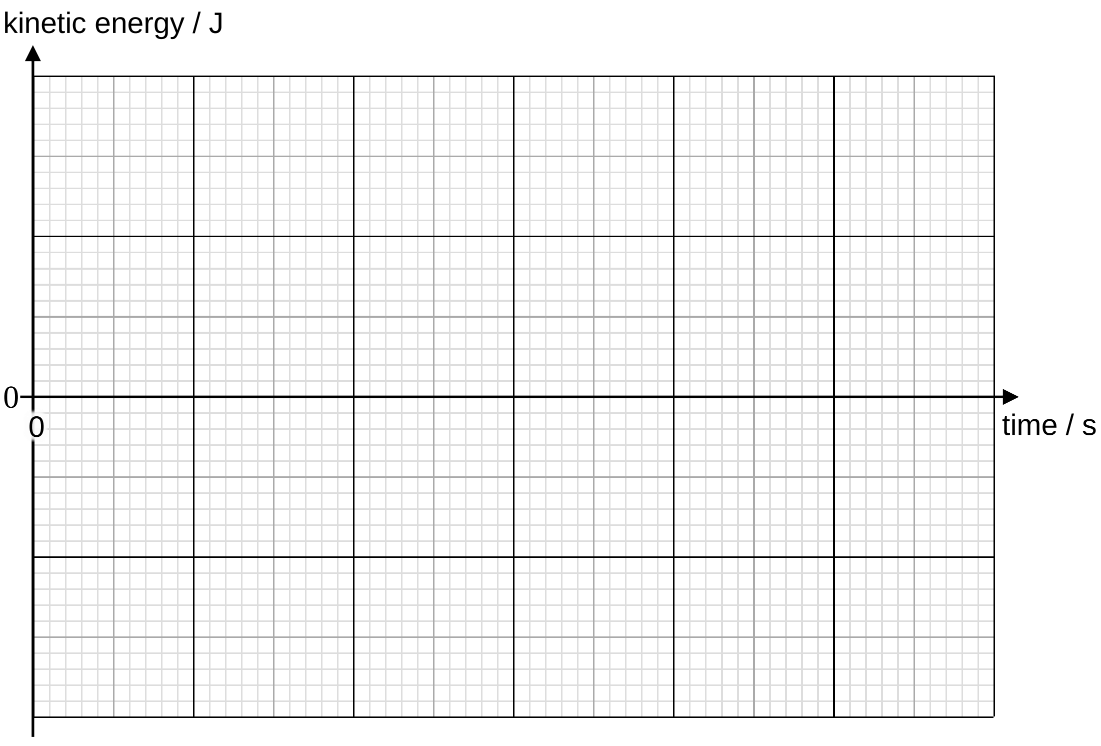

Fig. 4.2 [2]

[Total: 12]

5 Coherent light is incident normally on a double slit, as shown in Fig. 5.1.

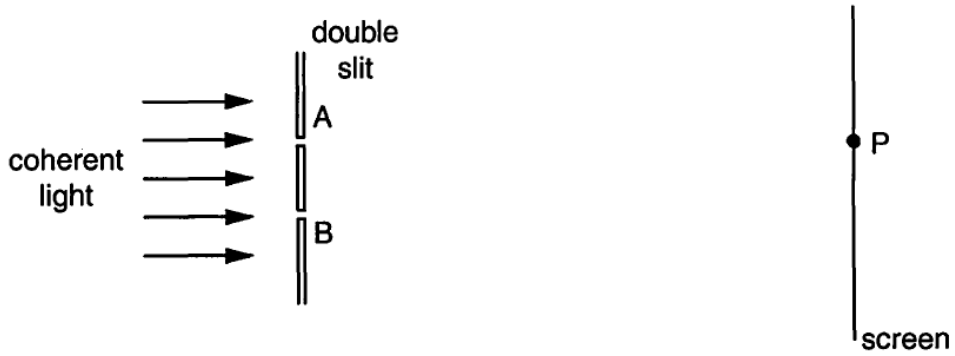

Fig. 5.1 (not to scale)

Light passes through the two slits A and B and is incident on a screen.

The variation with time *t* of the displacement *x* of the light arriving at point P on the screen is shown in Fig. 5.2.

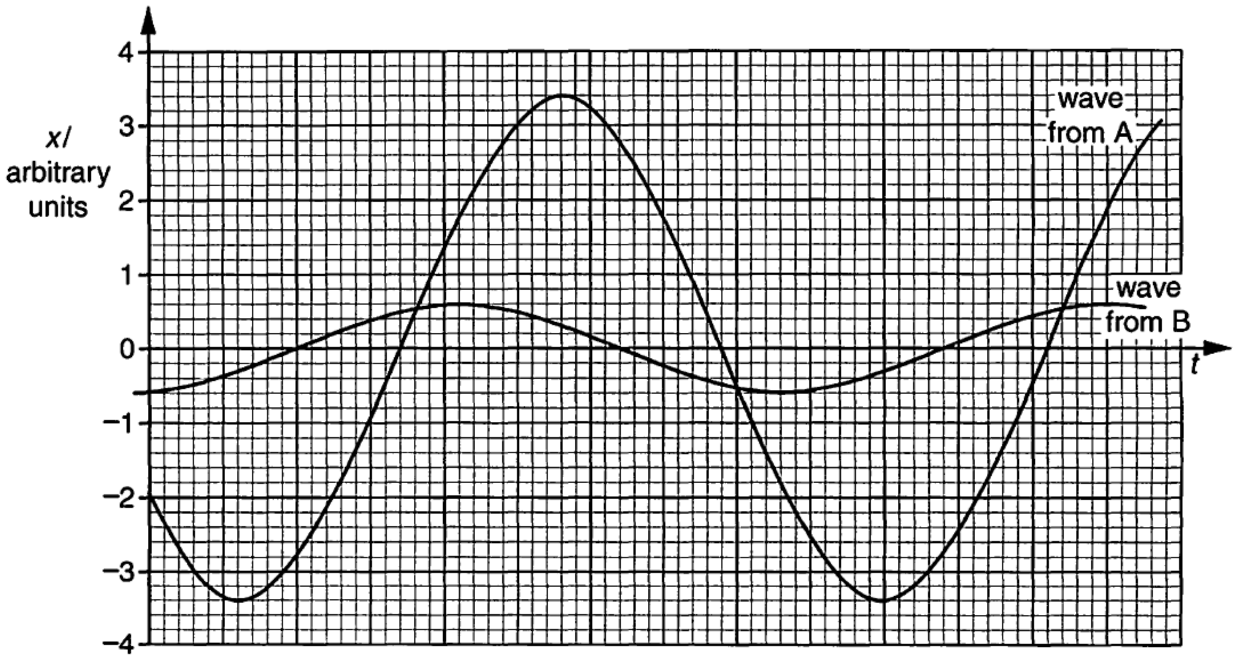

Fig. 5.2

(a) Use Fig. 5.2 to determine the phase difference between the waves from slit A and from slit B that arrive at point P.

phase difference = ...° [2]

(b) Dark fringes and bright fringes are both formed on the screen.

Use Fig. 5.2 to determine, for the bright fringe and the dark fringe closest to point P, the ratio

$$\frac{\text{intensity of light at the bright fringe}}{\text{intensity of light at the dark fringe}}.$$

ratio = ………………………………. [3]

(c) In an attempt to produce brighter fringes, the student widens each of the two slits, keeping their separation constant. Fringes are no longer observed.

Suggest why the fringes are no longer observed.

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[Total: 7]

6 Two metal plates X and Y are contained in an evacuated container and are connected as shown in Fig. 6.1. Metal plate X is then illuminated with monochromatic light.

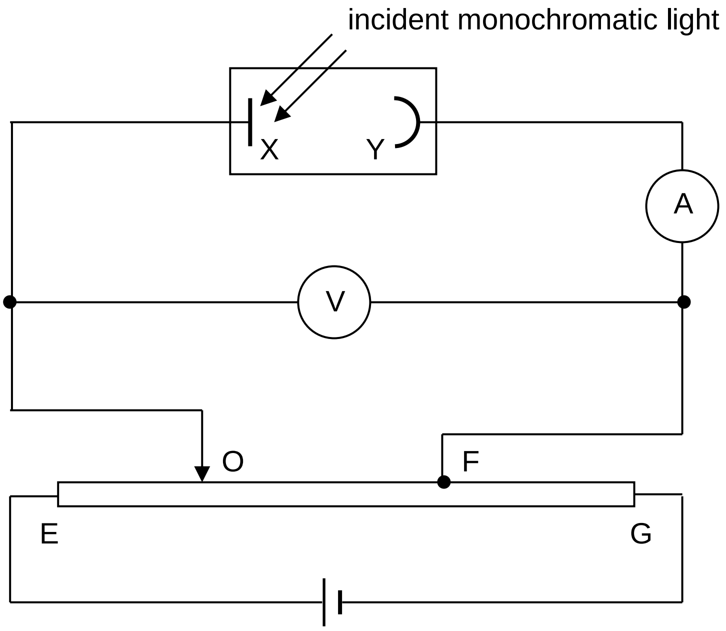

Fig. 6.1

The graph shown in Fig. 6.2 depicts the relationship between the voltmeter reading V and the ammeter reading I.

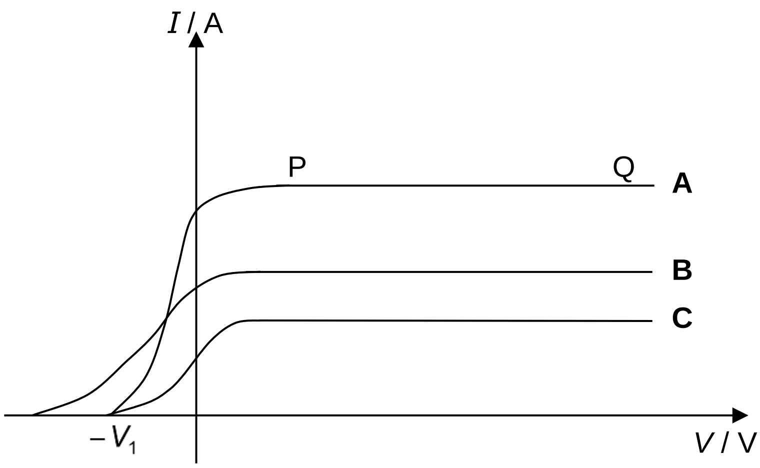

Fig. 6.2 (not to scale)

(a) A student obtained the part PQ on graph A by shifting the sliding contact O.

State and explain where the position of O along EG should be shifted to for the student to obtain part PQ of graph A.

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……………………………………………………………………………………………………… [4]

(b) Given that the work function energy of X is 1.3 eV and the wavelength of the light is 550 nm, calculate the value of the stopping potential V_1.

V_1 = ……………………………… V [2]

(c) Describe the changes, if any, to the intensity and frequency of the incident monochromatic light that the student made to obtain graphs B and C if the same metal plate X is used.

graph B: …………………………………………………………………………………………

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graph C: …………………………………………………………………………………………

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

[Total: 8]

7 **(a)** The decay of radioactive nuclei is said to be *random* and *spontaneous*.

Explain what is meant by the radioactive decay is *random* and *spontaneous*.

random: ……………………………………………………………………………………………..

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spontaneous: ……………………………………………………………………………………….

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

(b) A Geiger-Müller counter was used to measure the count rate *C* of a radioactive source over several years. The readings were recorded and used to obtain the graph in Fig. 7.1.

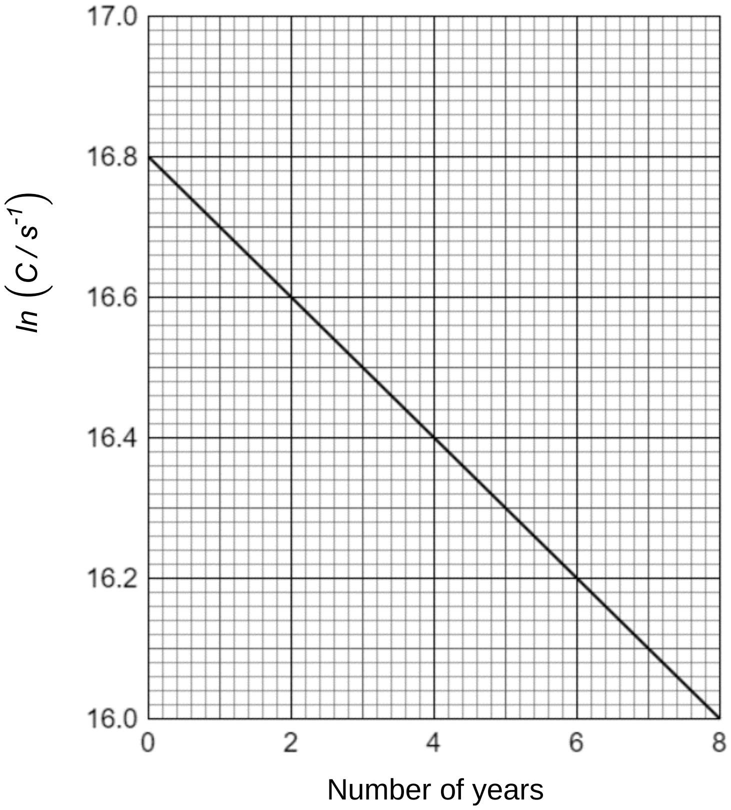

Fig. 7.1

(i) Using Fig. 7.1, determine the decay constant.

decay constant = …………..………………… s^{-1} [3]

(ii) Determine the half-life of the radioactive isotope.

half-life = ……………………………..… s [1]

(c) Describe what an experimenter would do in the measurement of the half-life of the sample to reduce the effect of

(i) the random nature of the radioactivity decay process,

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(ii) the background radiation.

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[Total: 8]

Section B

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

8 A mass spectrometer separates charge particles based on mass-to-charge ratio so that the composition of the charge particles can be identified.

The schematic diagram of a type of mass spectrometer is shown in Fig. 8.1. There are three sections to this mass spectrometer – the accelerator, the velocity selector and the mass separator.

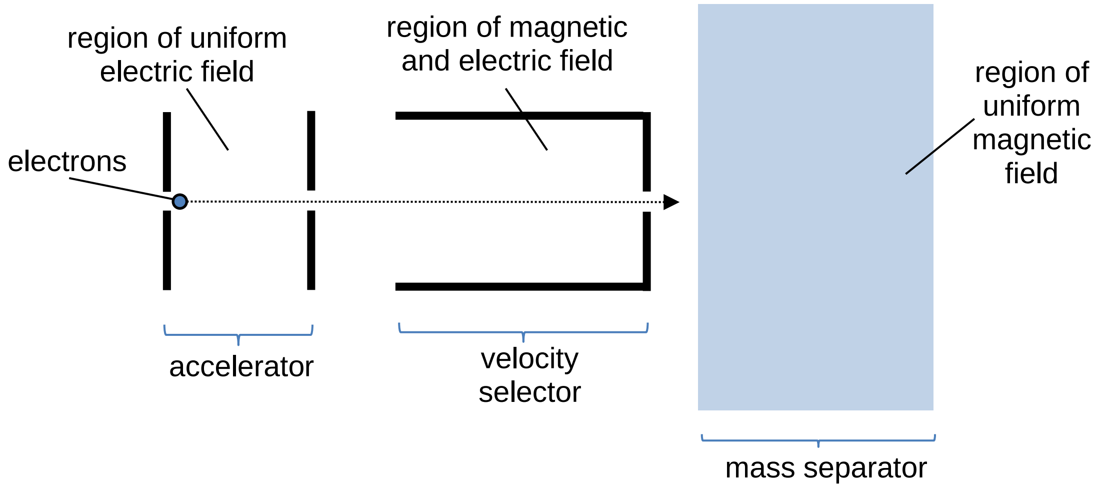

Fig. 8.1

Electrons are ejected into the mass spectrometer to demonstrate the working principle of the mass spectrometer.

(a) **(i)** Electrons enter the mass spectrometer at the accelerator near to the negatively charged plate so that they accelerate towards the positively charged plate as shown in Fig. 8.2.

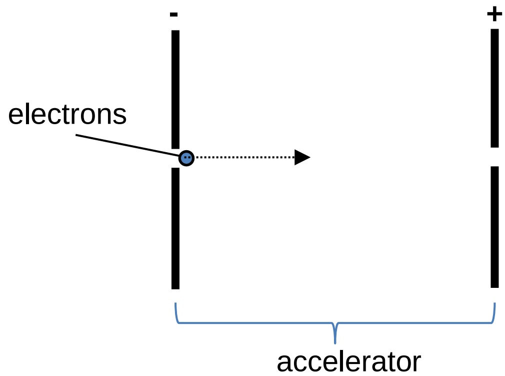

Fig. 8.2

The kinetic energy of the electrons increases by 2.50 $\times 10^{-16}$ J between leaving the negatively charged plate and reaching the positively charged plate.

Calculate the accelerating potential difference (p.d.).

accelerating p.d. = ………………..……………….V [2]

[Turn over

(ii) Suggest a reason why the electrons reaching the positively charged plate have a range of speeds.

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.... [1]

(b) At the velocity selector, the electrons enter a region in between two horizontal parallel charged plates placed 16 mm apart with a potential difference of 1500 V across them.

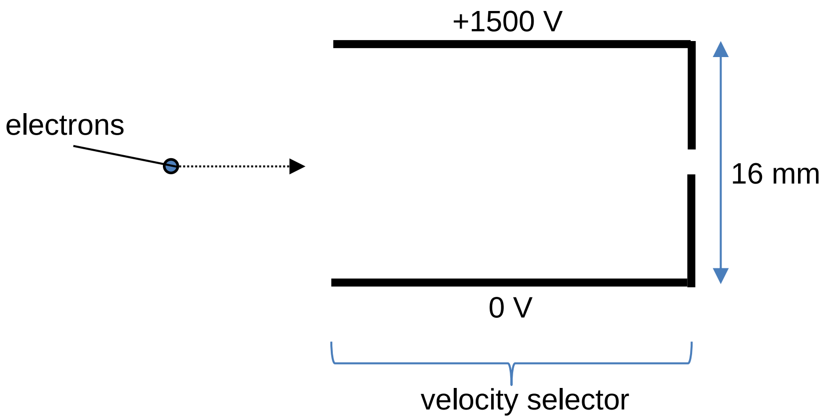

Fig. 8.3

Describe and explain the path of the electrons due to only the uniform electric field set up in between the parallel charged plates.

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.... [3]

(c) A uniform magnetic field is subsequently applied to the region in between the parallel charged plates such that only electrons with specific velocity pass through the velocity selector undeflected.

(i) State the direction of the magnetic field.

.... [1]

(ii) Calculate the magnetic flux density in the velocity selector if the electrons that are undeflected have a speed of 3.25×10^6 m s^{-1} after passing through the fields.

magnetic flux density = ……………..………………….. T [3]

(d) At the mass separator, the electrons then enter a region of uniform magnetic field set up by a large solenoid.

The solenoid has 120 turns for every 15 cm of the solenoid. The current in the solenoid is 3.5 A.

(i) Calculate the magnitude of the magnetic flux density *B* at the centre of the solenoid due to the current of 3.5 A.

B = ………………...…………….. T [2]

(ii) Inside the dashed region on Fig. 8.4, sketch the magnetic field pattern due to the current in the solenoid.

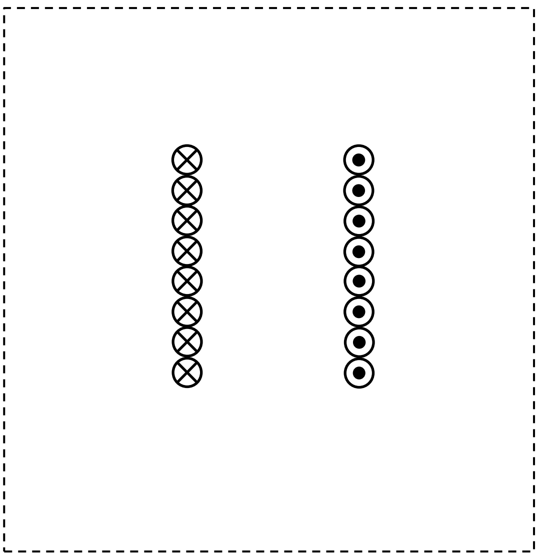

Fig. 8.4 [3]

(iii) The electrons enter the region of the uniform magnetic field perpendicularly.

Explain why the path of the electrons in the magnetic field is circular.

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.... [3]

(iv) In usual application, charged particles of different masses enter the mass separator instead of just electrons.

Suggest how the uniform magnetic field can separate the charge particles by mass.

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.... [2]

[Total: 20]

9 The variation with distance *r* of the electric potential *V* of a charged object is shown in Fig. 9.1.

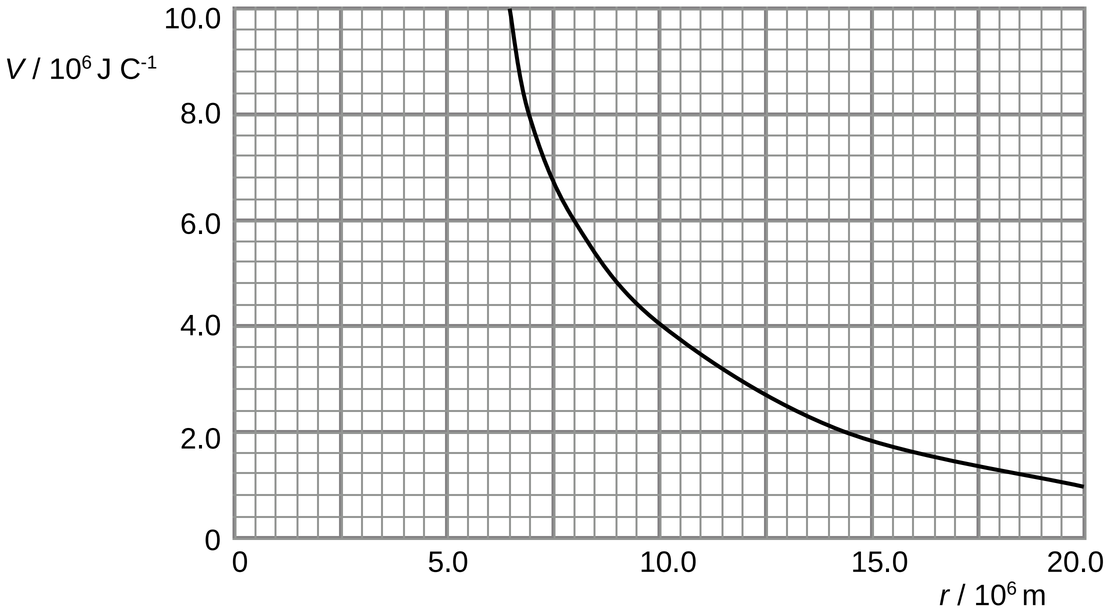

Fig. 9.1

(a) The charged object is fixed in its position. A proton is initially at rest at 7.5×10^6 m from the centre of the charged object.

Determine its kinetic energy when it has moved a distance of 7.0×10^6 m away from the charged object.

kinetic energy =………………………………… J [3]

(b) On Fig. 9.2, draw a graph to show the variation with distance *r* of the electric field strength *E* for values of *r* from 7.5 x 10^6 m to 17.5 x 10^6 m.

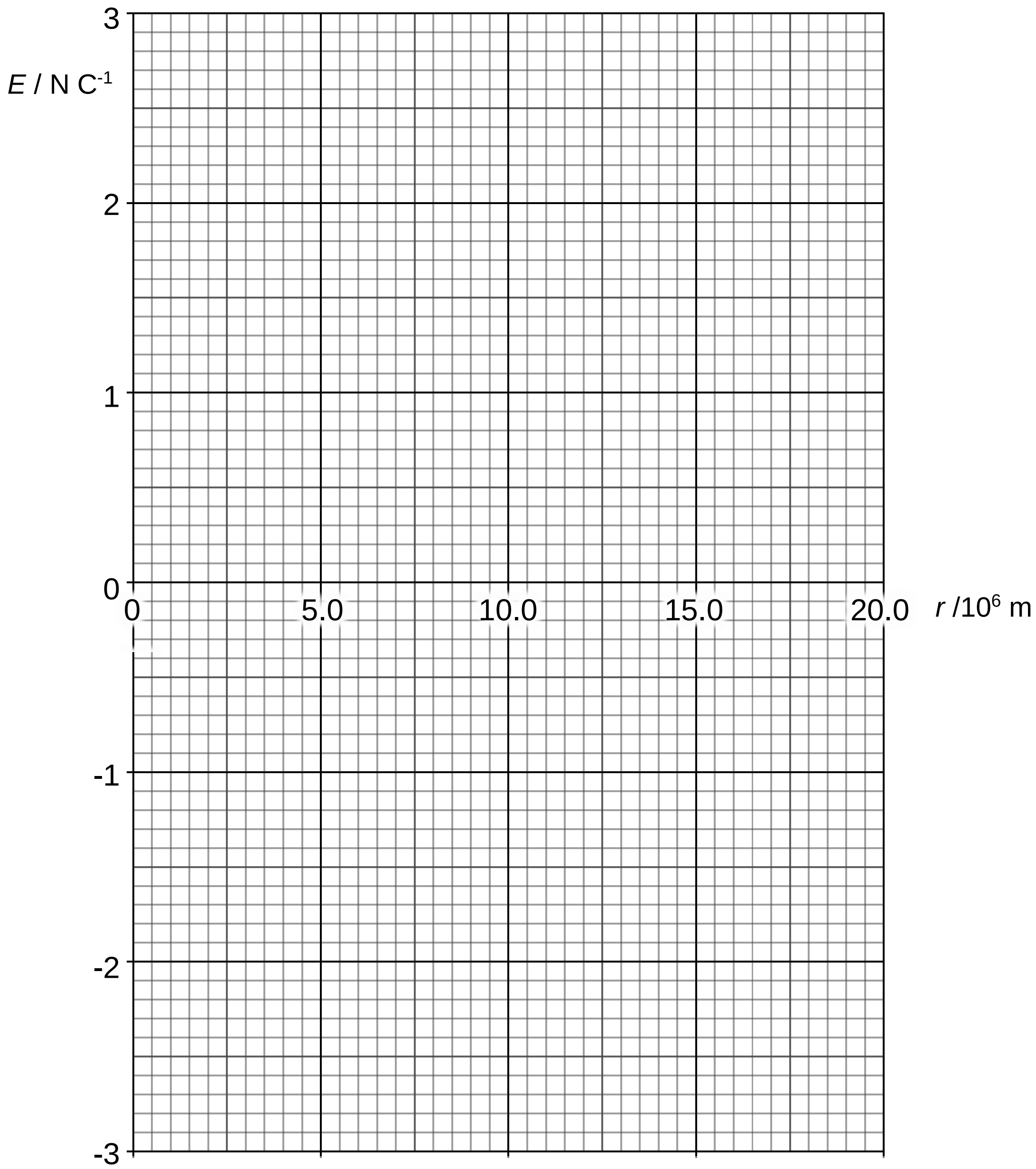

Fig. 9.2

[3]

(c) A certain planet has a radius of 1150 km. Fig. 9.3 below shows the variation with the distance x from the centre of this planet, of the gravitational potential ϕ near it. The planet may be assumed to be isolated in space.

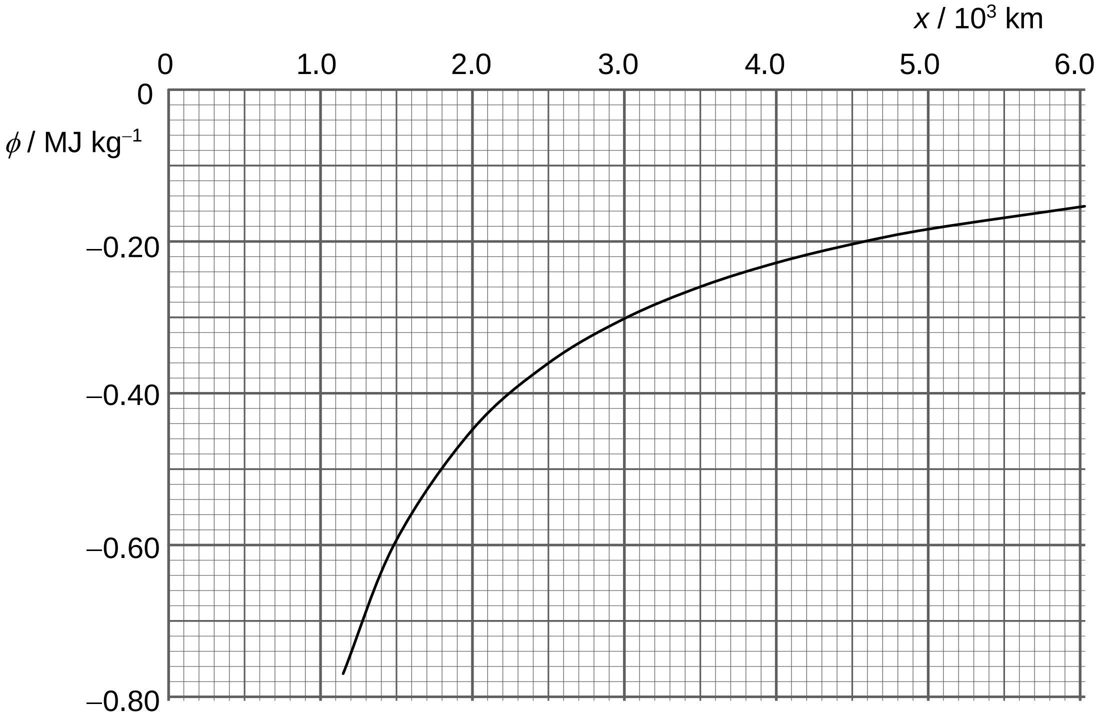

Fig. 9.3

(i) Explain why gravitational potential has a negative value.

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

(ii) Use Fig. 9.3 to determine the mass of the planet.

mass =……………………………… kg [2]

(iii) A moon of the planet has a circular orbit of radius 3.0×10^3 km. The period of its orbit is 3.44×10^4 s.

Calculate the centripetal acceleration of the moon.

centripetal acceleration =……………..………………. $m\ s^{-2}$ [2]

(iv) Explain why the gravitational field strength at the position of the moon has the same magnitude and same direction as the centripetal acceleration of the moon.

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

(v) The mass of the moon is 1.52 x 10^{21} kg.

Calculate the total energy of the moon.

total energy =…………………..……………. J [3]

(d) State and explain one similarity and one difference in the variations in the electric potential and gravitational potential shown in Fig. 9.1 and Fig. 9.3 respectively.

similarity: ……………………………………..………………………………..……………………

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difference: ……………………………………………………………..……………..…………..……

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[Total: 20]

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