INNOVA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATION 2
in preparation for General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME			
CLASS		INDEX NUMBER	

PHYSICS 9646/03

Paper 3 Structured Questions **24 September 2013**

Candidates answer on the Question Paper **2 hours**

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

For Section A
Answer **all** questions.

For Section B
Answer any **two** questions.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	7
2	8
3	10
4	7
5	8
Section B	
6	20
7	20
8	20
Significant Figures	
Total	80

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

Data

speed of light in free space,	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}$ F m^{-1}
		$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	$= 1.60 \times 10^{-19}$ C
the Planck constant,	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton,	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant,	R	$= 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	N_A	$= 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	G	$= 6.67 \times 10^{-11}$ 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	$= p\Delta V$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
hydrostatic pressure,	p	$= \rho gh$
gravitational potential,	Φ	$= -\frac{GM}{r}$
displacement of particle in s.h.m.,	x	$= x_o \sin\omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos\omega t$
		$= \pm\omega\sqrt{x_o^{2} - x^{2}}$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential	V	$= Q/4\pi\varepsilon_o r$
alternating current/voltage,	x	$= x_o \sin\omega t$
transmission coefficient	T	$= \exp(-2kd)$
		where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant,	λ	$= \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in this section.

1 Fig. 1.1 shows a rock climber abseiling down a rock face. At the instant shown the climber is stationary. The forces acting on the climber are shown in Fig. 1.1.

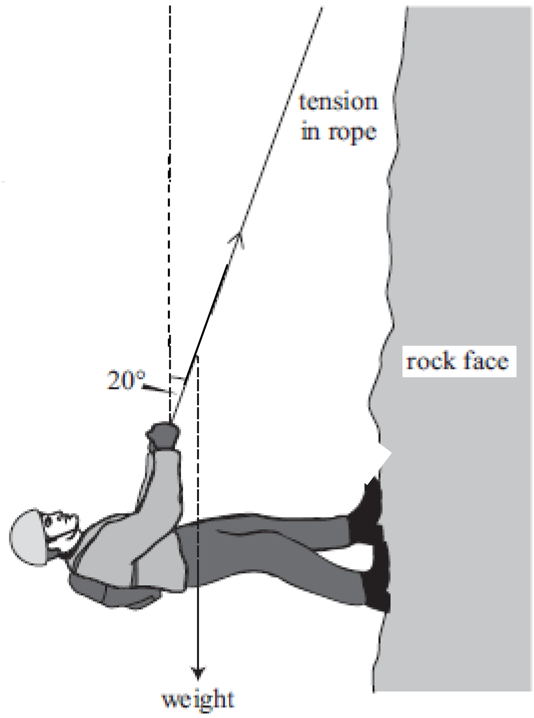

Fig. 1.1

(a) The rock climber in Fig. 1.1 is in equilibrium.

(i) Explain why the reaction force F_R by the rock face on the climber's feet must have a horizontal component and a vertical component.

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....

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....[2]

(ii) Draw an arrow in Fig. 1.1 to represent the reaction force F_R by the rock face on the climber's feet. [1]

For Examiner's Use

(b) Given that the weight of the rock climber is 590 N, and that the tension in the rope is 610 N and it acts at an angle of 20° to the vertical, calculate the magnitude of the reaction force F_R and the angle it makes with the vertical.

magnitude of F_R = ... N

angle of F_R = ... [4]

2 A block of wood of mass *m* floats in still water as shown in Fig. 2.1.

For Examiner's Use

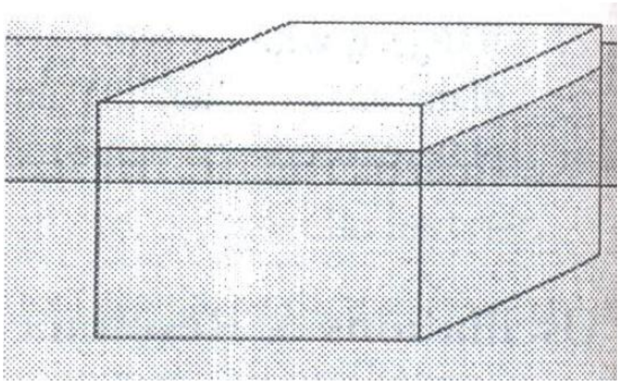

Fig. 2.1

When the block is pushed down into the water, without totally submerging it, and is then released, it bobs up and down in the water with a frequency *f* given by the expression

$$f = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$$

where *f* is measured in Hz and *m* in kg.

Surface water waves of speed 0.90 m s^{-1} and wavelength 0.30 m are then incident on the block. These cause resonance in the up-and-down motion of the block.

(a) Calculate

(i) the frequency of the water waves,

frequency = ... Hz [1]

(ii) the mass of the block.

mass = ... kg [1]

For Examiner's Use

(b) Describe and explain what happens to the amplitude of the vertical oscillations of the block after the following changes are made independently:

(i) water waves of larger amplitude are incident on the block,

....

....

....

....

....[2]

(ii) the distance between the wave crests increases,

....

....

....

....

....[2]

(iii) the block now bobs in oil.

....

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....[2]

For Examiner's Use

3 Fig. 3.1 shows the current-voltage characteristic graph for an intrinsic semiconductor X.

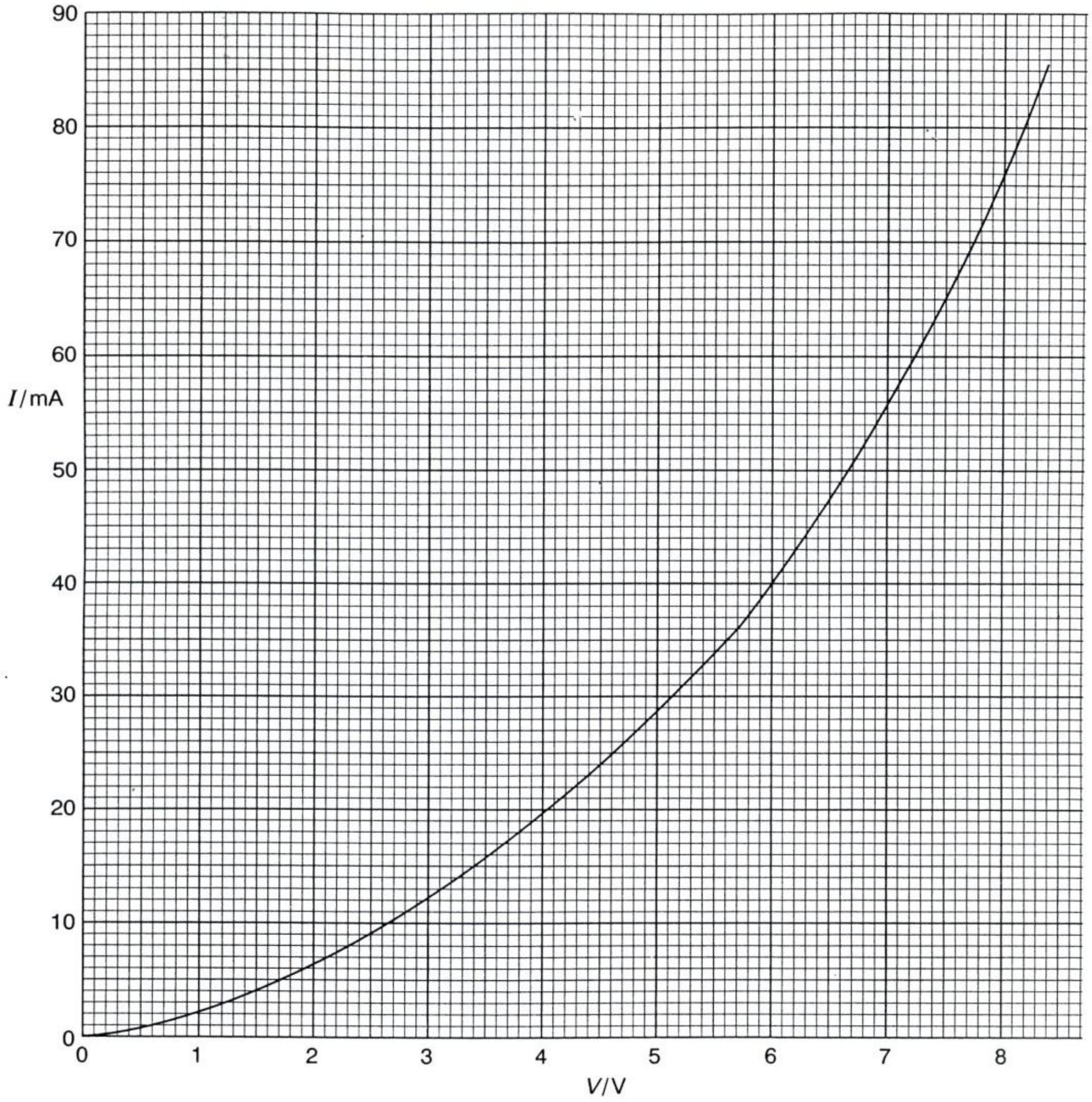

Fig. 3.1

(a) Using relevant features of the graph in Fig. 3.1, explain how it can be deduced that the resistance of the intrinsic semiconductor X decreases with voltage.

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....[2]

(b) Using band theory, explain why the resistance decreases with voltage for intrinsic semiconductors like X.

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....[3]

(c) The intrinsic semiconductor X is included in a circuit as shown in Fig. 3.2.

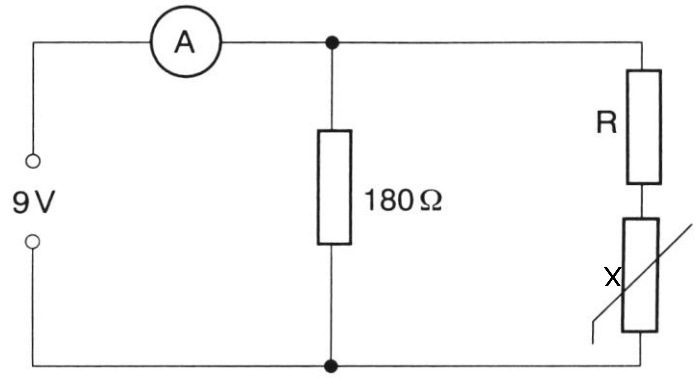

Fig. 3.2

It was found that the ammeter gave a reading of 90 mA and a current of 47 mA passes through the 180 Ω resistor.

(i) Determine the p.d. across X.

p.d. across X = ... V [2]

For Examiner's Use

(ii) Calculate the value of the resistance of resistor *R*.

value of R = ... Ω [2]

(iii) Explain what can be deduced about the 9 V cell in Fig. 3.2.

....

....

....[1]

4 An X-ray spectrum is shown in Fig. 4.1. The current of electrons I is accelerated through a potential difference of *V* as measured in volts before striking the metal target *M* inside the X-ray tube. λ_0 is the minimum wavelength detected in the spectrum.

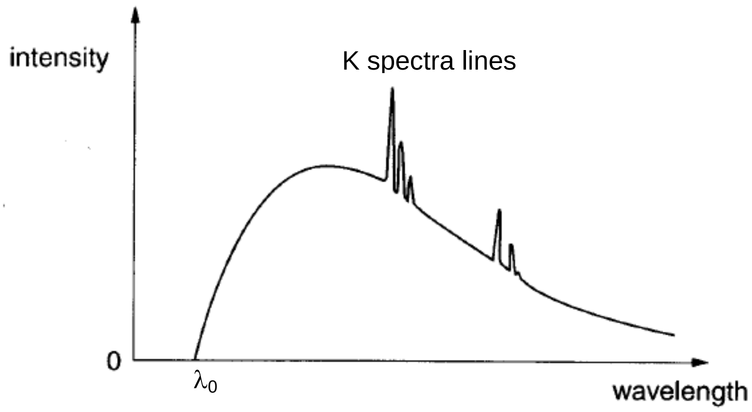

Fig. 4.1.

(a) Complete the table below to indicate the change (if any) in Fig. 4.1 with the new adjustments made independently to the experiment.
Use one of the following terms for each answer; "**increase**", "**unchanged**" or "**decrease**". [3]

A single change made to the experiment	Minimum wavelength, λ_0	Wavelengths of K spectra lines
V is increased		
I is decreased		
M is replaced with another metal of a lower mass number		

(b) **(i)** Show that λ_o is given by

$$\lambda_0 = \frac{1240}{V} \text{ nm}$$

[3]

For Examiner's Use

(ii) Determine the value of λ_0 in the X-ray spectrum for electrons accelerating across a p.d. of 50 kV.

λ_0 = ... nm [1]

5 **(a)** A student is provided with a freshly prepared sample of a radioactive material and the count rate C from the source is found to vary with time t as shown in Fig. 5.1(a).

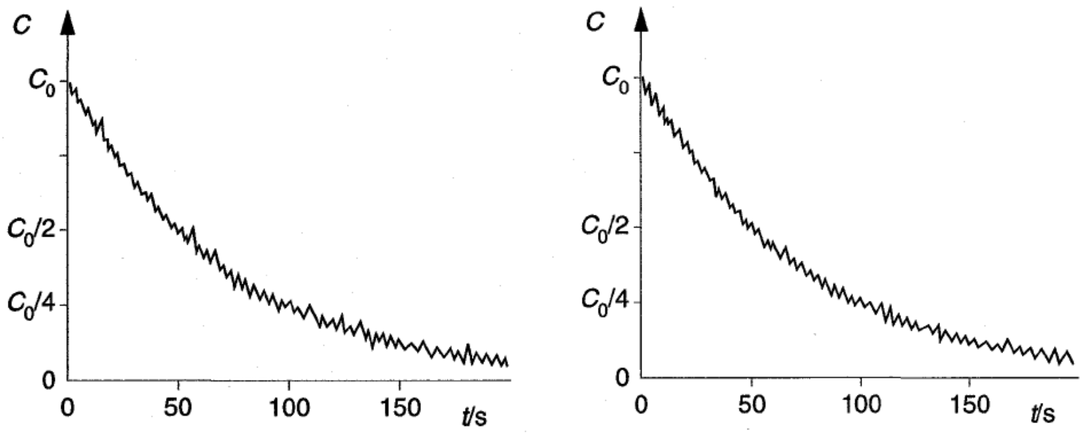

Fig. 5.1(a) **Fig. 5.1(b)**

A second similar sample of the radioactive material is then prepared and the student repeats the experiment, but with the sample at a higher temperature. The variation with time of the count rate C for the second sample is shown in Fig. 5.1(b).

State the evidence that is provided by these two experiments for

(i) the *random* nature of radioactive decay,

....

....[1]

(ii) the *spontaneous* nature of radioactive decay.

....

....[1]

For Examiner's Use

(b) Radium-224 has a half-life of 3.6 days.

(i) Show that the decay constant of Radium-224 is 2.23×10^{-6} s^{-1}. [1]

(ii) Hence, determine the activity of a sample of Radium-224 of mass 2.24 mg.

activity = ... s^{-1} [3]

(iii) Calculate the number of half-lives that must elapse before the activity of a sample of a radioactive isotope is reduced to one tenth of its initial value.

number of half-lives = ... [2]

For Examiner's Use

Section B

Answer **two** of the questions in this section.

6 A collision takes place between an α-particle travelling at 3.0×10^7 m s^{-1} and a stationary nitrogen nucleus. It results in the following nuclear reaction.

$$^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$$

The masses of the nuclei involved are listed below.

$^{14}_{7}\mathrm{N}$	13.9993 *u*
$^{4}_{2}\mathrm{He}$ (α-particle)	4.0015 *u*
$^{17}_{8}\mathrm{O}$	16.9947 *u*
$^{1}_{1}\mathrm{H}$ (proton)	1.0073 *u*

The particles move in a straight line, as shown in Fig. 6.1. The speed of the proton after the collision is 6.0×10^7 m s^{-1}.

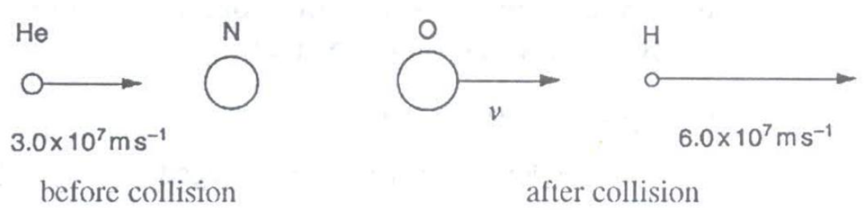

Fig. 6.1

(a) State the number and type of particles which form an α-particle. [1]

Type of particle	Number of particle

(b) State and explain whether the reaction is a fusion or fission process.

....

....

....

....

....[2]

For Examiner's Use

(c) Calculate the small change in mass, in kilograms, which takes place in this nuclear reaction.

change in mass = ... kg [3]

(d) Calculate the minimum kinetic energy needed by the α-particle to cause the nuclear reaction.

kinetic energy = ... J [2]

(e) Use the principle of conservation of momentum to determine the magnitude and direction of v, the velocity of the oxygen nucleus after the collision.

magnitude of v = ... m s^{-1}

direction = ... [4]

For Examiner's Use

(f) **(i)** What is meant by the *momentum* of a body?

....[1]

(ii) A body, initially at rest, explodes into two unequal fragments of mass m_1 and m_2. Mass m_1 has a velocity v_1 and mass m_2 has a velocity v_2. Using the principle of conservation of momentum, derive an expression for $\frac{v_1}{v_2}$.

$\frac{v_1}{v_2}$ = ...[2]

(iii) An isolated nucleus of mass 4.0 x 10^{-25} kg is initially at rest. It decays, emitting an alpha particle of mass 6.7 x 10^{-27} kg with kinetic energy of 1.2 x 10^{-14} J.

1. Find the speed of the alpha particle.

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

2. Hence, by considering the mass of the recoiling nucleus, use the expression found in **(f)(ii)** or otherwise to find the speed of the recoiling nucleus.

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

3. Explain how alpha-particle decay is possible using quantum tunneling.

....

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....[2]

7 **(a)** Define *electric potential* at a point.

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....

....[2]

(b) Two point charges **A** and **B** each have a charge of +3.6 x 10^{-9} C. They are separated in a vacuum by a distance of 30 cm, as shown in Fig. 7.1.

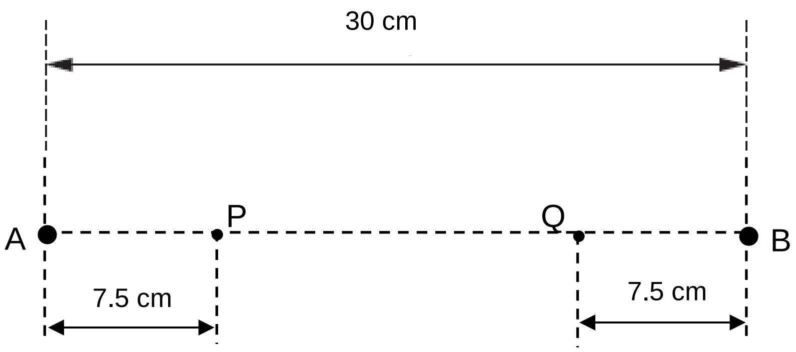

Fig. 7.1

Points **P** and **Q** are situated on the line **AB**. Points **P** and **Q** are 7.5 cm from charges **A** and **B** respectively.

(i) Calculate the force of repulsion between the charges **A** and **B**.

force = ... N [2]

(ii) Explain why, without any calculation, when a small test charge is moved from point **P** to point **Q**, the net work done is zero.

....

....

....

....[2]

For Examiner's Use

(iii) Calculate the electrical potential at point **P** due to the charges at **A** and **B**.

electrical potential = ... V [2]

(iv) Hence, calculate the work done in moving an electron from the midpoint of the line **AB** to point **P**.

work done = ... J [3]

(c) The point charge at **B** is removed and replaced by charges of unknown value *q* as shown in Fig. 7.2.

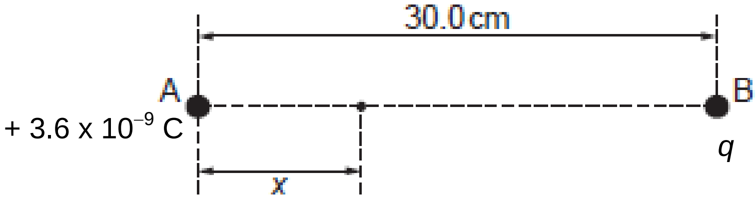

Fig. 7.2

The variation with distance *x* from **A** along **AB** of the potential *V* is shown in Fig. 7.3.

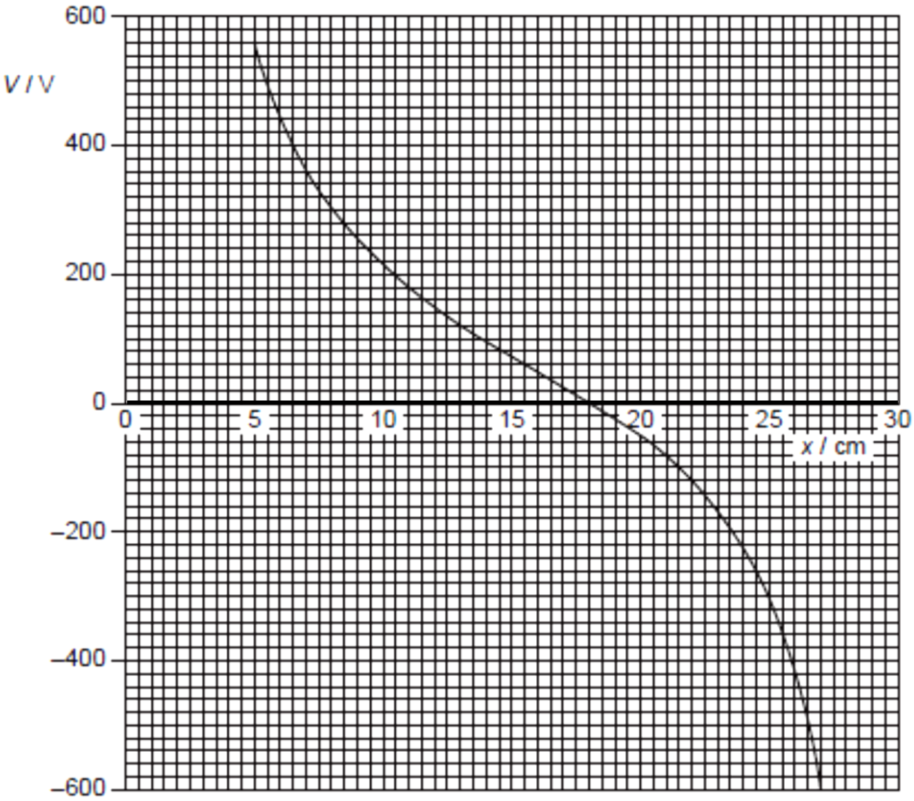

Fig. 7.3

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

x = ... cm [1]

(ii) State and explain the direction of the electric field between **A** and **B** at this point where the potential is zero.

....

....

....[2]

For Examiner's Use

(iii) Use your answer in **(i)** to determine the charge q.

charge q = ... C [3]

(iv) A small test charge is now moved along the line AB from x = 5.0 cm to x = 27 cm. State and explain the value of x at which the force on the test charge will be a maximum.

....

....

....

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....

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....[3]

For Examiner's Use

8 (a) Sketch and describe the motion of a particle of mass *m* of charge *q* moving with speed *v* when it enters at right angles to

(i) an electric field of field strength *E*,

....

....[2]

(ii) a magnetic field of flux density *B*.

....

....[2]

(b) A *mass spectrometer* is an instrument for measuring nuclear masses. Fig. 8.1 shows some basic features of such an instrument which, when working, is evacuated.

Negative ions of mass 2.84×10^{-26} kg and charge -1.60×10^{-19} C, are generated at $\mathbf{S_1}$ which is at a potential of –3000 V. The ions are accelerated in a narrow beam towards $\mathbf{S_2}$, which is a hole in a hollow metal conductor. The container is kept at zero potential.

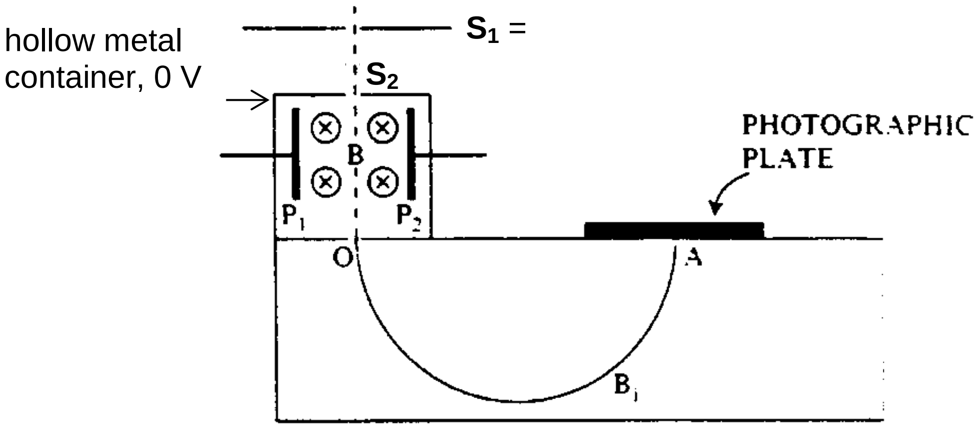


Fig. 8.1

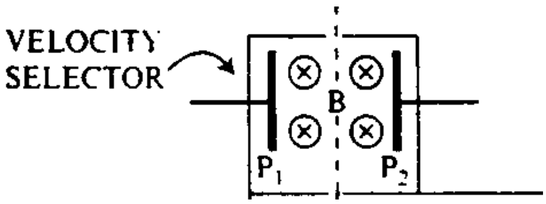
For Examiner's Use

Once inside the container, the negative ions enter a region in which there is still an electric field of field strength E, and a magnetic field of flux density 0.83 T. When in these fields the negative ions continue in a straight line with constant velocity.

(i) Calculate the velocity of the ions when they reach $\mathbf{S_2}$. Explain your working clearly.

velocity = ... m s^{-1} [2]

(ii) Explain how it is possible for the ions not to be deflected in the fields when the ions are moving inside the hollow container.



....

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....[2]

(iii) Calculate the electric field strength *E.*

electric field strength = ... V m^{-1} [2]

For Examiner's Use

(c) The ions passing through O now enter a region where a different magnetic field of uniform flux density B_1 is applied, again at right angles to the motion. As a result the ions travel along a semi-circular path of radius r and strike a photographic plate at A, where they are recorded.

(i) By reference to Fig. 8.1, state the direction of the magnetic field B_1.

....

....[1]

(ii) Explain why the ions follow a circular path.

....

....

....

....[2]

(iii) Show that the distance OA is proportional to the mass m of the ions. [3]

(iv) What is the significance of the result of **(iii)** for a beam consisting of ions of different masses but all having the same charge?

....

....[1]

(d) The mechanism by which the ions are formed is changed so that the ions still have the same specific charge (q/m). State what change occurs in

For Examiner's Use

(i) the speed of the ions entering the slit $\mathbf{S_2}$,

....

....[1]

(ii) the path of the ions in the two fields in the hollow container.

....

....[1]

(iii) the path of the ions in the magnetic field B_1.

....

....[1]

END OF PAPER

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