Electric Fields 3

1.

(a) Define *electric field strength*.

……

…… **[1]**

(b) Fig. 3.1 shows two horizontal, parallel metal plates **A** and **B**.

Fig. 3.1

The potential difference across the plates is 3.4 kV and the arrangement provides a uniform electric field between the plates.

On Fig. 3.1 draw at least six lines to represent the electric field between the plates. **[2]**

(c) A beam of electrons enters between the plates at right angles to the electric field. The horizontal velocity of the electrons is $4.0 \times 10^{7}\,\text{m}\,\text{s}^{-1}$. The path of the electrons is shown on Fig. 3.2. The horizontal length of each plate is 0.080 m and the separation of the plates is 0.050 cm. **P** is a point 0.040 m from where the beam enters the plates.

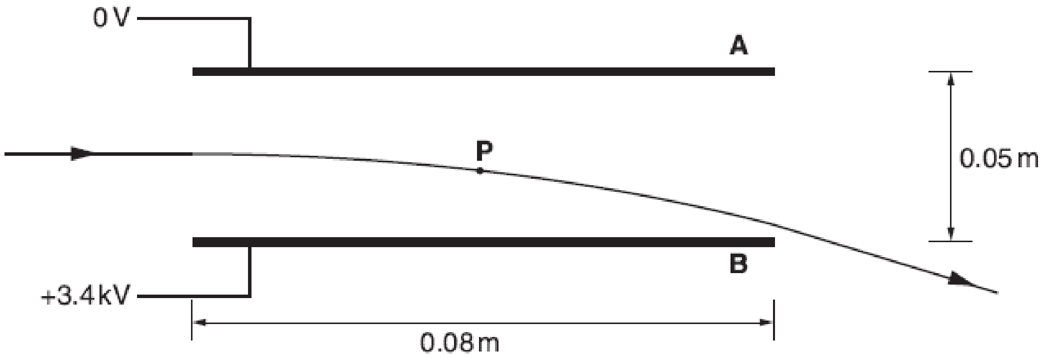

Fig. 3.2

(i) Draw an arrow on Fig. 3.2 to show the direction of the acceleration of an electron at **P**. **[1]**

(ii) Show that the acceleration of an electron between the plates is about $1 \times 10^{16}\,m\,s^{-2}$.

[2]

(iii) Calculate the time taken for an electron on entering the plates to reach **P**.

time = ... s **[1]**

(iv) Show that the vertical velocity of the electron at **P** is $1.2 \times 10^{7}\,m\,s^{-1}$.

[1]

(v) Calculate the magnitude of the resultant velocity of the electron at **P**.

magnitude of the velocity = ... $m\,s^{-1}$ **[2]**

(vi) Calculate the kinetic energy of the electron at **P**.

kinetic energy = ... J **[2]**

(vii) On Fig. 3.3 sketch the variation of kinetic energy E_k of the electron with the horizontal distance x it travels through the electric field and beyond. No calculations are required.

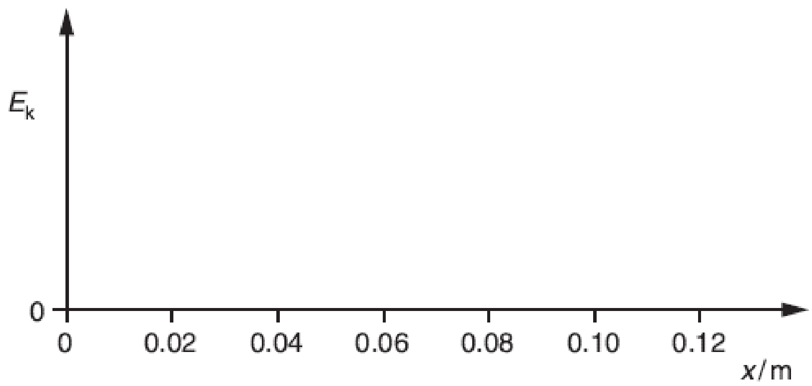

Fig. 3.3

[3]

2.

(a) Fig. 3.1 shows two charged horizontal plates.

Fig. 3.1

The potential difference across the plates is 60 V. The separation of the plates is 5.0 mm.

(i) On Fig. 3.1 draw the electric field pattern between the plates. **[2]**

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ **[1]**

(b) Positive ions are accelerated from rest in the horizontal direction through a potential difference of 400 V. The charged plates in **(a)** are then used to deflect the ions in the vertical direction. Fig. 3.2 shows the path of these ions.

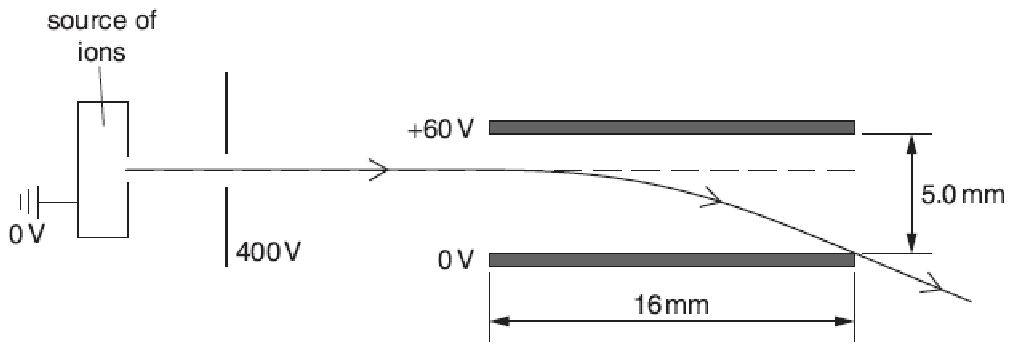

Fig. 3.2

Each ion has a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C.

(i) Show that the horizontal velocity of an ion after the acceleration by the 400 V potential difference is $2.0 \times 10^{5}\,m\,s^{-1}$.

[2]

(ii) The ions enter at right angles to the uniform electric field between the plates. Calculate the vertical acceleration of an ion due to this electric field.

acceleration = ... $m s^{-2}$ **[2]**

(iii) The length of each of the charged plates is 16 mm.

1 Show that an ion takes about 8.0×10^{-8} s to travel through the plates.

[1]

2 Calculate the vertical deflection of an ion as it travels through the plates.

deflection = ... m **[2]**

(c) A uniform magnetic field is applied in the region between the plates in Fig. 3.2. The magnetic field is perpendicular to both the path of the ions and the electric field between the plates.

Calculate the magnitude of the magnetic flux density of field needed to make the ions travel horizontally through the plates.

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

(d) Ions of the same charge but greater mass are accelerated by the potential difference of 400V described in **(b)**. Describe and explain the effect on the deflection of the ions after they have travelled between the plates using the same electric and magnetic fields of **(c)**.

....

....

....

.... **[2]**

3.

This question is about changing the motion of a beam of electrons travelling in a vacuum.
Fig. 4.1 shows a simple device for accelerating or decelerating electrons. It consists of two parallel conducting plates, labelled **P** and **Q**, each with a hole at its centre.

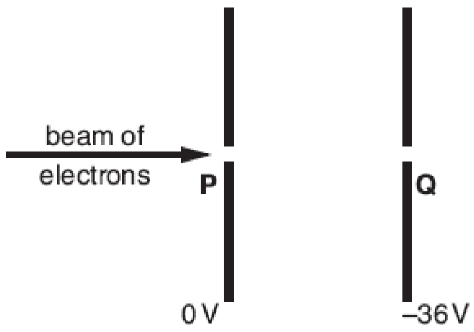

Fig. 4.1

(a) On Fig. 4.1 draw at least **six** arrowed lines to represent the electric field between the plates. **[2]**

(b) The electrons, all travelling at $4.0 \times 10^6\,\text{m s}^{-1}$, pass through the holes in **P** and **Q**. The plates, a distance of 8.0 mm apart, are maintained at 0 V and –36 V as shown in Fig. 4.1.

Calculate

(i) the electric field strength E between the plates

E = ... N C^{-1} **[1]**

(ii) the magnitude F of the force on an electron when between the plates

F = ... N **[1]**

(iii) the loss of kinetic energy $\Delta\varepsilon$ of each electron between **P** and **Q**

$\Delta\varepsilon$ = ... J **[1]**

(iv) the decrease in velocity Δv of each electron between **P** and **Q**.

Δv = ... m s^{-1} **[3]**

(c) The plates are rotated through 90°. Fig. 4.2 shows the same beam of electrons, travelling at $4.0 \times 10^6\,\mathrm{m\,s^{-1}}$, entering the region between the plates, but now parallel to the plates. A uniform magnetic field is applied into the paper in the region between the plates.

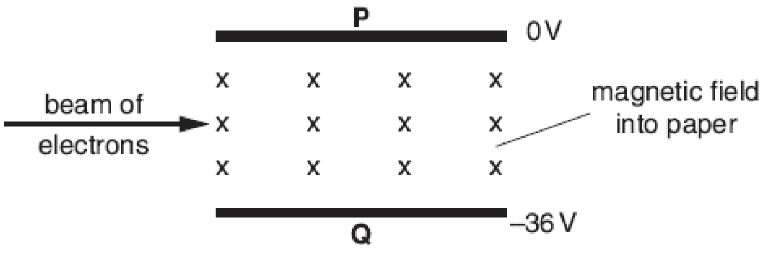

Fig. 4.2

(i) State the direction in which the force due to the magnetic field acts on the electrons as they enter the field.

....

.... **[1]**

(ii) Explain why, by adjusting the strength of the magnetic field, the electrons can pass undeflected between the plates.

....

....

....

....

.... **[2]**

(iii) Calculate the magnitude *B* of the magnetic field density needed for these electrons to pass undeflected between the plates. Give a unit with your answer.

B = ... unit .... **[4]**

4.

A small conducting sphere is attached to the end of an insulating rod. It carries a charge of $+5.0 \times 10^{-9}$ C.

(a) Fig. 4.1 shows the sphere held at the midpoint between two parallel metal plates. The plates are uncharged. When the sphere was inserted, negative charges were induced on the parts of the plates closest to it.

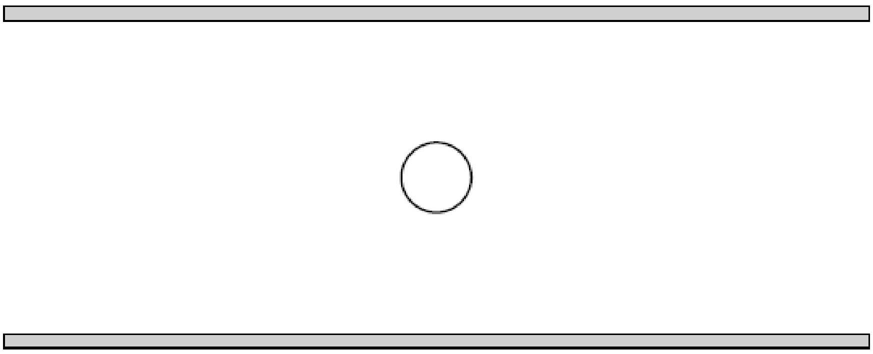

Fig. 4.1

Draw at least **six** electric field lines between the sphere and the plates. [3]

(b) The plates, which are 4.0 cm apart, are now connected to a 50 000 V supply.

Calculate

(i) the magnitude of the electric field strength E between the plates

E = ... NC^{-1} [2]

(ii) the magnitude F of the force on the sphere, treated as a point charge of $+5.0 \times 10^{-9}$ C.

F = ... N [2]

(c) Fig. 4.2 shows a second identically charged sphere attached to a top-pan balance by a vertical insulating rod. The original charged sphere is clamped vertically above the second sphere such that their centres are 4.0 cm apart.

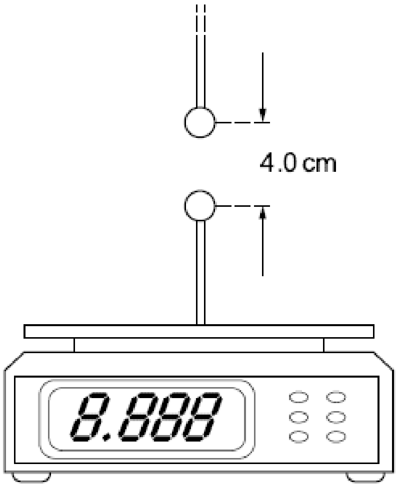

Fig. 4.2

(i) Show that the force between the two spheres acting as point charges is about 0.14 mN.

[3]

(ii) The balance can record masses to the nearest 0.001 g. The initial reading on the balance before the original charged sphere is clamped above the second sphere is 8.205 g. Calculate the final reading on the balance.

final reading = ... g [2]

5.

A nitrogen atom is initially stationary at point **P** in Fig. 5.1, midway between two large horizontal parallel plates in an evacuated chamber. The nitrogen atom becomes charged. There is an electric field between the plates. Ignore any effects of gravity.

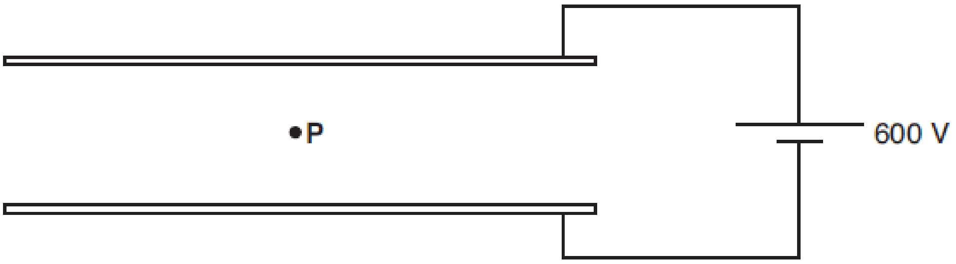

Fig. 5.1

(a) The direction of the electric force on the nitrogen ion is vertically downwards. State with a reason the sign of the charge on the ion.

....

....

....[1]

(b) The voltage between the plates is 600 V. At the instant that the ion, charge 1.6×10^{-19} C and mass 2.3×10^{-26} kg, reaches the lower plate, show that

(i) the kinetic energy of the ion is 4.8×10^{-17} J

[2]

(ii) the speed of the ion is 6.5×10^{4} m s^{-1}.

[2]

(c) The electric field strength between the plates is 4.0×10^{4} N C^{-1}. Calculate the separation of the plates.

separation = ... m [2]

(d) The ion passes through a hole in the lower plate at a speed of $6.5 \times 10^4\,\mathrm{m\,s^{-1}}$. It enters a region of uniform magnetic field of flux density 0.17 T perpendicularly into the plane of Fig. 5.2.

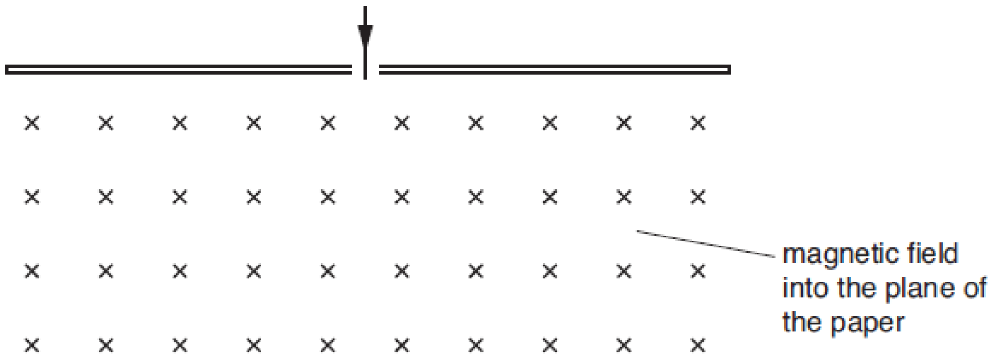

Fig. 5.2

(i) Sketch on Fig. 5.2 the semicircular path taken by the ion. [1]

(ii) Calculate how far from the hole the ion will collide with the plate. Use data from **(b)**.

distance = ... m [5]