1

Fig. 4.1 shows two horizontal parallel metal plates, 1.2×10^{-2} m apart, connected to a 600 V power supply.

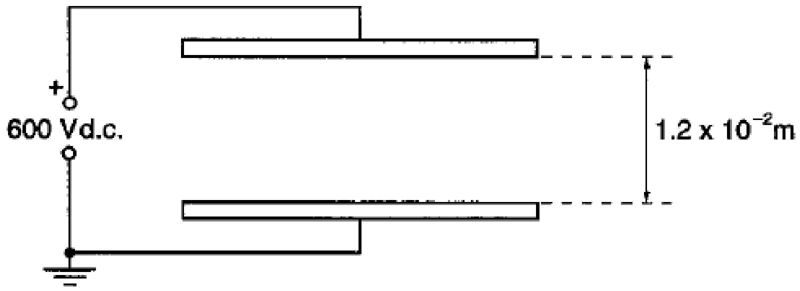

Fig. 4.1

(a) **(i)** On Fig. 4.1 draw lines to represent the electric field between the central region of the plates. [2]

(ii) Calculate the electric field strength between the plates, expressing your answer with a suitable unit.

electric field strength = ...[3]

(c) A tiny sphere of weight 3.3×10^{-14} N has acquired a charge so that it is held in equilibrium midway between the plates by the electric field. See Fig. 4.2.

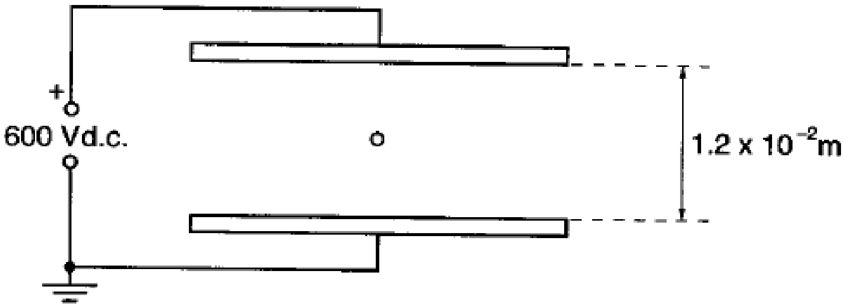

Fig. 4.2

(i) State the magnitude and direction of the electric force on the sphere.

magnitude = ...N

direction = ... [1]

(ii) Calculate the magnitude of the charge on the sphere.

charge = ... C [2]

(iii) The voltage between the plates is doubled suddenly. Describe the motion of the sphere.

....

....

.... [2]

[Total : 14]

2

(a) An aircraft is flying horizontally at a constant speed v close to the North Pole. Fig. 5.1 shows the aircraft viewed from above. The vertical component B of the Earth's magnetic field is indicated by crosses.

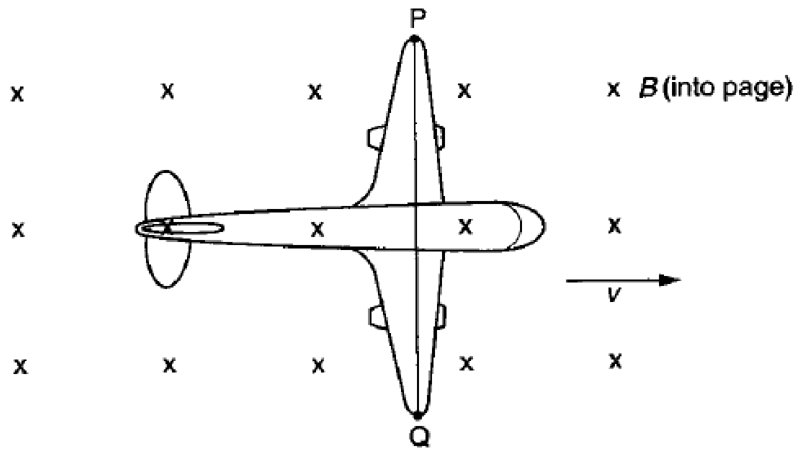

Fig. 5.1

(i) A wire stretches from wing tip P to wing tip Q. Each free electron, charge $-e$, in the wire experiences a force along the wire. Write down an expression for this force.

.... [1]

(ii) On Fig. 5.1 mark with an arrow the direction of this force. [1]

(iii) Explain why a steady voltage is induced between the wing tips.

....

....

....

....

....[3]

(b) The vertical component B of the Earth's magnetic field is 5.0×10^{-5} T. The aircraft is flying at 200 m s^{-1}. The distance PQ between the wing tips is 40 m.

(i) Calculate the force exerted by the magnetic field on each electron in the wire.

force = ...N [2]

(ii) Hence, or otherwise, calculate the voltage induced between the wing tips.

voltage = ...V [3]

[Total : 10]

3

Two very small identical conducting balls, each of mass 8.0×10^{-4} kg, are suspended from a single point by insulating threads of negligible mass as shown in Fig. 4.1. Each sphere has been given the same charge of 3.0×10^{-8} C so that they repel each other and are in equilibrium with their centres a distance 6.0×10^{-2} m apart.

data:
$(4\pi\varepsilon_o)^{-1} = 9.0 \times 10^9\,\mathrm{m\,F^{-1}}$
$g = 9.8\,\mathrm{N\,kg^{-1}}$

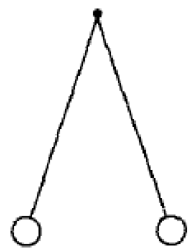

Fig. 4.1

(a) (i) On Fig. 4.1 draw two arrows, each labelled F_e, to show the direction of the electrostatic force on each ball. [1]

(ii) Show that the value of F_e is about 2.3×10^{-3} N.

[2]

(b) Each ball experiences three forces. On Fig. 4.1 draw and label arrows to represent the other two main forces acting on one ball. [1]

(c) Using the data above, calculate the angle between the threads.

angle = ...° [4]

(d) The gravitational force F_g between the two balls is much smaller than the electrostatic force F_e between them. Calculate $\frac{F_g}{F_e}$.

$\frac{F_g}{F_e}$ = ...[4]

[Total : 12]

4

Fig. 6.1 shows a section of an electro-mechanical oscillator. The coil inside the oscillator is attached by a spring to the casing, so that the coil can move freely to the left and right in the space between the poles of a permanent magnet. A cross-section through the magnet and coil is shown in Fig. 6.2. The coil and magnet are being viewed from the right of Fig. 6.1.

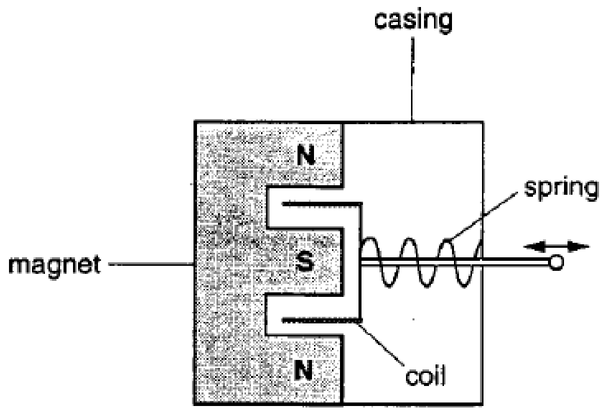

Fig. 6.1

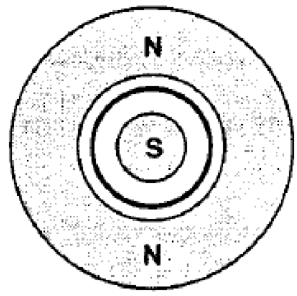

Fig. 6.2

(a) (i) On Fig. 6.2 draw lines with arrows to represent the magnetic field between the poles. [1]

(ii) Draw an arrow on the coil to indicate the direction of the current which will cause the coil to move upwards, that is, out of the plane of the examination paper. [1]

(iii) Write down an expression for the force F on a wire of length l carrying a current I at right angles to a magnetic field of flux density B.

....[1]

(iv) Calculate the force on the coil when there is a current of 80 mA in the coil. The flux density of the magnetic field at the coil is 0.40 T. The length of the wire in the coil is 15 m.

force = ... N [2]

5

Fig. 4.1 shows two large parallel insulated capacitor plates, separated by an air gap of 4.0×10^{-3} m. The capacitance of the arrangement is 200 pF. The plates are connected by a switch to a 2000 V d.c. power supply. The switch is closed and then opened.

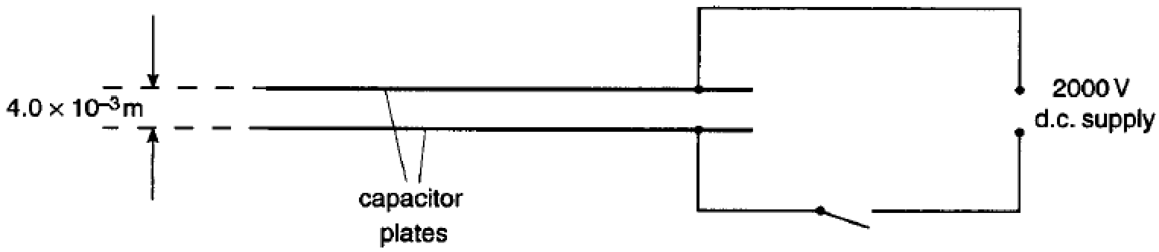

Fig. 4.1

(a) Calculate

(i) the magnitude of the electric field strength between the plates giving a suitable unit for your answer

electric field strength = ... unit .... [2]

6

Fig. 6.1 shows a simple transformer used for demonstrations in the laboratory. It consists of two coils linked by a laminated soft iron core. The primary coil is connected to a signal generator and the secondary coil to a voltage sensor, interface and computer. The number of turns on the secondary coil is double that on the primary coil.

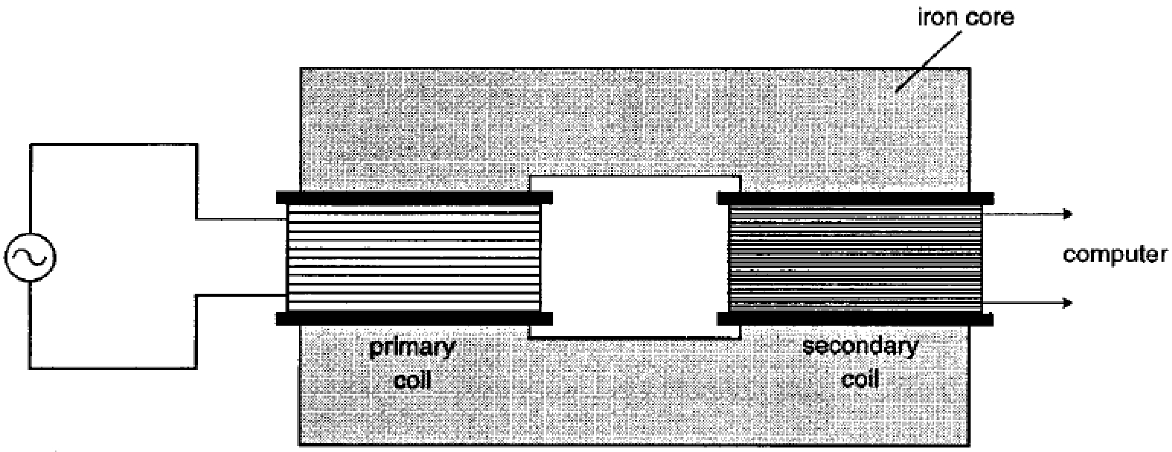

Fig. 6.1

(a) **(i)** Draw on Fig. 6.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) Define the term *magnetic flux*.

....

....

.... [2]

(iv) Use Faraday's law of electromagnetic induction to explain why an alternating current is necessary in the primary coil for a voltage to be detected across the secondary coil.

....

....

....

....

....

.... [3]

(b) Fig. 6.2 shows the computer screen in the demonstration where the number of turns on the secondary coil is double that on the primary coil.

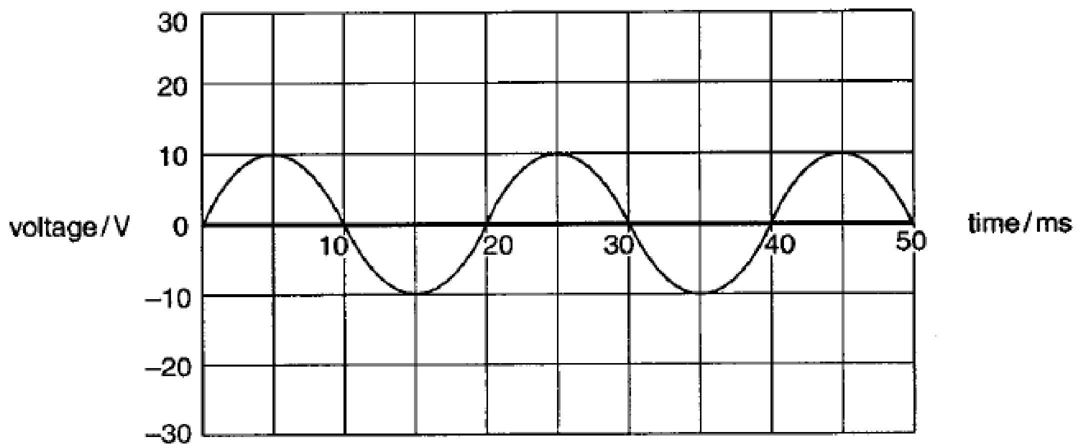

Fig. 6.2

(i) Show that the frequency of the supply is 50 Hz.

[1]

(ii) Calculate the amplitude of the **supply** voltage.

amplitude = ... V [2]

[Total: 12]

7

Fig. 6.1 shows the initial path of an electron observed in a nuclear particle detector. The electron has been created along with another particle, not shown here, in the detector at point **A**. There is a uniform magnetic field perpendicular to the plane of Fig. 6.1.

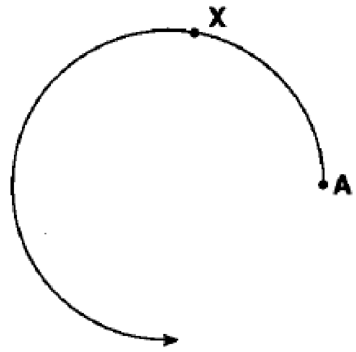

Fig. 6.1

(a) Explain how you can tell that there is a magnetic field in the particle detector.

....

....

....

.... [2]

(b) **(i)** The speed of the electron at point **X** is $1.0 \times 10^8\,m\,s^{-1}$. The radius of curvature of the electron path is 0.040 m. Calculate the magnitude of the force on the electron.

force = ... N [3]

(ii) Draw an arrow on Fig. 6.1 to indicate the direction of the force at **X**. [1]

(c) Calculate the magnitude of the magnetic flux density *B* in the detector. Give a suitable unit for your answer.

magnetic flux density = ... unit .... [4]

8

(a) Define *electric field strength* at a point in space.

....

.... [2]

(b) Fig. 3.1 shows two point charges of equal magnitude, 1.6×10^{-19} C, and opposite sign, held a distance 8.0×10^{-10} m apart at points **A** and **B**. The charge at **A** is positive.

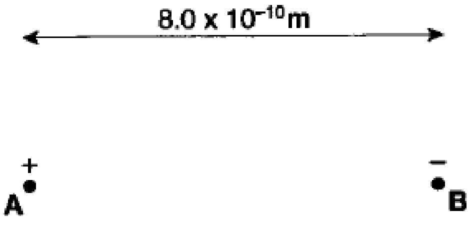

Fig. 3.1

(i) On Fig. 3.1, draw electric field lines to represent the field in the region around the two charges. [3]

(ii) Calculate the magnitude of the electric field strength at the mid point between the charges. Give a suitable unit for your answer.

electric field strength = ... unit .... [5]

(c) Imagine two equal masses, connected by a light rigid link, carrying equal but opposite charges. This is a system called *a dipole*. Fig. 3.2 and Fig. 3.3 show the dipole placed in different orientations between two uniformly and oppositely charged plates.

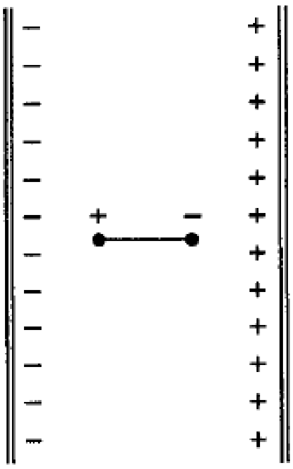

Fig. 3.2

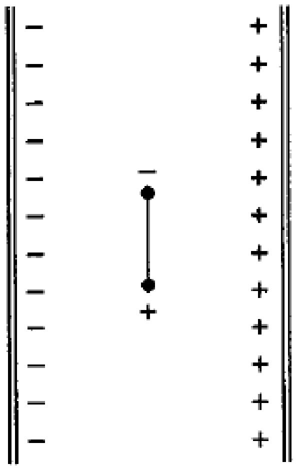

Fig. 3.3

Any effects of gravity are negligible.

(i) Describe the electric forces acting on the charges by drawing suitable arrows on the diagrams.

(ii) Explain the motion, if any, of the dipole when it is released from rest

in Fig. 3.2

....

....

....

in Fig. 3.3.

....

....

....

....

[5]

[Total: 15]

9

Read the short passage before answering the questions below.

Fig. 6.1 shows a section of a mass spectrometer. A beam of identical positively-charged ions, all travelling at the same speed, enters an evacuated chamber through a slit **S**. A uniform magnetic field directed vertically out of the plane of the diagram causes the ions to move along the semicircular path **SPT**. The beam exits the chamber through the slit at **T**.

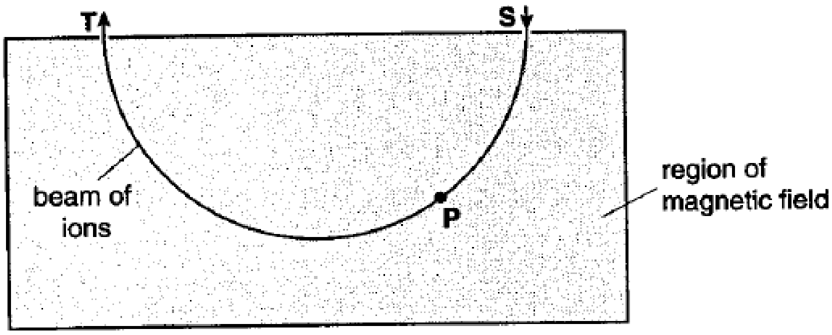

Fig. 6.1

(a) **(i)** On Fig. 6.1, draw an arrow to indicate the direction of the force on the ion beam at **P**. [1]

(ii) Name the rule you would use to verify that the ions are positively charged.

....

.... [1]

(iii) Explain why the ions follow a circular path in the chamber.

....

....

....

.... [2]

(b) Describe and explain the changes to the path of the ions for a beam of ions of greater mass but the same speed and charge.

....

....

....

....

.... [3]

(c) The speed of the singly charged ions is $3.0 \times 10^5\,m\,s^{-1}$ in the magnetic field of flux density 0.60 T. The mass of each ion is 4.0×10^{-26} kg.

(i) Show that the force on each ion in the beam in the magnetic field is about 3×10^{-14} N.

[2]

(ii) Calculate the radius of the semicircular path.

radius = ... m [3]

[Total: 12]

10

Fig. 4.1 shows a square flat coil of insulated wire placed in a region of uniform magnetic field of flux density B. The direction of the field is vertically out of the paper. The coil of side x has N turns.

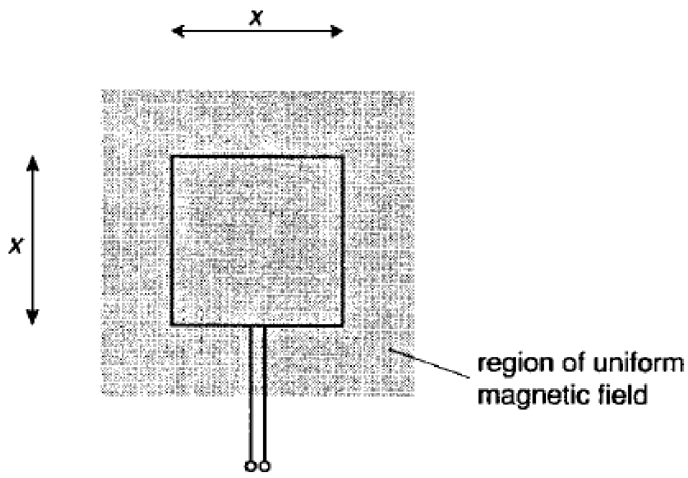

Fig. 4.1

(a) **(i)** Define the term *magnetic flux*.

....

....

.... [1]

(ii) Show that the magnetic flux linkage of the coil in Fig. 4.1 is NBx^2.

....

....

.... [2]

(b) The coil of side x = 0.020 m is placed at position **Y** in Fig. 4.2. The ends of the 1250 turn coil are connected to a voltmeter. The coil moves sideways steadily through the region of magnetic field of flux density 0.032 T at a speed of 0.10 m s^{-1} until it reaches position **Z**. The total motion takes 1.0 s.

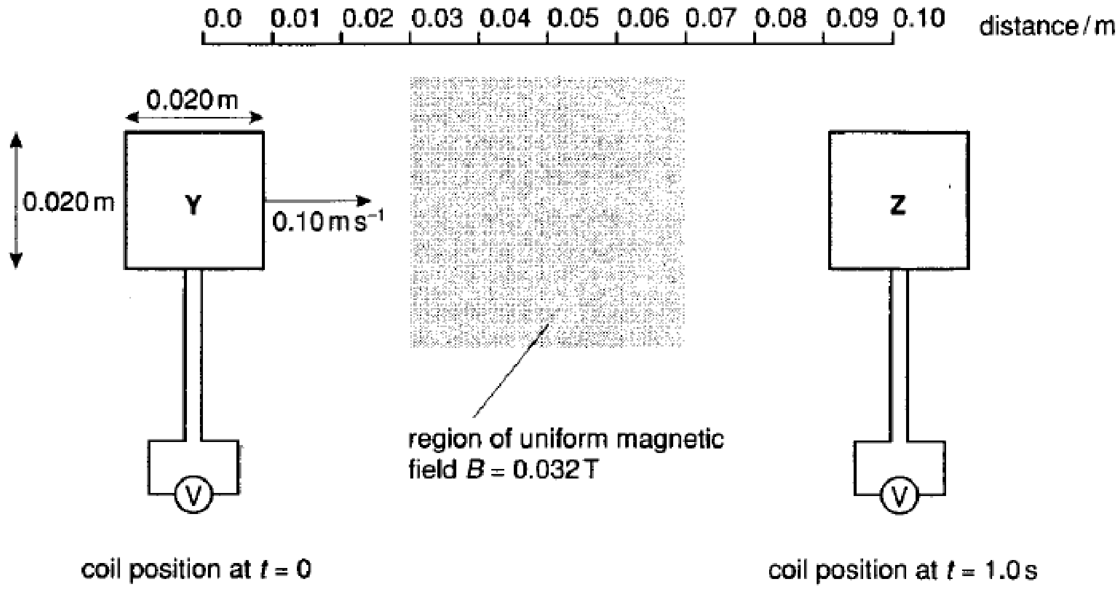

Fig. 4.2

(i) Show that the voltmeter reading as the coil enters the field region, after $t = 0.2$ s, is 80 mV. Explain your reasoning fully.

[3]

(ii) On Fig. 4.3, draw a graph of the voltmeter reading against time for the motion of the coil from **Y** to **Z**. Label the y-axis with a suitable scale. [4]

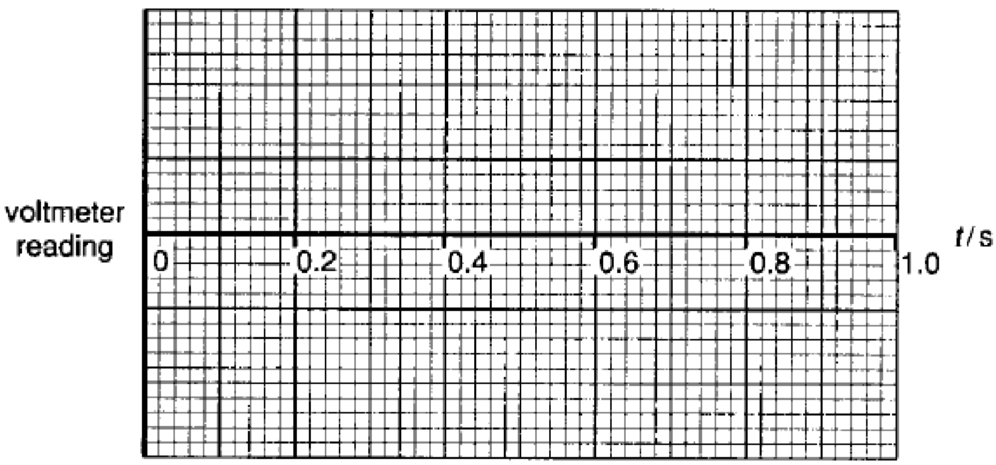

Fig. 4.3

[Total: 10]

11 This question is about changing the motion of electrons using electric fields. Fig. 3.1 shows a horizontal beam of electrons moving in a vacuum. The electrons pass through a hole in the centre of a metal plate **A**. At **B** is a metal grid through which the electrons can pass. At **C** is a further metal sheet. The three vertical conductors are maintained at voltages of +600 V at **A**, 0 V at **B** and +1200 V at **C**. The distance from plate **A** to grid **B** is 40 mm.

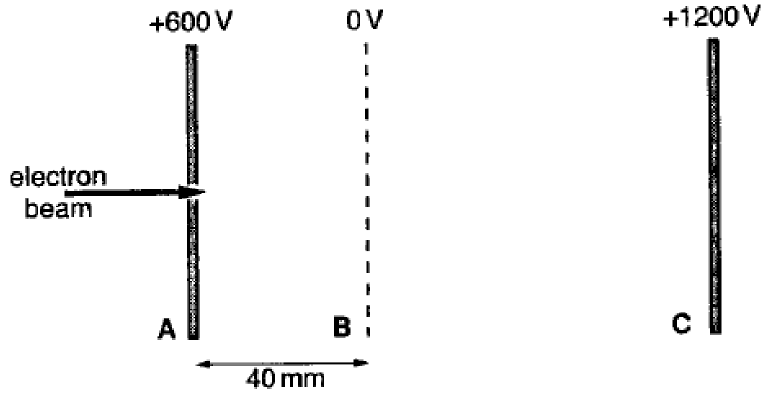

Fig. 3.1

(a) On Fig. 3.1 draw electric field lines to represent the fields in the regions between the three plates. [3]

(b) Show that the magnitude of the electric field strength between plate **A** and grid **B** is $1.5 \times 10^4\,V\,m^{-1}$.

[2]

(c) Calculate the horizontal force on an electron after passing through the hole in **A**.

force = ... N [2]

(d) Show that the minimum speed that an electron in the beam must have at the hole in **A** to reach the grid at **B** is about $1.5 \times 10^7\,m\,s^{-1}$.

[2]