7 **(a)** **(i)** Define the moment of a force and the torque of a couple.

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

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

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

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

(ii) A field may be electric, magnetic or gravitational. State the type of field for each of the following when a mass is

1. uncharged and the force is in the direction of the field,

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

2. charged and the force is in the opposite direction to the field,

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

3. charged and a force is experienced only when it has motion.

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

(b) A wire frame ABCD is supported on two knife-edges P and Q so that the section PBCQ of the frame lies within a solenoid, as shown in Fig. 7.1.

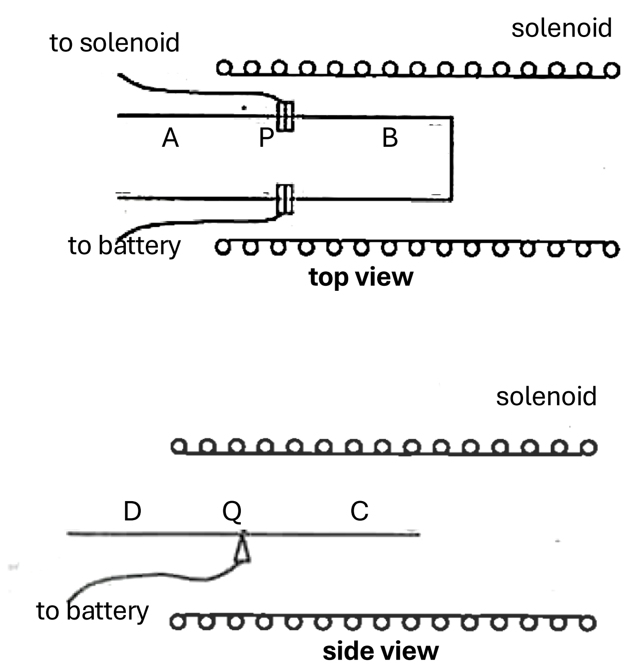

Fig. 7.1

Electrical connections are made to the frame through the knife-edges so that part PBCQ of the frame and the solenoid can be connected in series with a battery. When there is no current in the circuit, the frame is horizontal.

(i) The solenoid has 700 turns m^{-1} and carries a current of 3.5 A. Calculate the magnetic flux density in the region of side BC of the frame.

magnetic flux density = …………………… T [1]

(ii) Side BC has length 5.0 cm. Calculate the force acting on BC due to the magnetic field in the solenoid.

force = …………………… N [2]

(iii) If the magnetic force acting on BC is downwards, a small piece of paper of mass 0.10 g has to be placed on the side DQ to keep the frame horizontal.

Given that length of QC is 15 cm, calculate the distance from the knife-edge that the piece of paper needs to be positioned.

distance from the knife-edge = …………………… cm [2]

(c) A method of measuring the specific charge e/m_e of the electron is illustrated in Fig. 7.2.

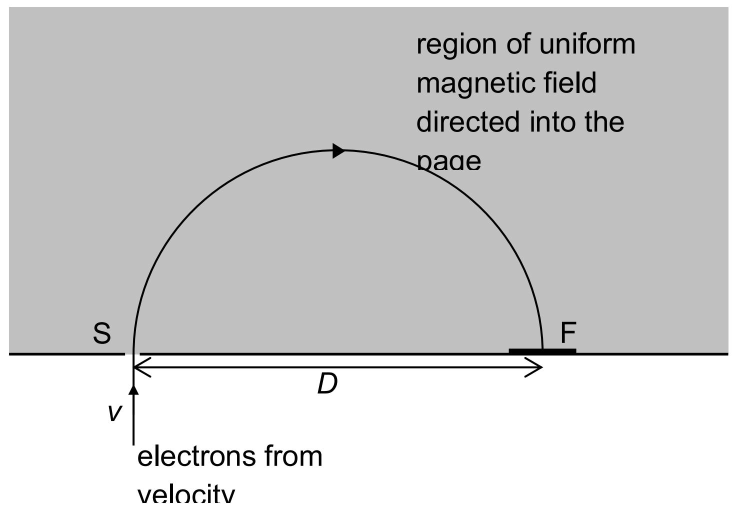

Fig. 7.2

A narrow beam of electrons, all moving with fixed speed v determined by a velocity selector, passes through a narrow slit S in an evacuated chamber where a uniform magnetic field of flux density B is applied perpendicularly into the page. Electrons emerging from the slit S move in a semicircular path and hit a photographic plate F at a distance D from S. When the plate is removed and developed, it is found that a sharp, dark image of the slit is formed. The distance D can then be measured, and with knowledge of v and B, allows the quantity e/m_e (specific charge) to be calculated.

(i) In the space below, draw a clear fully labelled diagram to illustrate the direction of the force F acting on a positive charge moving with velocity v at an angle θ to a uniform magnetic field of flux density B.

[1]

(ii) Show that the specific charge of electron is given by

$$e/m_e = \frac{2v}{BD} .$$

[2]

(iii) In a certain experiment, the speed of the electrons is 1.50×10^6 m s^{-1} and the distance D is 68.5 mm. The magnetic flux density is 2.50×10^{-4} T.

Calculate the value of the specific charge corresponding to these data.

specific charge = …………………… C kg^{-1} [2]

(iv) Because of the finite widths of slits in the velocity selector and at S, the electrons do not all move with the same speed. This causes broadening of the image of the slit.

Some electrons are found to emerge at small angles at either side of the normal. The situation is illustrated in Fig. 7.3.

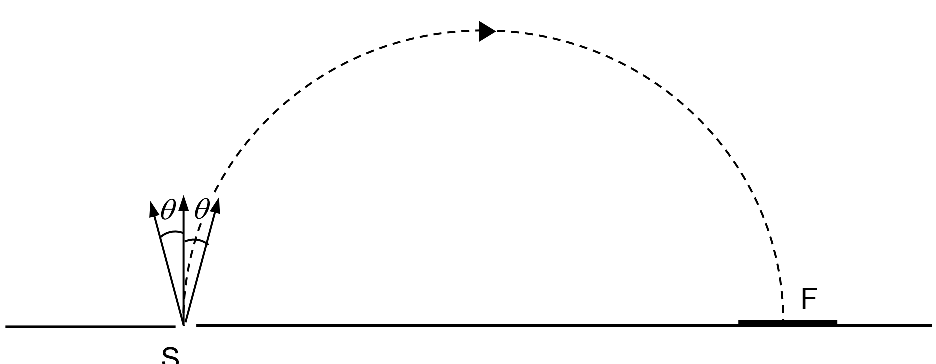

Fig. 7.3

1. For electrons leaving S with the same speed v at an angle θ on each side of the normal at S, draw and label their trajectories on Fig. 7.3.

[2]

2. Hence, discuss the error that would arise in D due to this divergence of the electron paths at S.

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

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

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

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

(d) Another method of determining the specific charge of the electron is to replace the magnetic field of Fig. 7.2 by a radial electric field of constant magnitude as shown in Fig. 7.4.

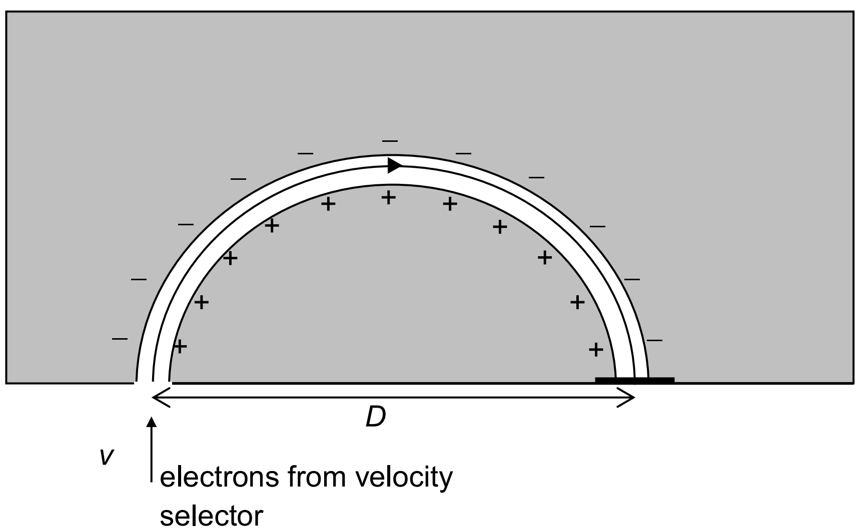

Fig. 7.4

Obtain an expression for the specific charge of the electron for this set-up, in terms of v, D and the electric field E.

[1]

[Total: 20]