MAGNETIC FIELD

1 **(a)** Define the *tesla*.

....

....

....

.... [3]

(b) A large horseshoe magnet produces a uniform magnetic field of flux density *B* between its poles. Outside the region of the poles, the flux density is zero.
The magnet is placed on a top-pan balance and a stiff wire XY is situated between its poles, as shown in Fig. 6.1.

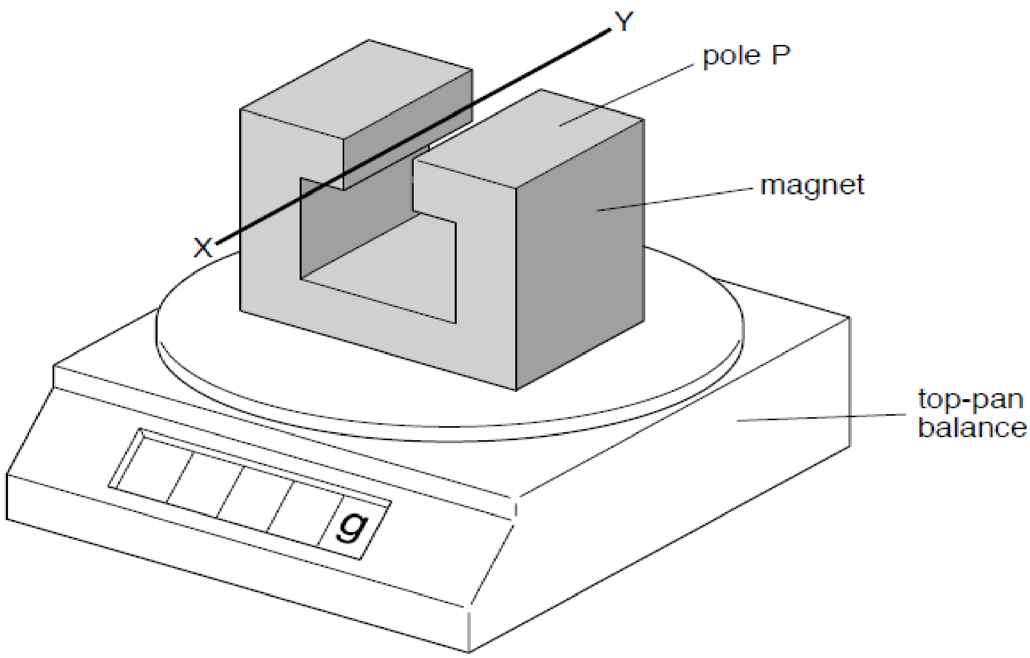

Fig. 6.1

The wire XY is horizontal and normal to the magnetic field. The length of wire between the poles is 4.4 cm.
A direct current of magnitude 2.6 A is passed through the wire in the direction from X to Y.
The reading on the top-pan balance increases by 2.3 g.

(i) State and explain the polarity of the pole P of the magnet.

....

....

....

.... [3]

(ii) Calculate the flux density between the poles.

flux density = ... T [3]

(c) The direct current in **(b)** is now replaced by a very low frequency sinusoidal current of r.m.s. value 2.6 A.
Calculate the variation in the reading of the top-pan balance.

variation in reading = ... g [2]

2 The current in a long, straight vertical wire is in the direction XY, as shown in Fig. 6.1.

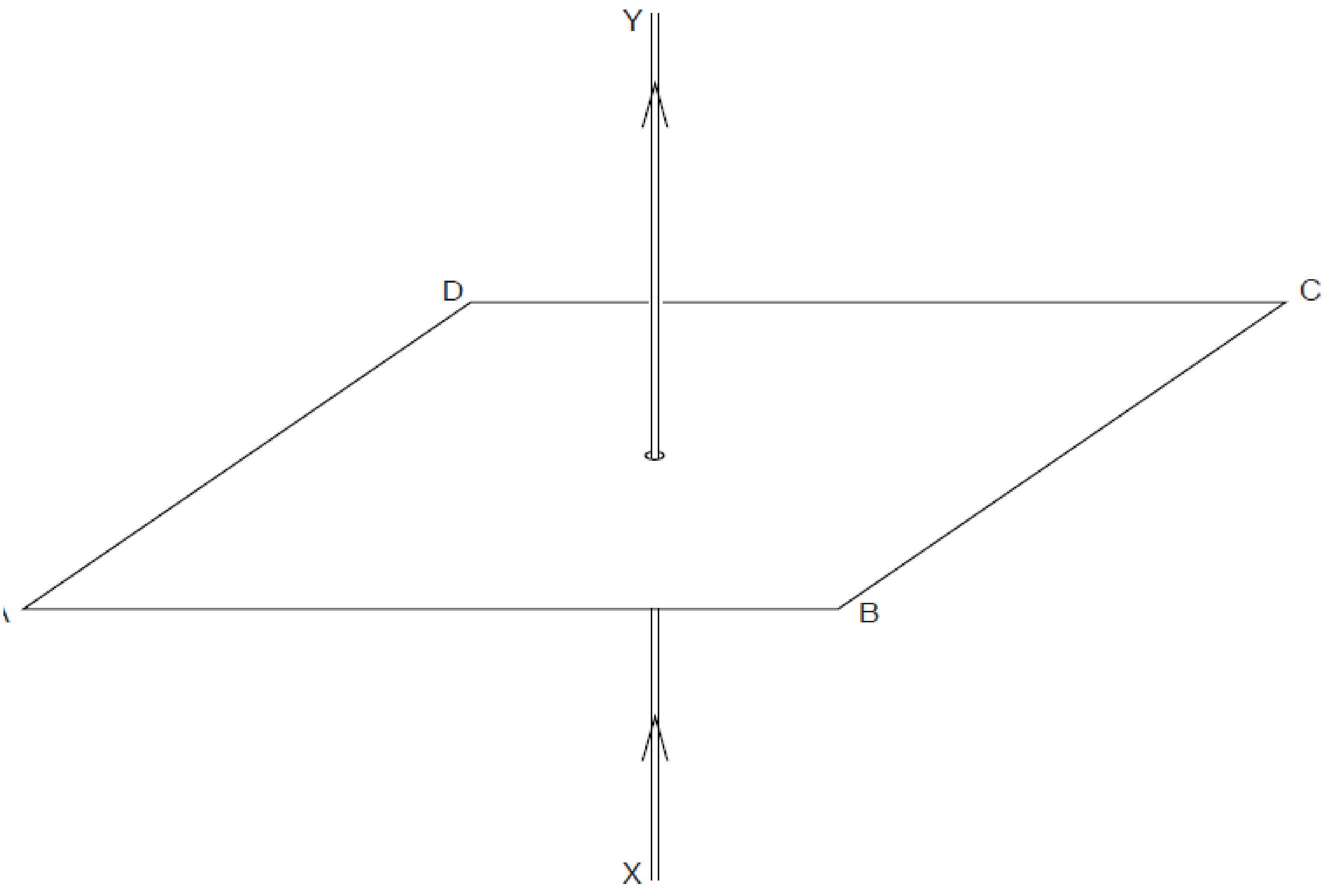

Fig. 6.1

(a) On Fig. 6.1, sketch the pattern of the magnetic flux in the horizontal plane ABCD due to the current-carrying wire. Draw at least four flux lines. [3]

(b) The current-carrying wire is within the Earth's magnetic field. As a result, the pattern drawn in Fig. 6.1 is superposed with the horizontal component of the Earth's magnetic field.

Fig. 6.2 shows a plan view of the plane ABCD with the current in the wire coming out of the plane.

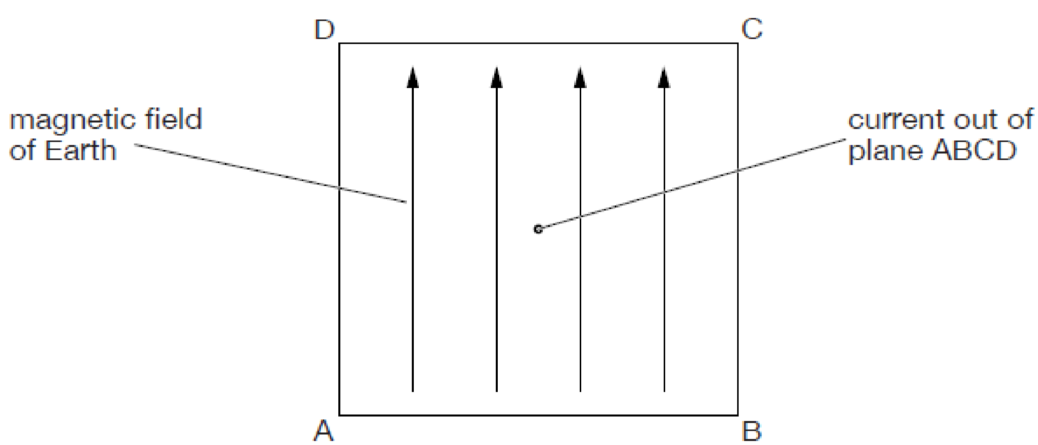

Fig. 6.2

The horizontal component of the Earth's magnetic field is also shown.

(i) On Fig. 6.2, mark with the letter P a point where the magnetic field due to the current-carrying wire could be equal and opposite to that of the Earth. [1]

(ii) For a long, straight wire carrying current I, the magnetic flux density B at distance r from the centre of the wire is given by the expression

$$B = \mu_0 \frac{I}{2\pi r}$$

where μ_0 is the permeability of free space.

The point P in **(i)** is found to be 1.9 cm from the centre of the wire for a current of 1.7 A.

Calculate a value for the horizontal component of the Earth's magnetic flux density.

flux density = ... T [2]

(c) The current in the wire in **(b)(ii)** is increased. The point P is now found to be 2.8 cm from the wire.

Determine the new current in the wire.

current = ... A [2]

3 Two long straight vertical wires X and Y pass through a horizontal card, as shown in Fig. 5.1.

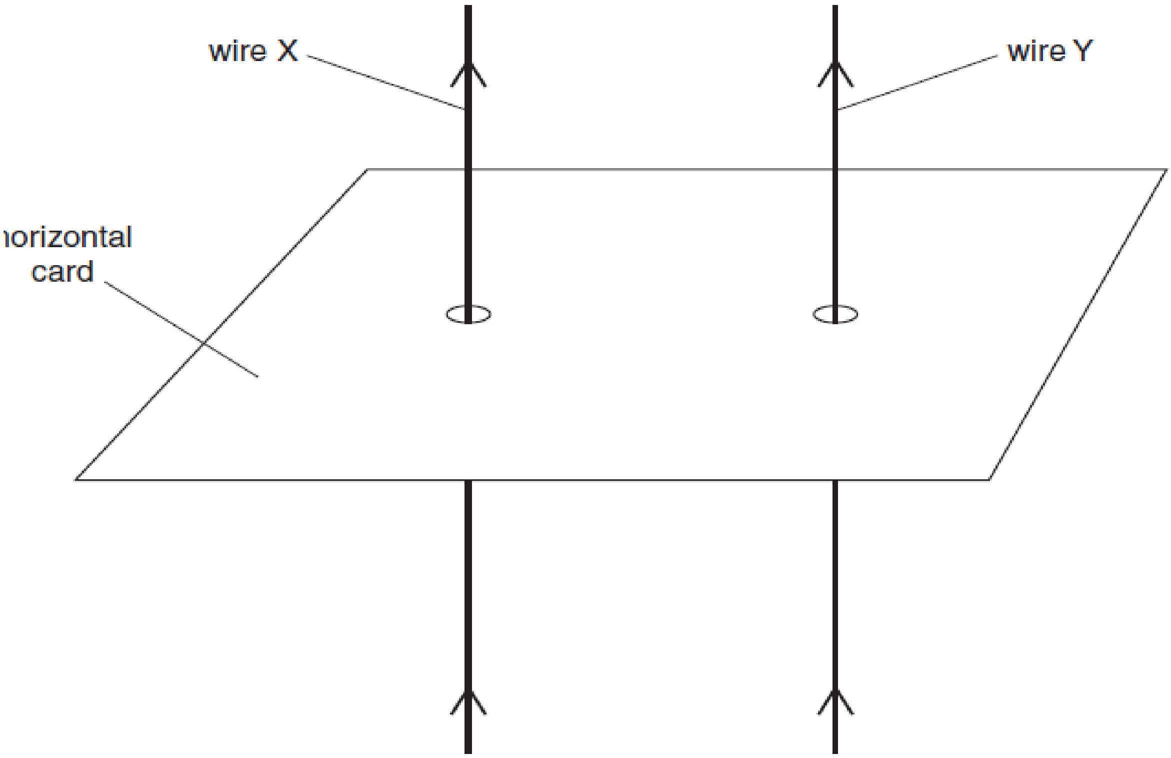

Fig. 5.1

The current in each wire is in the upward direction.

The top view of the card, seen by looking vertically downwards at the card, is shown in Fig. 5.2.

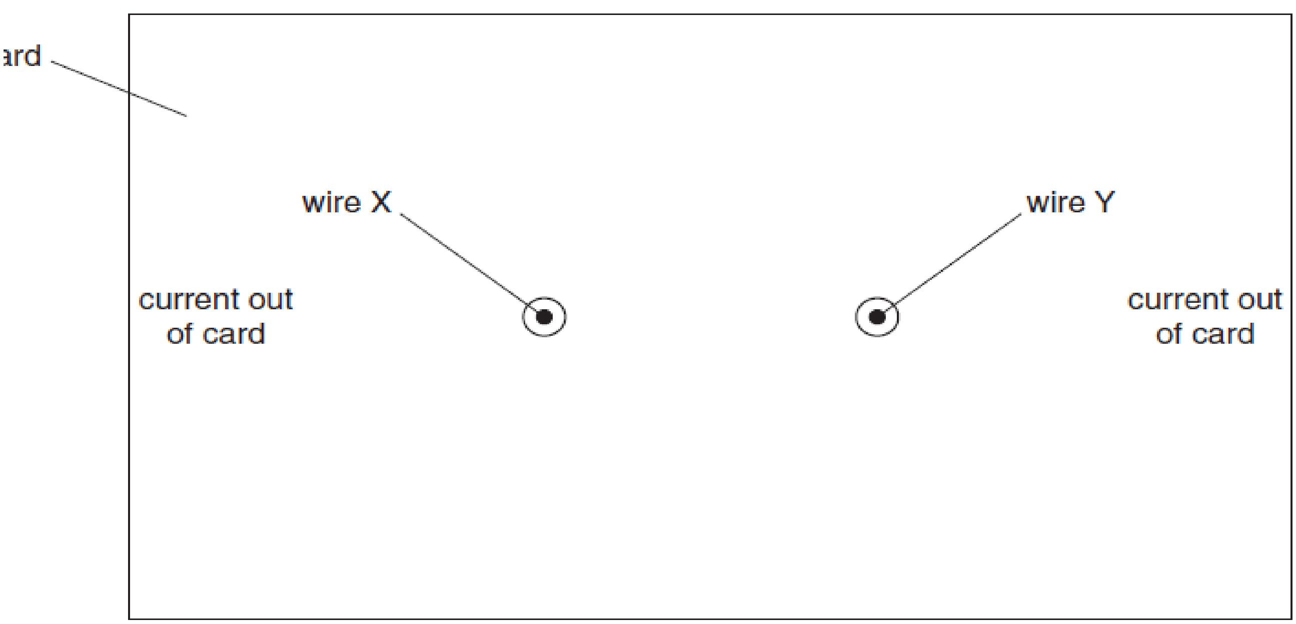

Fig. 5.2 (not to scale)

(a) On Fig. 5.2,

(i) draw four field lines to represent the pattern of the magnetic field around wire X due solely to the current in wire X, [2]

(ii) draw an arrow to show the direction of the force on wire Y due to the magnetic field of wire X. [1]

(b) The magnetic flux density B at a distance x from a long straight wire due to a current I in the wire is given by the expression

$$B = \frac{\mu_0 I}{2\pi x},$$

where μ_0 is the permeability of free space.

The current in wire X is 5.0 A and that in wire Y is 7.0 A. The separation of the wires is 2.5 cm.

(i) Calculate the force per unit length on wire Y due to the current in wire X.

force per unit length = ... $N m^{-1}$ [4]

(ii) The currents in the wires are not equal.

State and explain whether the forces on the two wires are equal in magnitude.

....

....

.... [2]

4 **(a)** A uniform magnetic field has constant flux density *B*. A straight wire of fixed length carries a current *I* at an angle *θ* to the magnetic field, as shown in Fig. 6.1.

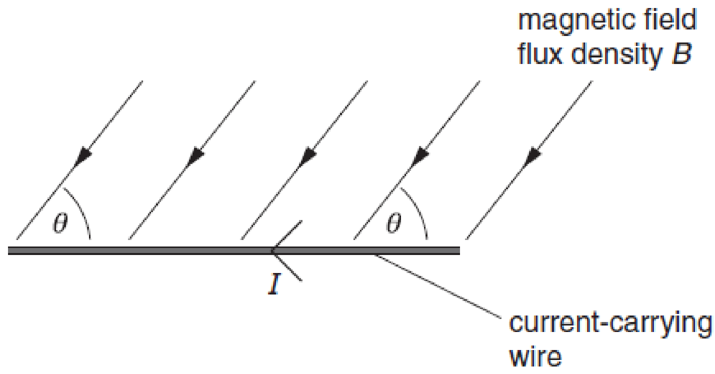

Fig. 6.1

(i) The current *I* in the wire is changed, keeping the angle *θ* constant.
On Fig. 6.2, sketch a graph to show the variation with current *I* of the force *F* on the wire.

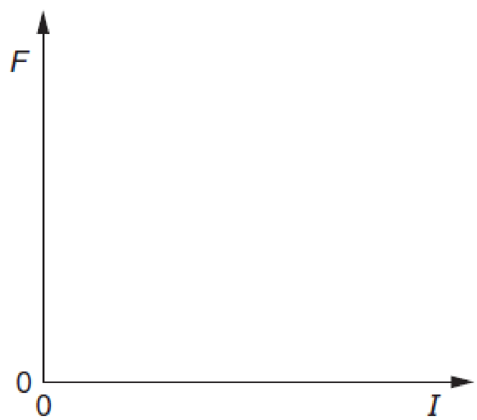

Fig. 6.2

[2]

(ii) The angle θ between the wire and the magnetic field is now varied. The current I is kept constant.
On Fig. 6.3, sketch a graph to show the variation with angle θ of the force F on the wire.

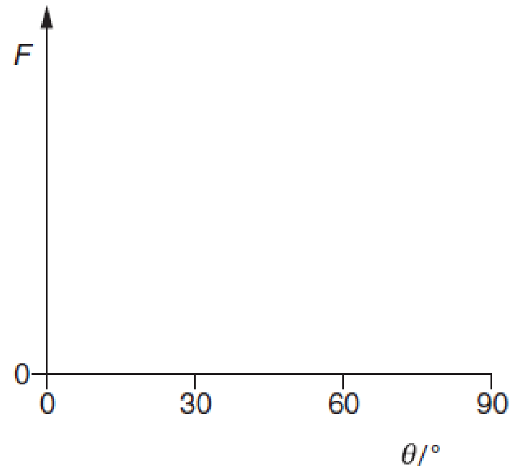

Fig. 6.3 [3]

(b) A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 6.4.

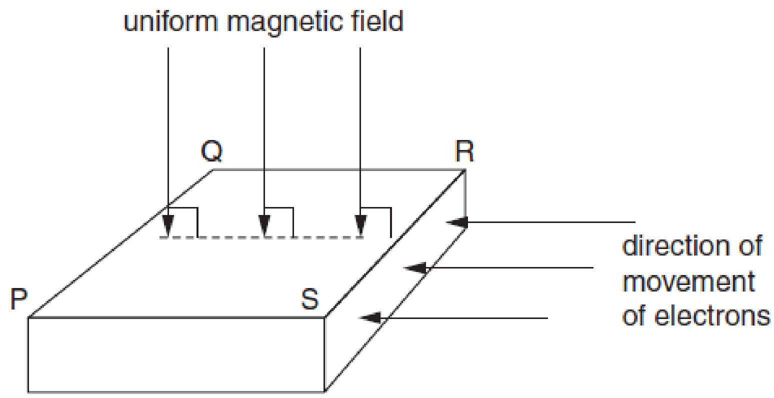

Fig. 6.4

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

(i) Explain why, initially, the electrons do not travel in straight lines across the slice from side SR to side PQ.

....

....

.... [2]

(ii) Explain to which side, PS or QR, the electrons tend to move.

....

....

.... [2]

5

Positive ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field of flux density *B* and are deflected in a semi-circular arc, as shown in Fig. 5.1.

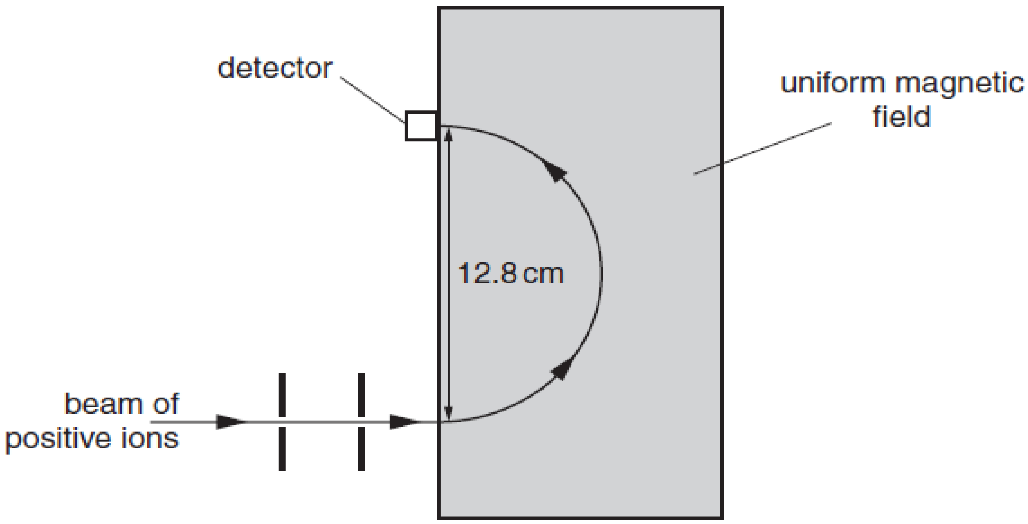

Fig. 5.1

The ions, travelling with speed $1.40 \times 10^5\,\mathrm{m\,s^{-1}}$, are detected at a fixed detector when the diameter of the arc in the magnetic field is 12.8 cm.

(a) By reference to Fig. 5.1, state the direction of the magnetic field.

.... [1]

(b) The ions have mass 20 u and charge $+1.6 \times 10^{-19}$ C. Show that the magnetic flux density is 0.454 T. Explain your working.

[3]

(c) Ions of mass 22 u with the same charge and speed as those in **(b)** are also present in the beam.

(i) On Fig. 5.1, sketch the path of these ions in the magnetic field of magnetic flux density 0.454 T. [1]

(ii) In order to detect these ions at the fixed detector, the magnetic flux density is changed.
Calculate this new magnetic flux density.

magnetic flux density = ... T [2]

ELECTROMAGNETIC INDUCTION

1 A small rectangular coil ABCD contains 140 turns of wire. The sides AB and BC of the coil are of lengths 4.5 cm and 2.8 cm respectively, as shown in Fig. 6.1.

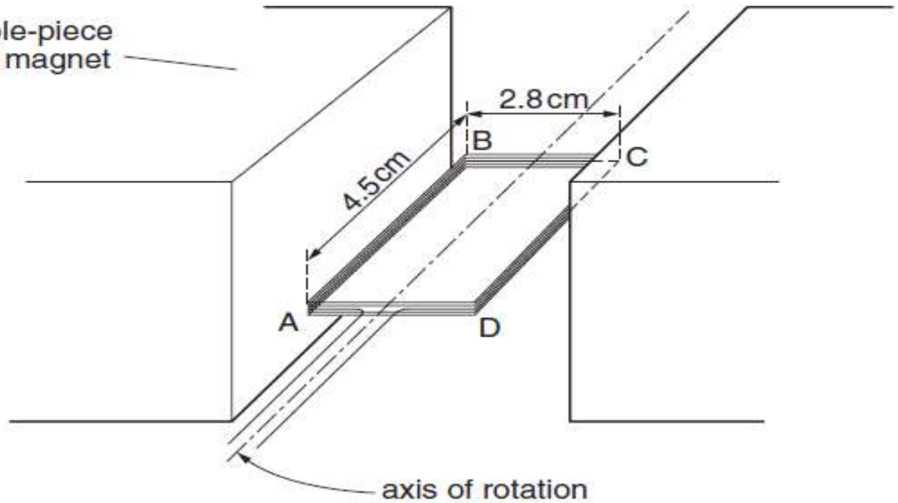

Fig. 6.1

The coil is held between the poles of a large magnet so that the coil can rotate about an axis through its centre.
The magnet produces a uniform magnetic field of flux density *B* between its poles.
When the current in the coil is 170 mA, the maximum torque produced in the coil is 2.1×10^{-3} N m.

(a) For the coil in the position for maximum torque, state whether the plane of the coil is parallel to, or normal to, the direction of the magnetic field.

.... [1]

(b) For the coil in the position shown in Fig. 6.1, calculate the magnitude of the force on

(i) side AB of the coil,

force = ... N [2]

(ii) side BC of the coil.

force = ... N [1]

(c) Use your answer to **(b)(i)** to show that the magnetic flux density *B* between the poles of the magnet is 70 mT.

[2]

(d) **(i)** State Faraday's law of electromagnetic induction.

....

....

.... [2]

(ii) The current in the coil in **(a)** is switched off and the coil is positioned as shown in Fig. 6.1.
The coil is then turned through an angle of 90° in a time of 0.14 s.
Calculate the average e.m.f. induced in the coil.

e.m.f. = ... V [3]