Magnetic Fields & Moving Charges

Question paper 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Magnetic Fields
Sub Topic	Magnetic Fields & Moving Charges
Paper Type	Theory
Booklet	Question paper 3

Time Allowed: **75 minutes**

Score: **/62**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 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.

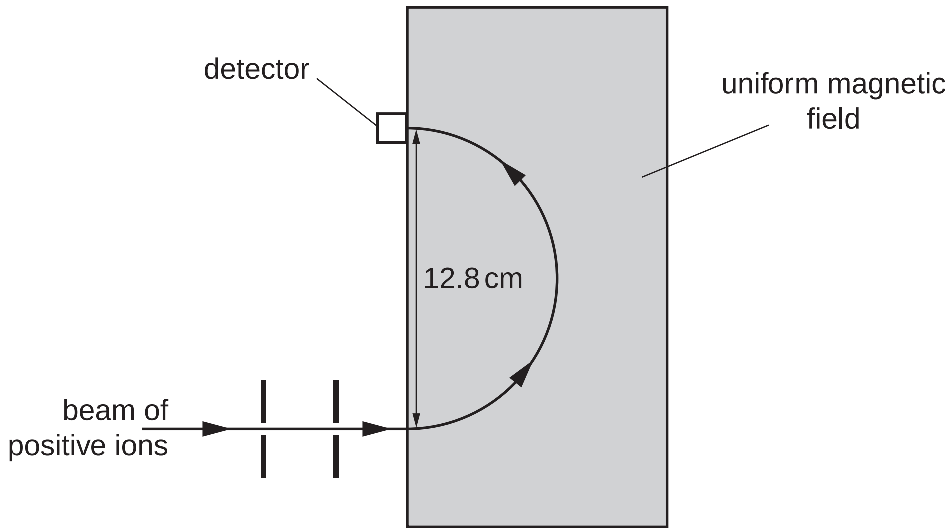

Fig. 5.1

The ions, travelling with speed $1.40 \times 10^5\,\text{m s}^{-1}$, 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]

2 Electrons are moving through a vacuum in a narrow beam. The electrons have speed v.
The electrons enter a region of uniform magnetic field of flux density B. Initially, the electrons are travelling at a right-angle to the magnetic field.
The path of a single electron is shown in Fig. 7.1.

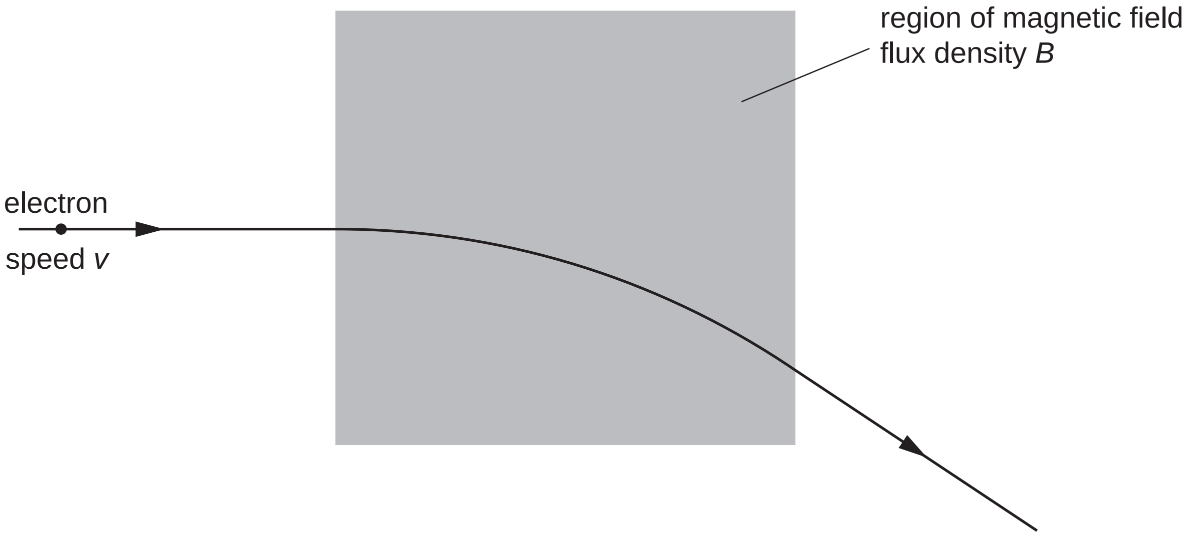

Fig. 7.1

The electrons follow a curved path in the magnetic field.

A uniform electric field of field strength E is now applied in the same region as the magnetic field.
The electrons pass undeviated through the region of the two fields.
Gravitational effects may be neglected.

(a) Derive a relation between v, E and B for the electrons not to be deflected. Explain your working.

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.... [3]

(b) An α-particle has speed v and approaches the region of the two fields along the same path as the electron. Describe and explain the path of the α-particle as it passes through the region of the two fields.

....

....

.... [2]

3 Negatively-charged particles are moving through a vacuum in a parallel beam. The particles have speed *v*.
The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 7.1.

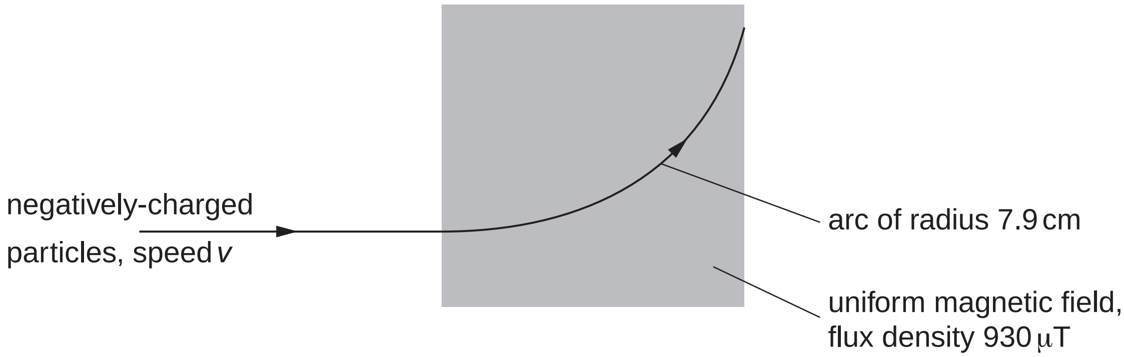

Fig. 7.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 kV m^{-1}, the particles are undeviated as they pass through the region of the fields.

(a) On Fig. 7.1, mark with an arrow the direction of the electric field. [1]

(b) Calculate, for the negatively-charged particles,

(i) the speed *v*,

v = ... m s^{-1} [3]

(ii) the ratio $\frac{\text{charge}}{\text{mass}}$.

ratio = ... C kg^{-1} [3]

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.

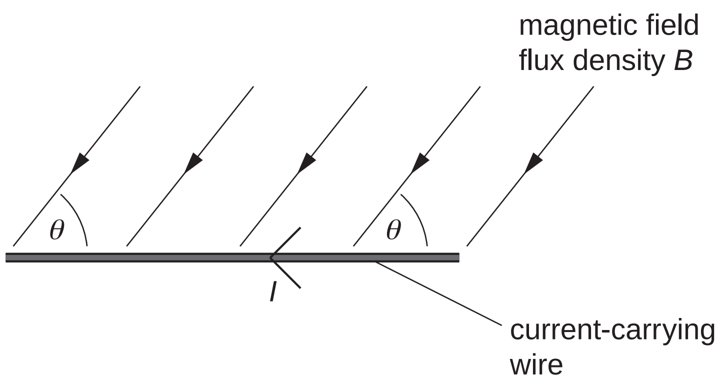

Fig. 6.1

(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.

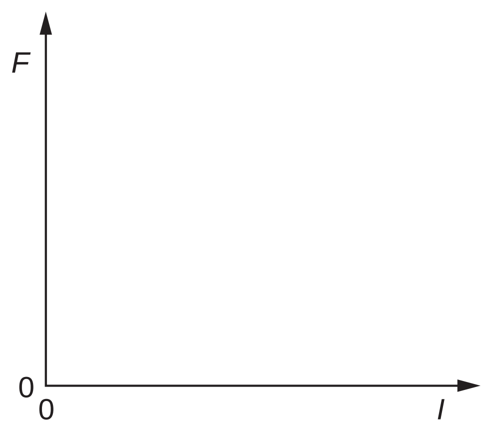

Fig. 6.2

[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.

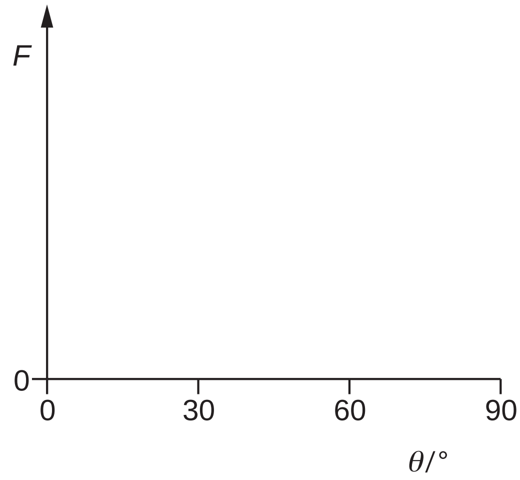

Fig. 6.3 [3]

(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.

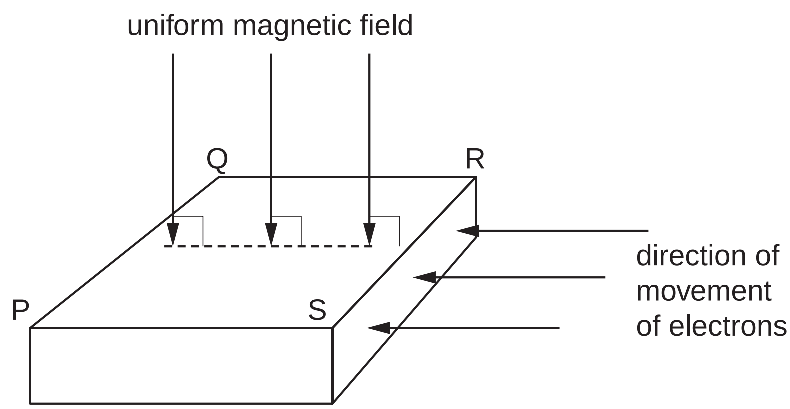

Fig. 6.4

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.

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.... [2]

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

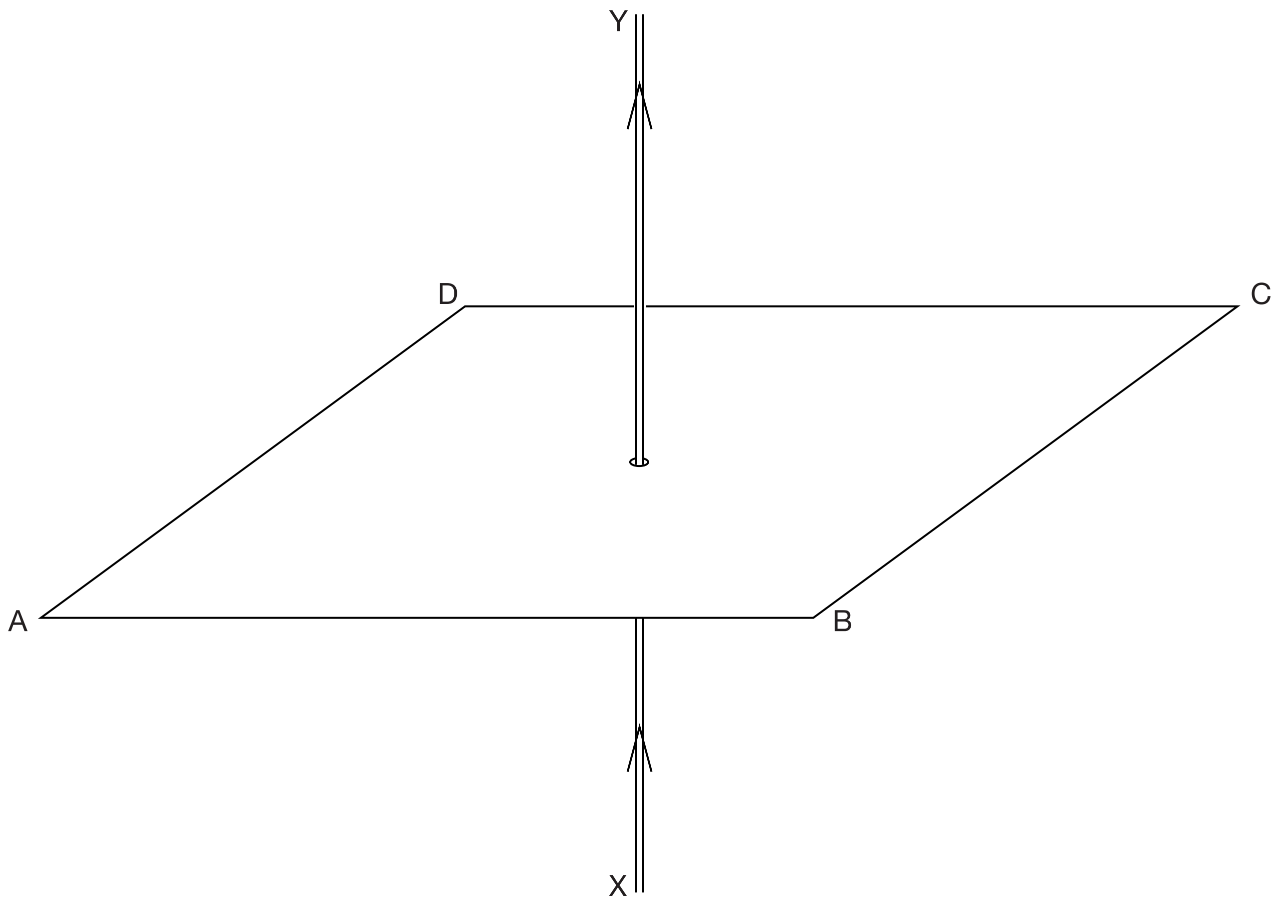

Fig. 6.1

(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.

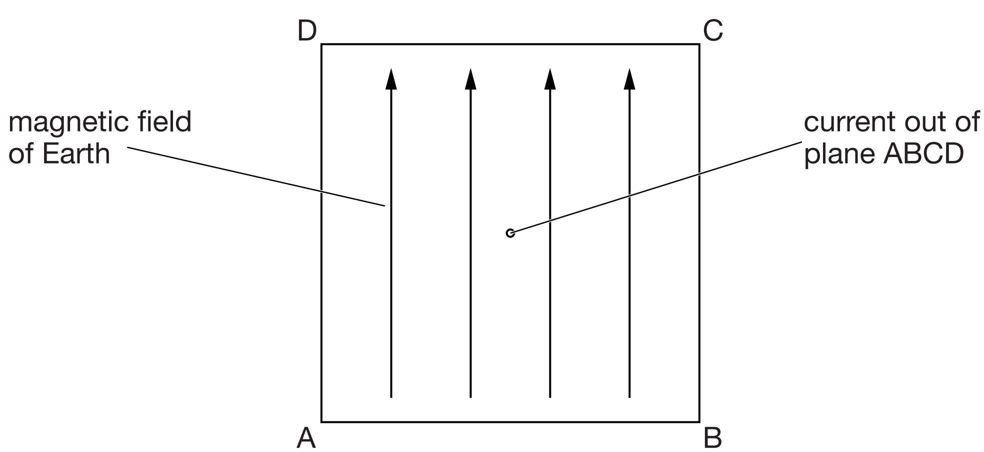

Fig. 6.2

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]

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

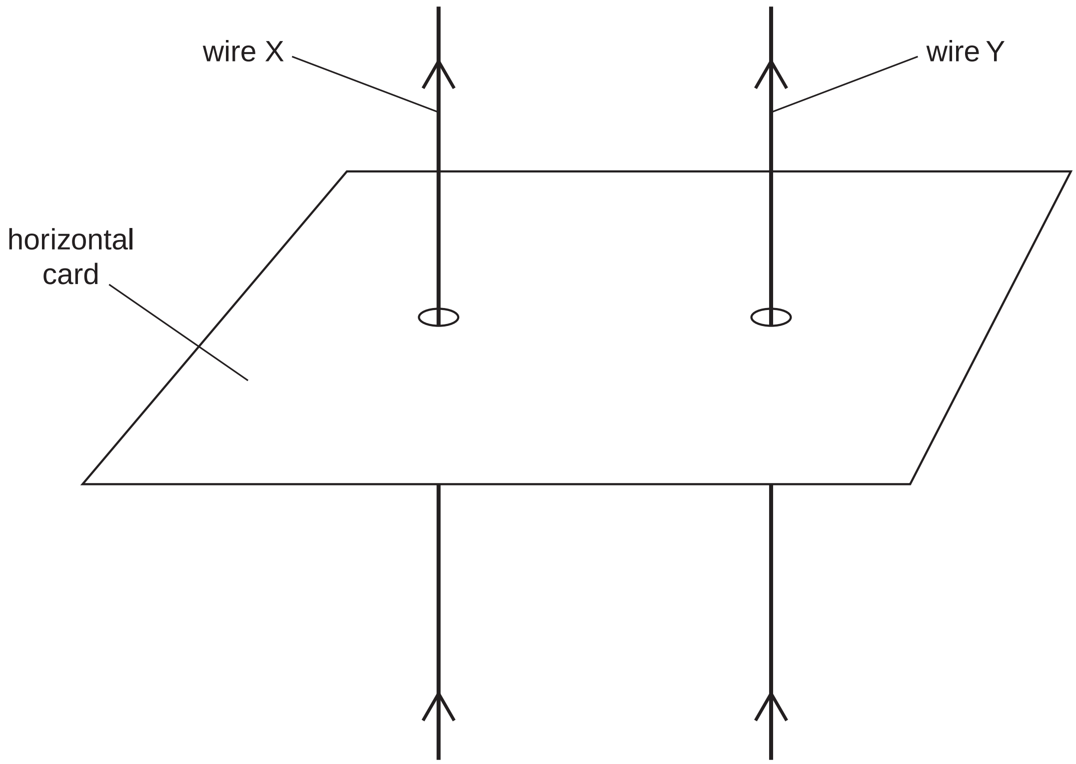

Fig. 5.1

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.

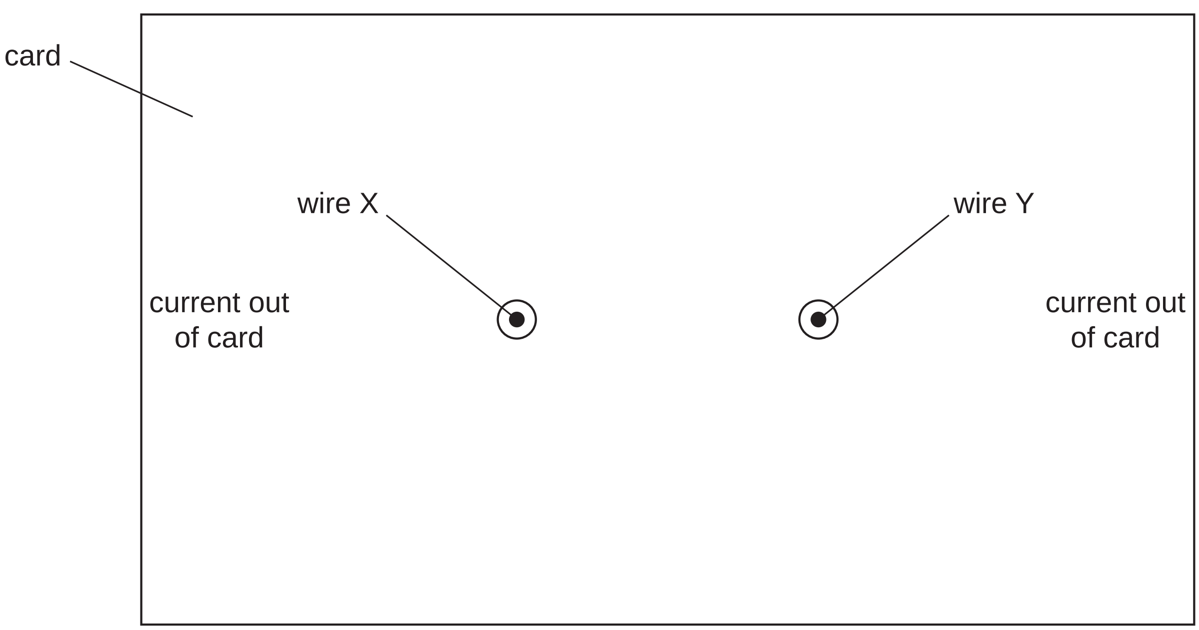

Fig. 5.2 (not to scale)

(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]

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

....

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.... [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.

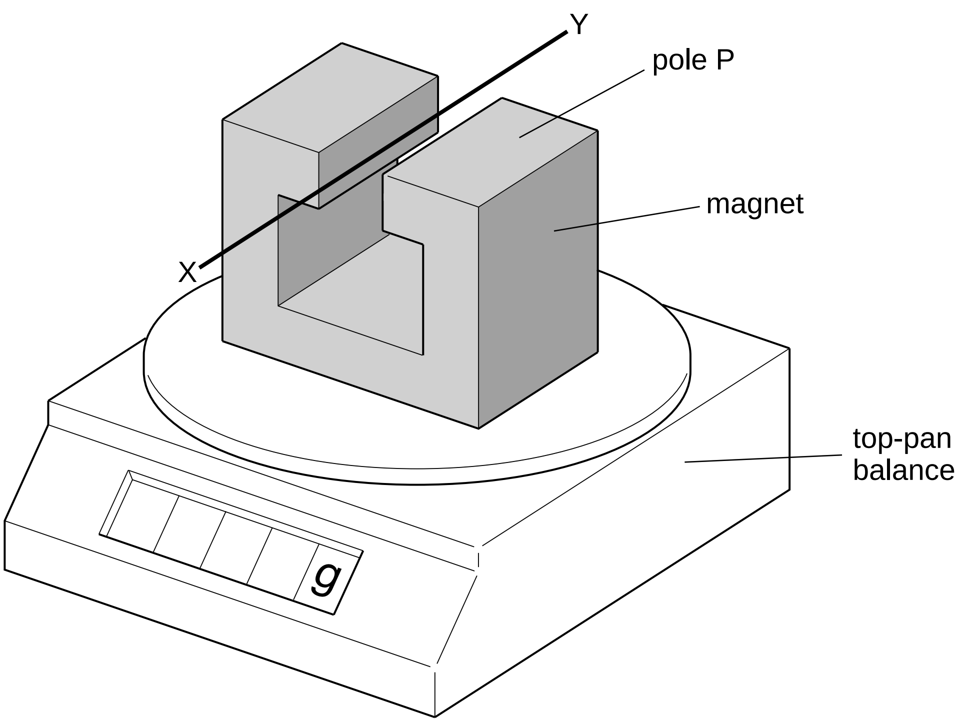

Fig. 6.1

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]

8 **(a)** Describe what is meant by a *magnetic field.*

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.... [3]

(b) A small mass is placed in a field of force that is either electric or magnetic or gravitational.
State the nature of the field of force when the mass is

(i) charged and the force is opposite to the direction of the field,

.... [1]

(ii) uncharged and the force is in the direction of the field,

.... [1]

(iii) charged and there is a force only when the mass is moving,

.... [1]

(iv) charged and there is no force on the mass when it is stationary or moving in a particular direction.

.... [1]