A charged particle passes through a region of uniform magnetic field of flux density 0.74 T, as shown in Fig. 5.1.

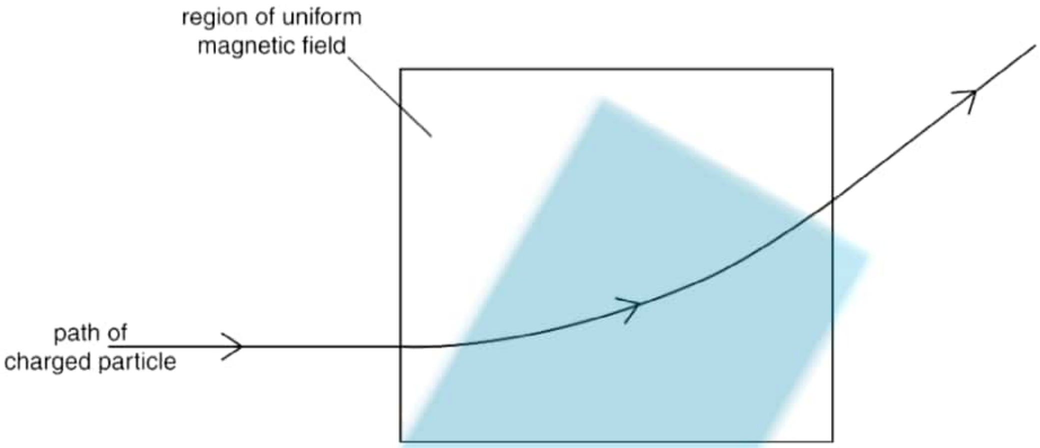

Fig. 5.1

The radius r of the path of the particle in the magnetic field is 23 cm.

(a) The particle is positively charged. State the direction of the magnetic field.

Into the sreen ....[1]

(b) **(i)** Show that the specific charge of the particle (the ratio $\frac{q}{m}$ of its charge to its mass) is given by the expression

$$\frac{q}{m} = \frac{v}{rB},$$

where v is the speed of the particle and B is the flux density of the field.

$F_B = F_C$

$Bq\cancel{v} = \frac{mv^{\cancel{2}}}{r}$

$\frac{q}{m} = \frac{v}{rB}$

[2]

(ii) The speed v of the particle is $8.2 \times 10^6\,\mathrm{m\,s^{-1}}$. Calculate the specific charge of the particle.

$$\frac{8.2 \times 10^6}{0.23 \times 0.74}$$

specific charge = 4.82×10^7 $\mathrm{C\,kg^{-1}}$ [2]

(c) **(i)** The particle in **(b)** has charge 1.6×10^{-19} C. Using your answer to **(b)(ii)**, determine the mass of the particle in terms of the unified atomic mass constant u.

$$\frac{1.6 \times 10^{-19}}{4.82 \times 10^7} = m \qquad m = 3.32 \times 10^{-27}$$

mass = 2 u [2]

(ii) The particle is the nucleus of an atom. Suggest the composition of this nucleus.

1 Proton , 1 neutron

....................[1]

(a) An electron is accelerated from rest in a vacuum through a potential difference of 1.2×10^4 V.

Show that the final speed of the electron is $6.5 \times 10^7\, m\, s^{-1}$.

Potential difference $\Delta V q = \frac{1}{2} m v^2$ velocity

$$\sqrt{\frac{1.2 \times 10^4 \times 1.6 \times 10^{-19}}{\frac{1}{2} \times 9.1 \times 10^{-31}}} = 6.495 \times 10^7$$
$$= 6.7 \times 10^7\, m s^{-1}$$

[2]

(b) The accelerated electron now enters a region of uniform magnetic field acting into the plane of the paper, as illustrated in Fig. 5.1.

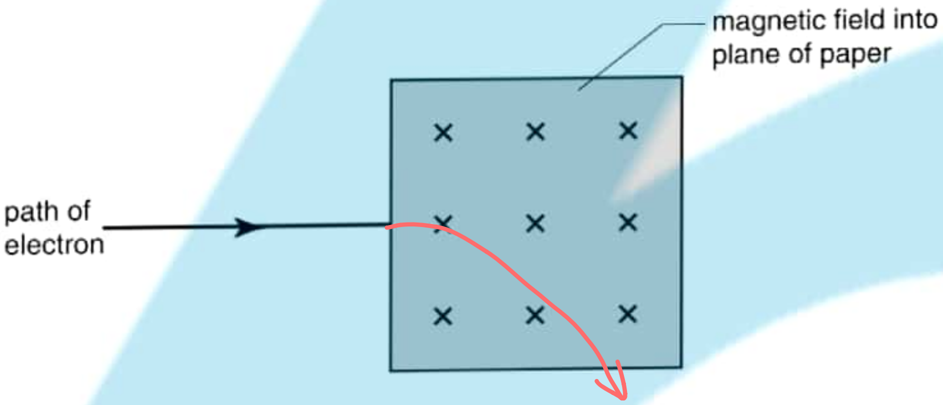

Fig. 5.1

(i) Describe the path of the electron as it passes through, and beyond, the region of the magnetic field. You may draw on Fig. 5.1 if you wish.

path within field: circular arc in downward direction

path beyond field: straight without any kink on leaving the field. [3]

(ii) State and explain the effect on the magnitude of the deflection of the electron in the magnetic field if, separately,

1. the potential difference accelerating the electron is reduced,

$r = \frac{mv}{Bq}$, if V is decreased, v decreases and thus value of r will decrease, thus more deflection [2]

2. the magnetic field strength is increased.

$r = \frac{mv}{Bq}$, If B increases, r decreases, thus more deflection [2]

Two long, straight, current-carrying conductors, PQ and XY, are held a constant distance apart, as shown in Fig. 6.1.

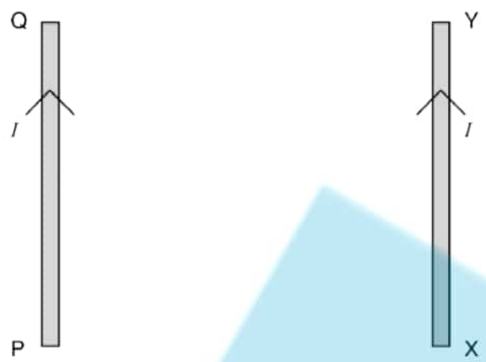

Fig. 6.1

The conductors each carry the same magnitude current in the same direction.

A plan view from above the conductors is shown in Fig. 6.2.

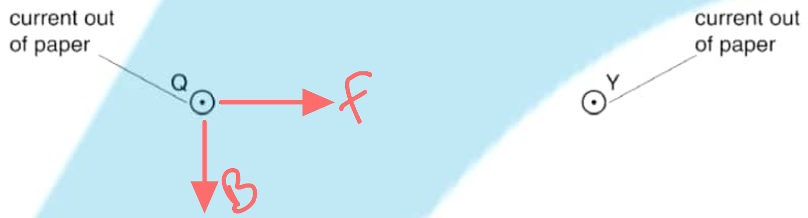

Fig. 6.2

(a) On Fig. 6.2 draw arrows, one in each case, to show the direction of

(i) the magnetic field at Q due to the current in wire XY (label this arrow B), [1]

(ii) the force at Q as a result of the magnetic field due to the current in wire XY (label this arrow F). [1]

(b) (i) State Newton's third law of motion.

Every action has an equivalent and opposite reaction

.... [1]

(ii) Use this law and your answer in **(a)(ii)** to state the direction of the force on wire XY.

towards the left

.... [1]

(c) The magnetic flux density B at a distance d from a long straight wire carrying a current I is given by

$$B = 2.0 \times 10^{-7} \times \frac{I}{d}.$$

Use this expression to explain why, under normal circumstances, wires carrying alternating current are not seen to vibrate. Make reasonable estimates of the magnitudes of the quantities involved.

$F = BIL$ say $I = 1A$

$= \frac{2 \times 10^{-7} \times I^2 L}{d}$ $L = 10\,cm = 0.1\,m$

$d = 1\,cm = 0.01\,m$

$\therefore F = \frac{2 \times 10^{-7} \times 1^2 \times 0.1}{0.01} = 2 \times 10^{-6}\,N$

F is very small [4]

(a) A straight conductor carrying a current I is at an angle θ to a uniform magnetic field of flux density B, as shown in Fig. 6.1.

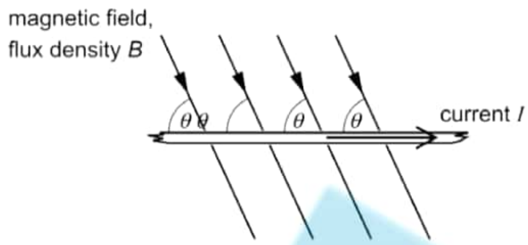

Fig. 6.1

The conductor and the magnetic field are both in the plane of the paper. State

(i) an expression for the force per unit length acting on the conductor due to the magnetic field,

force per unit length = $BI\sin\theta$ ....[1]

(ii) the direction of the force on the conductor.

into the page. ....[1]

15

(b) A coil of wire consisting of two loops is suspended from a fixed point as shown in Fig. 6.2.

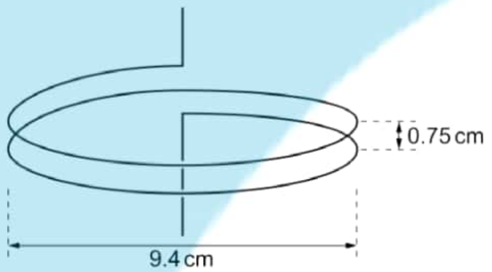

Fig. 6.2

Each loop of wire has diameter 9.4 cm and the separation of the loops is 0.75 cm.
The coil is connected into a circuit such that the lower end of the coil is free to move.

(i) Explain why, when a current is switched on in the coil, the separation of the loops of the coil decreases.

Magnetic field due to the current in 1 loop is normal to the current in the second loop, which will cause a force on the it and because of newtons 1st law the force on the second will be equal and opposite ....[4]

(ii) Each loop of the coil may be considered as being a long straight wire.
In SI units, the magnetic flux density B at a distance x from a long straight wire carrying a current I is given by the expression

$$B = 2.0 \times 10^{-7}\,\frac{I}{x}.$$

When the current in the coil is switched on, a mass of 0.26 g is hung from the free end of the coil in order to return the loops of the coil to their original separation.
Calculate the current in the coil.

$$f = BIL$$

$$= \frac{2\times10^{-7} \times I^2 \times L}{x}$$

$$I = \sqrt{\frac{Fx}{2\times10^{-7}\times L}} = \sqrt{\frac{\frac{0.26}{1000}\times 9.81\times\frac{0.75}{100}}{2\times10^{-7}\times\frac{2\pi\times4.7}{100}}} = 17.996 = 18A$$

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.

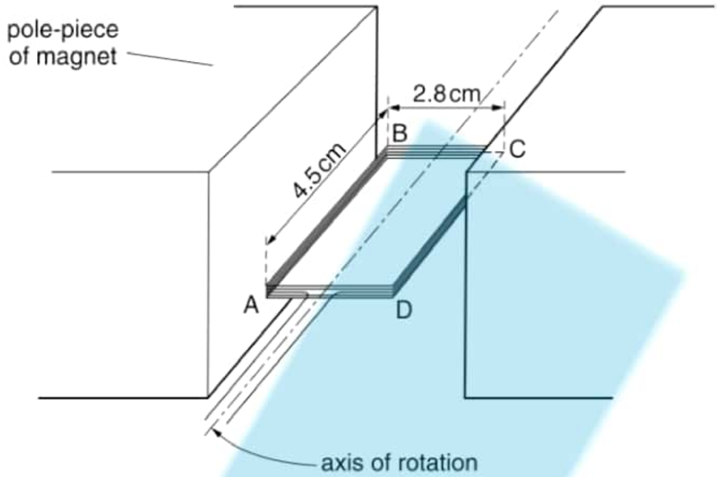

Fig. 6.1

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.

Paralles ..... [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,

$F \times d = T$

$F = \frac{T}{d}$

force = 0.075 N [2]

(ii) side BC of the coil.

force = 0 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.

$B = \frac{F}{IL} = \frac{0.075}{.170 \times \frac{4.5}{100}} = \frac{9.803}{140} = 70$ mT

[2]

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

Its a region of space where a force is experienced by a current carrying conductor, a charged particle, a pole

....[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,

electric ....[1]

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

Gravitational ....[1]

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

magnetic ....[1]

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

magnetic ....[1]

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

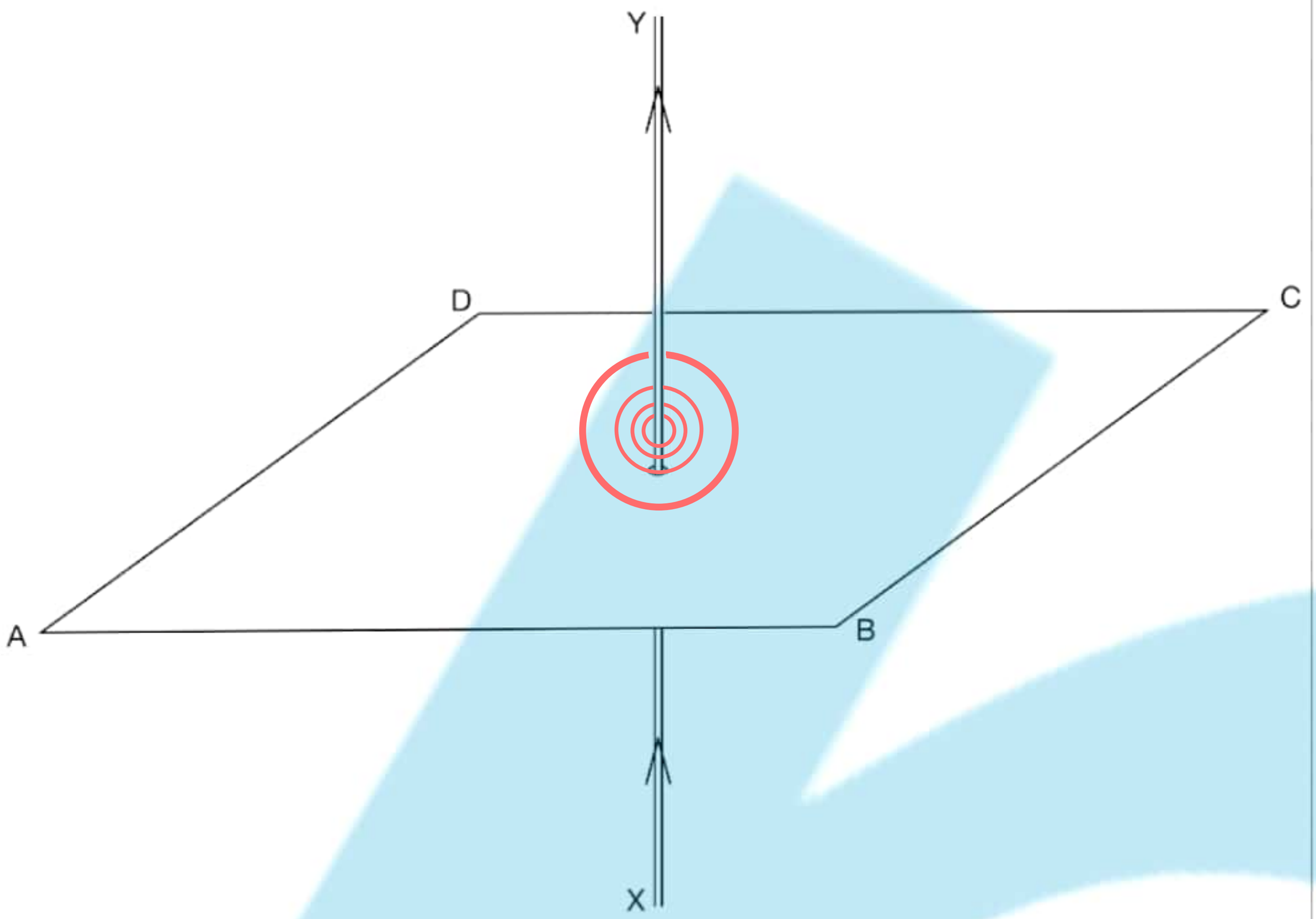

Fig. 6.1

(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.

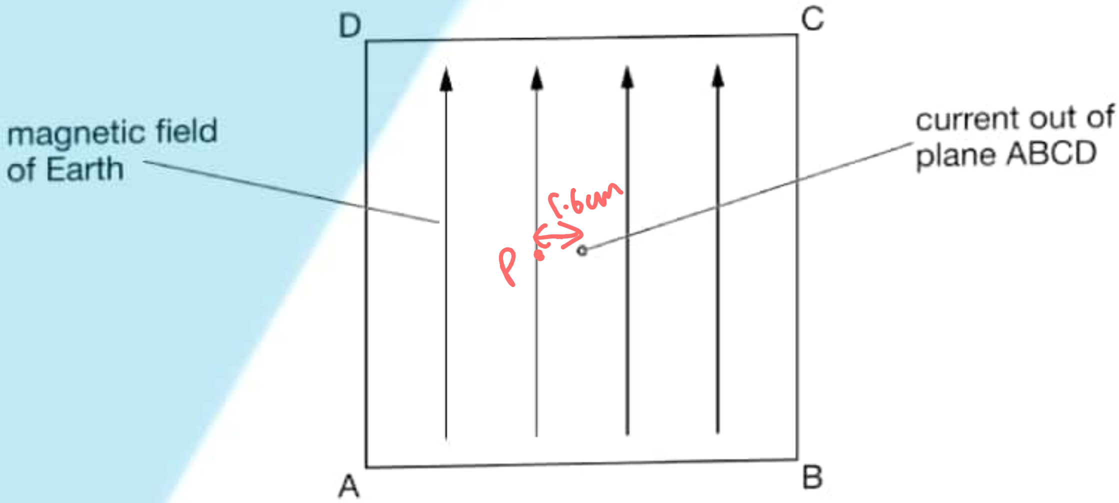

Fig. 6.2

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

$$B = \mu_0 \frac{I}{2\pi r}$$ 1.26×10^{-6}

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.

$$B = \frac{1.26 \times 10^{-6} \times 1.7}{2\pi \times \frac{1.9}{100}}$$

flux density = 1.8×10^{-5} 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.

$$I = \frac{B \times 2\pi r}{\mu_0} = \frac{1.7942 \times 10^{-5} \times 2\pi \times \frac{2.8}{100}}{1.26 \times 10^{-6}}$$

current = 2.5 A [2]

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