ELECTROMAGNETISM

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 **(a)** An electron is travelling at right angles to a uniform magnetic field of flux density **1.5 mT**, as illustrated in Fig 3.1.

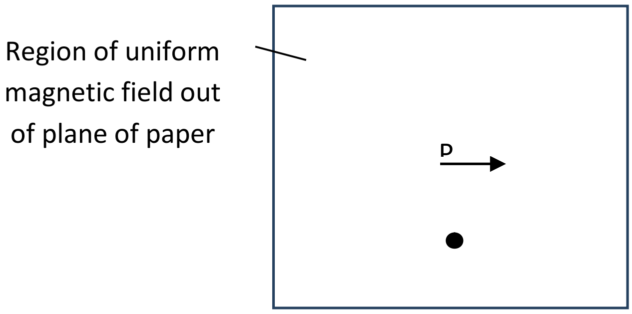


Fig 3.1

The magnetic field is acting out of the plane of the paper.

When the electron is at P, its velocity is **1.8×10^7 m s^{-1}** in the direction shown.

This is normal to the magnetic field.

(i) On Fig 3.1, sketch the path of the electron, assuming that it does not leave the region of the magnetic field.

[1]

(ii) **1.** Show that the force on the electron due to the magnetic field is **4.32×10^{-15} N**.

[1]

2. Hence calculate the radius of the electron's path.

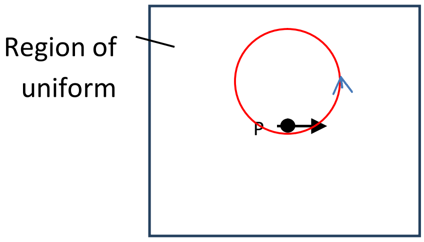
radius = ……………………….. m [3]

(b) A uniform electric field is now produced in the same region and in the opposite direction to the magnetic field. Suggest the shape of the resultant path of the electron and draw a sketch to illustrate the path.

……………………………………………………………………………………………

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

Ans (a)(i)



(ii) 1. $F_B = Bqv$

$= 1.5 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.8 \times 10^{7}$

$= 4.32 \times 10^{-15}$ N (Shown)

2. Magnetic force provides centripetal force for circular motion

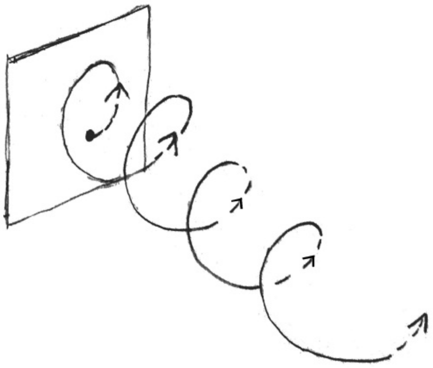
$$F_B = F_c$$

$$4.32 \times 10^{-15} = \frac{mv^2}{r}$$

$$r = \frac{9.11 \times 10^{-31} \times (1.8 \times 10^{7})^2}{4.32 \times 10^{-15}}$$

$$r = 0.068\ m$$

(b)



The helical path has progressively larger pitch

(since F_E acts out of the plane of the paper
⇨ Electrons accelerates out)

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

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(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 the wire XY is situated between its poles, as shown in Fig. 6.1.

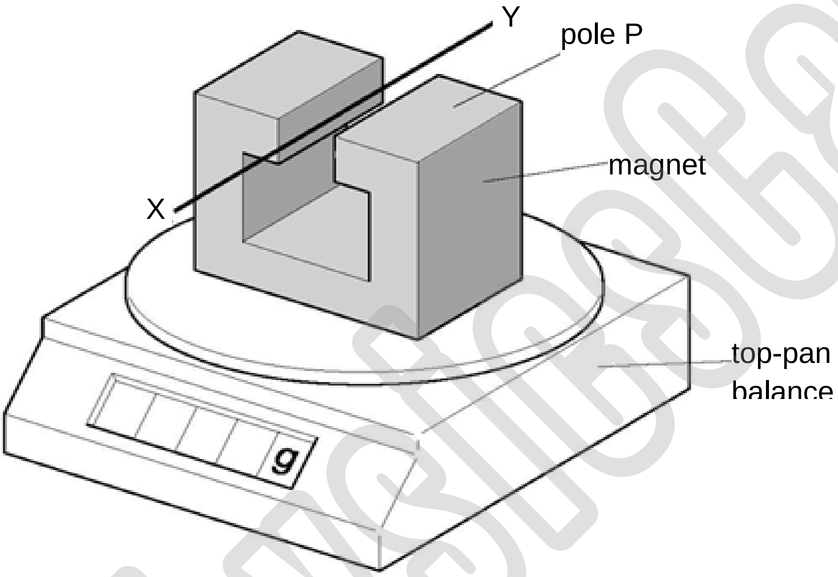


Fig. 6.1

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 [2]

(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 [1]

Ans **a** One **tesla** is the magnetic flux density which causes a force per unit length of one newton per metre on a straight wire carrying a current of one ampere and is at right angles to the direction of the magnetic field.

bi As seen from the increased balance reading, there is a downward force on magnet due to wire carrying current.
By Newton's third law, there is an upward force on wire by magnet.
By Fleming's left hand rule, pole P is a **north** pole

bii By Newton's 2nd law, $W - BIL = 0 \Rightarrow W = BIL$
$2.3 \times 10^{-3} \times 9.81 = B \times 2.6 \times 4.4 \times 10^{-2}$
B = 0.20 T (g = 10, loses this mark)

c Reading for maximum current = $2.6 \times \sqrt{2}$ = 3.68 A
$F = BIL = (0.20)(3.68)(4.4\times10^{-2}) = 0.032$ N
mg = 0.032 N, m = 0.032/9.81 = 3.3 g
total variation of mass = 2 x 3.3 = 6.6 g
OR

$$m = \frac{BL}{g} I \text{ , } m \propto I$$

$$\therefore \frac{m_{\text{max}}}{m_{dc}} = \frac{I_{\text{max}}}{I_{dc}} \Rightarrow \frac{m_{\text{max}}}{2.3} = \frac{2.6\sqrt{2}}{2.6}$$

$m_{\text{max}} = 2.3\sqrt{2} = 3.3$ g

total variation of mass = 3.3 x 2 = 6.6 g

3 **(a)** Two long, straight, current-carrying conductors, PQ and XY, are held a constant distance apart, as shown in Fig. 3.1.

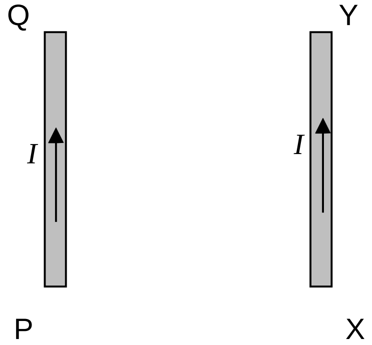


Fig. 3.1

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

A plan view from above the conductors is shown in Fig. 3.2.

Fig. 3.2

(i) On Fig. 3.2 draw arrows, one in each case, to show the direction of:

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

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

(ii) Conductor PQ is free to move.

Describe and explain the subsequent motion of the conductor PQ.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) Conductor PQ is now placed horizontally as shown in Fig. 3.3. Above PQ is another conductor CD that can slide up and down on two vertical metal rods while making electrical contact with them.

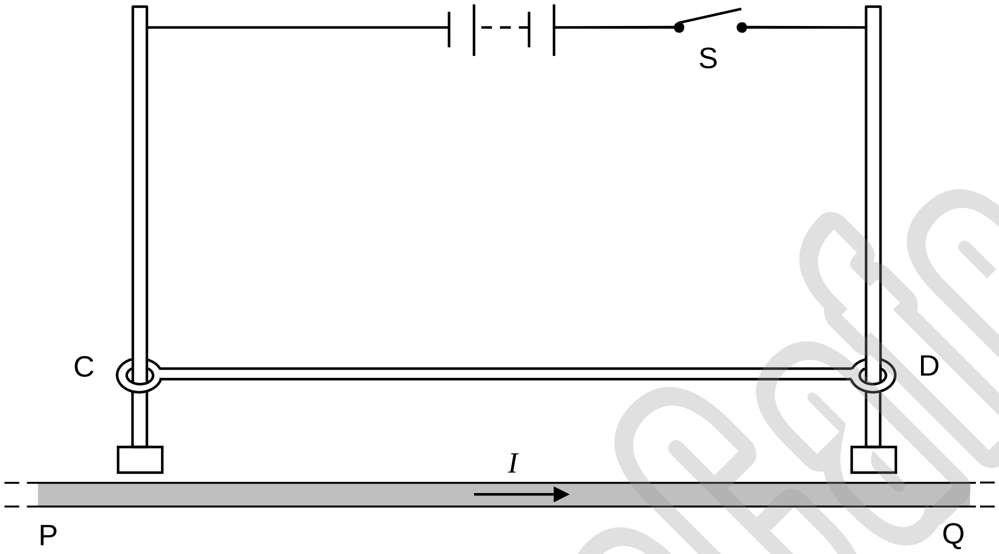


Fig. 3.3

When switch S is closed such that current flows in CD, CD moves upwards and eventually comes to rest at a certain height above PQ.

(i) Explain why CD initially starts to move upwards.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Explain why CD eventually comes to rest at a certain height above PQ.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

Ans	**(a)**	**(i)**	arrow B is down the page	B1	[1]
		(ii)	arrow F is towards Y	B1	[1]
		(iii)	force is increasing as PQ approaches XY	M1	
			PQ moves towards XY with increasing velocity and acceleration	A1	[2]
	(b)	**(i)**	when CD is near PQ the magnetic force on CD	B1	
			(due to magnetic field generated by current in PQ) is upwards and greater than weight of CD	B1	[2]
		(ii)	as CD moves away from PQ, magnetic force decreases	B1	
			CD can remain in equilibrium when magnetic force on CD is equal to weight of CD	B1	[2]