Learning CORNER

You should try to answer on your own before seeking H-E-L-P-S.

TOPIC *opening* ....

Question 1

A metal wire of length 0.57 m and cross-sectional area 1.0×10^{-6} m² is situated at right angles to a uniform magnetic field of flux density 1.8×10^{-3} T, as illustrated in Fig. 4.1.

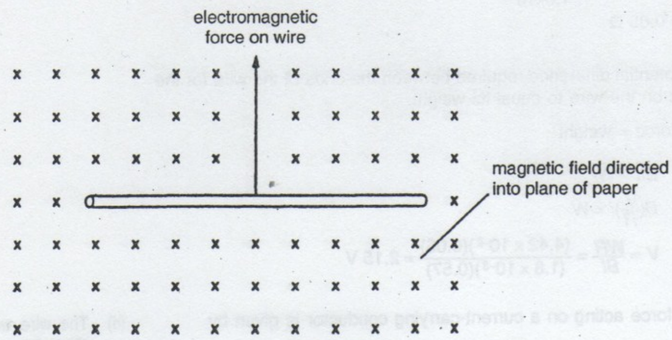


Fig. 4.1

The metal of the wire has density 7.9×10^{3} kg m^{-3} and resistivity 8.8×10^{-8} Ω m.

A potential difference is applied between the ends of the wire so that there is an electromagnetic force acting on the wire.

(a) On Fig. 4.1, mark the direction of the current in the wire. [1]

(b) For the wire, calculate

(i) its weight,

(ii) its resistance [5]

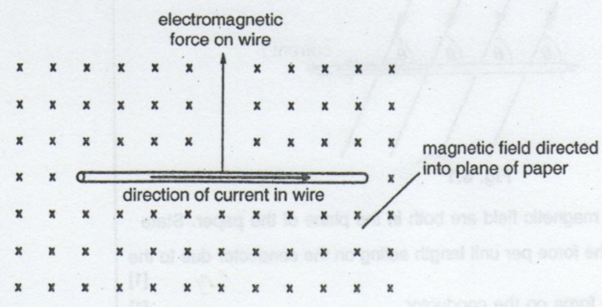
(c) Calculate the potential difference required between the ends of the wire for the electromagnetic force on the wire to equal its weight. [3]

(d) The horizontal component of the Earth's magnetic field is 1.8×10^{-5} T. State and explain why, in practice, current-carrying wires are not seen to lift off the ground. [2]

[D99/P2/Q4]

Suggested Solution:

(a)



(a) Use Fleming's left hand rule. The thumb points in the direction of the electromagnetic force and the first finger points downwards perpendicular to the plane of the paper in the direction of the magnetic field. The second finger points in the direction of the current. Note that the current flows only if there is a closed circuit in the wire.

(b) (i) Weight of wire,

$W = mg$
$= \text{density} \times \text{volume} \times \text{gravitational acceleration}$
$= \text{density} \times \text{cross - sectional area} \times \text{length} \times \text{gravitational acceleration}$
$= (7.9 \times 10^3)(1.0 \times 10^{-6})(0.57)(9.81)$
$= 4.42 \times 10^{-2}$ N

(ii) Resistance, $R = \rho \frac{l}{A}$

$= \text{resistivity} \times \frac{\text{length}}{\text{cross - sectional area}}$
$= 8.8 \times 10^{-8} \times \frac{0.57}{1.0 \times 10^{-6}}$
$= 0.05\ \Omega$

(c) Let *v* represent the potential difference required between the ends of the wire for the electromagnetic force on the wire to equal its weight.

For electromagnetic force = weight

$BIl = W$

$B(\frac{V}{R})l = W$

$V = \frac{WR}{Bl} = \frac{(4.42 \times 10^{-2})(0.05)}{(1.8 \times 10^{-3})(0.57)} = 2.15$ V

(d) The electromagnetic force acting on a current-carrying conductor is given by

$$F = BIl$$

where F : electromagnetic force
B : magnetic field strength
I : current in the conductor
l : length of conductor

Since the horizontal component of the Earth's magnetic field is only 1.8×10^{-5} T, the electromagnetic force acting on a 1 m long wire carrying a current of 1 A is only 1.8×10^{-5} N. This force is likely to be much lower than the weight of a 1 m long wire. Hence, the resultant force on the current-carrying wire will still act downwards and the wire will not be seen lifting off the ground.

(d) The wire would be seen lifting off the ground provided there is a net upward force acting on the wire. This would require an electromagnetic force (directed upwards) which exceeds the weight of the 1 m long wire (acting downwards).

Question 2

(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.

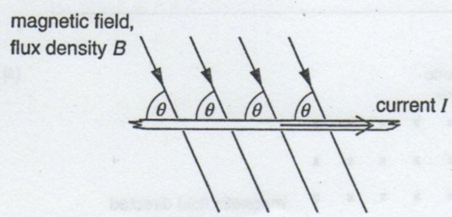


Fig. 6.1

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, [1]

(ii) the direction of the force on the conductor. [1]

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

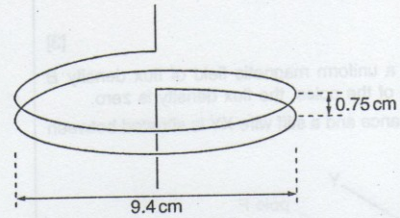


Fig. 6.2.

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. [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. [4]

[N07/P4/Q6]

Suggested Solution:

(a) (i) $BI \sin\theta$

(ii) into the plane of page / paper.

(b) (i) The current in one loop of wire produces magnetic field which is perpendicular to the current in the second loop. Therefore both exert equal and opposite force on each other by Newton's third law. Hence separation of the loops of coil decreases.

(ii)

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

$$= 2.0 \times 10^{-7} \left(\frac{I}{0.75 \times 10^{-2}} \right) = 2.67 \times 10^{-5} I$$

Force on 2nd loop as a result of magnetic field of first loop

$$F_B = BIL \sin\theta$$

$$= (B)(I)(2\pi r)(\sin 90)$$

$$= (2.67 \times 10^{-5} I)(I)(2)(3.14)\left(\frac{9.4 \times 10^{-2}}{2} \right) = (7.88 \times 10^{-6}) I^2$$

Now, $F_B = W$

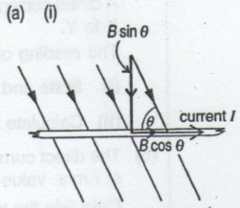
$$(7.88 \times 10^{-6}) I^2 = mg$$

$$I^2 = \frac{(0.26 \times 10^{-3})(9.81)}{7.88 \times 10^{-6}} = 323.7$$

$$I = 17.9 \approx 18.0$$

$\therefore$ current = 18.0 A

(a) (i)



Force on a current carrying conductor in a magnetic field,

$$F = BIL \sin\theta$$

$$\frac{F}{L} = BI \sin\theta$$

(ii) Make use of Flemming left hand rule to get the direction.

(b) (ii) To return to the original separation, upward magnetic force is equal to the downward weight.

Question 3

(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.

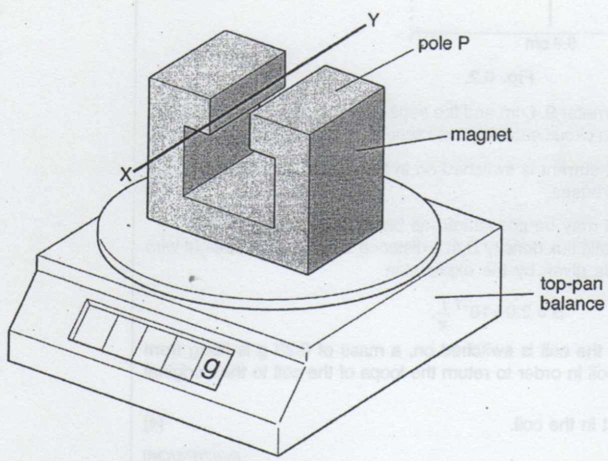


Fig. 6.1

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. [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. [2]

[J09/P4/Q6]

Suggested Solution:

(a) Magnetic flux density is equal to 1 *tesla* if a force of 1N is experienced by 1m length of a conductor carrying 1A current when placed perpendicular to field lines.

(a) $F = BIL\sin\theta$

$B = \frac{F}{IL\sin\theta}$

$1\text{T} = \frac{1\text{N}}{(1\text{A})(1\text{m})\sin 90°}$

(b) (i) The increase of force in downward direction measured by top pan balance on the magnet is equal to the force on the wire but in upward direction by Newton's third law. Hence by Fleming's Left Hand Rule, pole P is the North pole.

(ii)

$$F = BIL\sin 90°$$

$$mg = BIL$$

$$(2.3\times10^{-3})(9.81) = B(2.6)(4.4\times10^{-2})$$

$$B = 0.197 \approx 0.20\ \text{T}$$

(c) $I_{r.m.s} = \frac{I_o}{\sqrt{2}}$

$I_o = (\sqrt{2})(2.6) = 3.68$ A

2.6 A d.c. current causes variation = 2.3 g

3.68 A d.c. current causes variation = $\frac{2.3}{2.6} \times 3.68 = 3.26$ g

For both half cycles of A.C., the variation is = 2(3.26) = 6.52 g

Question 4

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

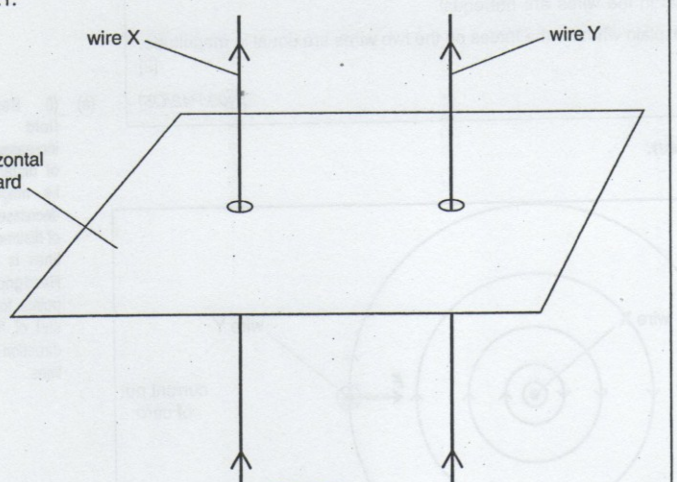


Fig. 5.1

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.

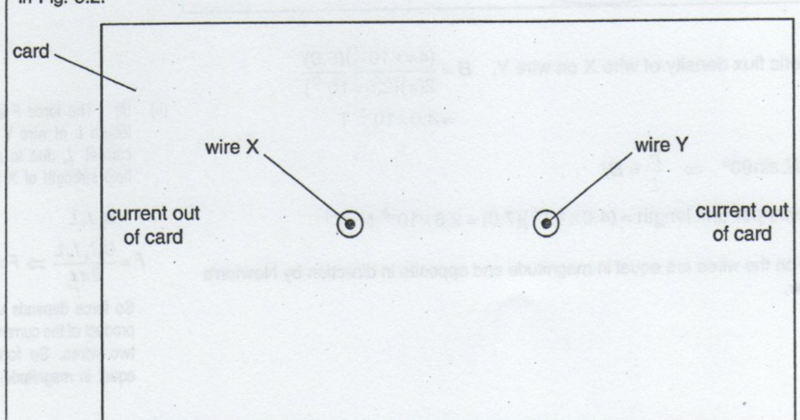


Fig. 5.2 (not to scale)

www.igcse.at.ua

igcse-alevel
one stop shop for all your problems

(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. [4]

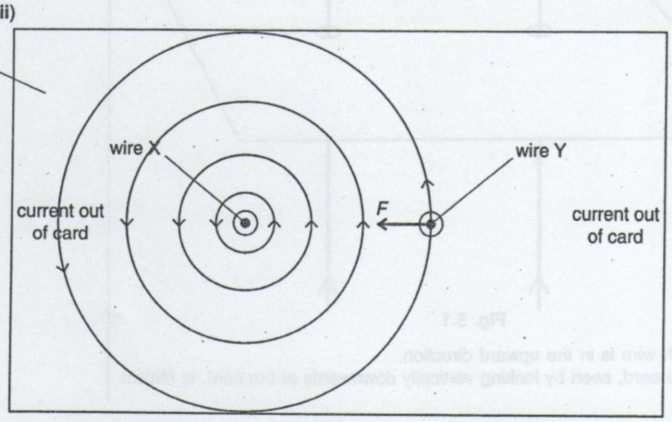
(ii) The currents in the wires are not equal.

State and explain whether the forces on the two wires are equal in magnitude. [2]

[N09/P42/Q5]

Suggested Solution:

(a) (i), (ii)



(a) (i) Separation between field lines must be increased with the increase of distance from the wire, i.e. magnetic field strength decreases with the increase of distance. Direction of field lines is obtained by Right Hand grip rule in which thumb points towards current and curl of fingers provide the direction of magnetic field lines.

(b) (i) Magnetic flux density of wire X on wire Y, $B = \frac{(4\pi\times10^{-7})(5.0)}{2(\pi)(2.5\times10^{-2})}$

$= 4.0\times10^{-5}$ T

$F = BIL\sin 90° \Rightarrow \frac{F}{L} = BI$

$\therefore$ force per unit length $= (4.0\times10^{-5})(7.0) = 2.8\times10^{-4}$ N m^{-1}

(ii) Forces on the wires are equal in magnitude and opposite in direction by Newton's third law.

(b) (ii) The force F acting on length L of wire Y carrying current I_Y due to magnetic field strength of X is:

$F = B_X I_Y L$

$F = \frac{U_0 I_X I_Y L}{2\pi x} \Rightarrow F \propto I_X I_Y$

So force depends upon the product of the currents in the two wires. So forces are equal in magnitude.