CONCEPTUAL QUESTIONS

Q 13.1 What is force that a conductor of length L carrying a current i, experiences when placed in magnetic field B? What is direction of this force?

Ans: Consider a conductor of length "L", placed in a uniform magnetic field "B". Let there be an electric current "i" passing through it. Then;

- The magnetic force is directly proportional to the current i through the conductor; $F \propto i$ (1)
- The magnetic force is directly proportional to the length of conductor; $F \propto L$ (2)
- The magnetic force is directly proportional to the strength of B; $F \propto B$ (3)
- The magnetic force also depends on the orientation of conductor in B such that; $F \propto \sin\theta$ (4)

Combining all the relations above; we get;

$$F = k\, i\, L\, B \sin\theta \quad (5)$$

Where k is a constant of proportionality and the value of k in SI system is 1; hence eq.5 can be written as;

$$F = i\, L\, B \sin\theta$$

As force is a vector quantity so its direction should also be determined by Fleming's left hand rule.

Fleming's Left Hand Rule

With the fore finger pointing in the direction of the field and middle finger pointing in the direction of current, the thumb gives the direction of the force.

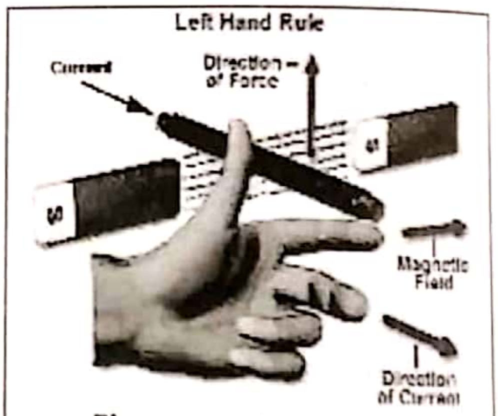

Figure with Sh.Q # 1

Q 13.2 What is the nature of force between two parallel current carrying wires (in same direction)?

Ans: Whenever two current carrying conductors are placed some distance apart, they exert force on one another because each conductor lies in the magnetic field set up by the other current carrying conductor. If the current in both conductors is in the same direction then their associated magnetic fields cancel the effect of each other in between the conductors while magnetic fields outside the conductors add up. Now by applying right hand rule it can be shown that force on first conductor is towards

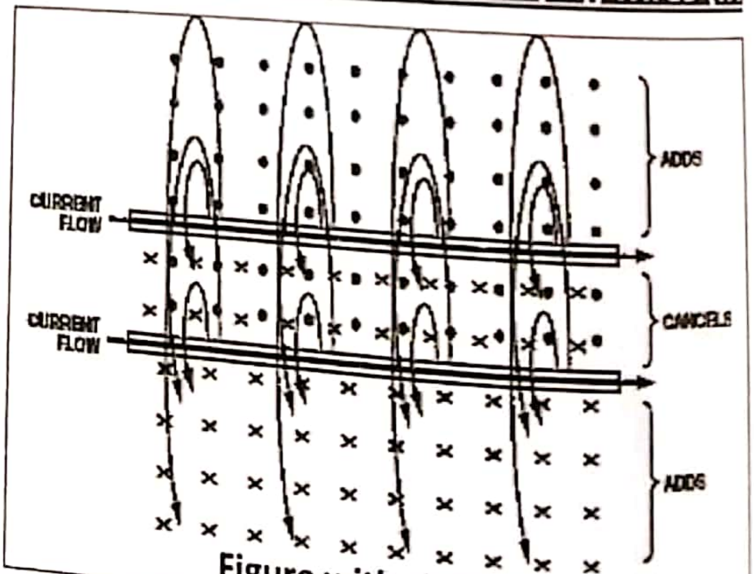

Figure with sh.Q #1

second and force on second conductor is towards first conductor. It means that both the conductors attract each other. This can be understood easily by the figure shown.

Q 13.3 What is the magnitude of the force on a charge q moving with a velocity v in a magnetic field B?

Ans: For a positive charge q moving with velocity v in a magnetic field of flux density B, the force acting on the charge depends on the following factors:

i. Magnetic force is directly proportional to the magnitude of charge.

$$F \propto q \qquad (1)$$

ii. Magnetic force is directly proportional to the velocity of the charged particle.

$$F \propto v \qquad (2)$$

iii. Magnetic force is directly proportional to the intensity of magnetic field.

$$F \propto B \qquad (3)$$

iv. Magnetic force is directly proportional to the Sine of the angle "θ" between v and B

$$F \propto \sin\theta \qquad (4)$$

Combining above relations: $F \propto q\,v\,B\,\sin\theta = k\,q\,v\,B\,\sin\theta$

In SI system k = 1, thus; $F = q\,v\,B\,\sin\theta \qquad (5)$

Equation 5 gives magnitude of force acting on charged particle in motion.

Q 13.4 In a uniform magnetic field B, an electron beam enters with velocity v. Write the expression for the force experienced by the electrons?

Ans: The force experienced by a charged particle in a uniform magnetic field is;

$$F = q\,(\vec{v} \times \vec{B})$$

For an electron beam

$$q = -ne$$

Hence

$$F = -ne\,(\vec{v} \times \vec{B})$$

Where n shows number of electrons contained in the beam. The –ve sign shows that deflection of electron beam will be opposite to that of positively charged beam of charges.

Q 13.5 What will be the path of a charged particle moving in a uniform magnetic field at any arbitrary angle with the field?

Ans: For a positive charge q moving with velocity "v" in a uniform magnetic field B, the magnitude of the force acting on the charge when it enters at an arbitrary angle with the field is given by equation;

$$F = q\,v\,B\,\sin\theta$$

For angle $\theta = 0°$ or $180°$ the charge particle experiences no magnetic force and follows a rectilinear path.

For angle $\theta = 90°$ the charge particle experiences maximum magnetic force and follows a circular trajectory.

For angle $0° < \theta < 90°$ the charge particle experiences magnetic force and follows a helical path.

Q 13.6 An electron does not suffer any deflection while passing through a region. Are you sure that there is no magnetic field?

Ans: The magnitude of Magnetic force on a charged particle is given by the equation

$$F = q\,v\,B\,\text{Sin}\,\theta$$

Where θ is the angle between v and B. The equation indicates that force will be zero at θ = 0° or θ = 180° even in the presence of magnetic field. Magnetic force is a sideways force. It does not affect the charged particle if direction of motion of charged particle is parallel or anti-parallel to magnetic field B.

Hence we are not sure that magnetic field exists or not in a region where electron beam passes un-deflected.

Q 13.7 An electron beam passes through a region of crossed electric and magnetic fields of intensity E and B respectively. For what value of electron speed beam will pass un-deflected?

Ans: A charged particle is passed through a region where both electric and magnetic fields are acting such that two forces balance each other, then;

$$F_B = F_E$$

$$\Rightarrow \quad q\,v\,B = q\,E$$

$$\Rightarrow \quad v\,B = E$$

$$\Rightarrow \quad v = E / B$$

Such arrangement is called velocity selector because charges with velocity v given by above equation will come out un-deflected.

Q 13.8 Uniform electric and magnetic fields are produced pointing in the same direction. An electron is projected in the direction of the fields. What will be the effect on the kinetic energy of the electron due to the two fields?

Ans: When the electron beam moves parallel to the magnetic field then the magnetic force at θ = 0° is given by;

$$F = -\,n\,e\,v\,B\,\text{Sin}\,0^\circ \qquad (q = -\,n\,e)$$

$$\Rightarrow \quad F = -\,n\,e\,v\,B \times 0 \qquad (\text{Sin}\,0^\circ = 0)$$

$$\Rightarrow \quad F = 0$$

This shows that there is no effect due to magnetic field.

When a beam of electrons is projected in a direction of electric field the magnitude of electric force is;

$$F = -\,n\,e\,E \qquad (q = -\,n\,e)$$

The electron beam will be decelerated due to the presence of electric field E. Whenever there is electric field E, potential difference will also exist in that region given by the equation;

$$E = \frac{V_o}{d}$$

Due to potential difference V_o charged particle losses it kinetic energy because it moves in a direction opposite to the electric field.

Hence when electron beam enters into uniform electric and magnetic fields, its kinetic energy decreases due to electric field only.

Q 13.9 What is the cyclotron frequency of a charged particle of mass m, charge q moving in magnetic field B?

Ans: The number of revolutions per unit time made by a charged particle entering perpendicular to a magnetic field is called as cyclotron frequency.
The centripetal force provided for the circular motion of a charged particle entering perpendicularly to a uniform magnetic field is given by;

$$F_c = F_B$$

$\Rightarrow \quad m v^2 / r = q v B$

$\Rightarrow \quad m v / r = q B$

$\Rightarrow \quad m r \omega / r = q B \qquad (V = r\omega)$

$\Rightarrow \quad m \omega = q B$

$\Rightarrow \quad \omega = q B / m$

Since $\omega = 2\pi f$, therefore; $\quad 2\pi f = q B / m$

$\Rightarrow \quad f = q B / 2\pi m$

The above expression accounts for the cyclotron frequency of a charged particle.

Q 13.10 Can neutrons be accelerated in a cyclotron? Give reason.

Ans: No, neutrons cannot be accelerated in a cyclotron. Cyclotron is a type of particle accelerator in which a charged particle is accelerated towards a target but neutrons have no charge, so they cannot be accelerated.

Q 13.11 A current carrying loop, free to turn, is placed in a uniform magnetic field B. what will be its orientation relative to B, in the equilibrium state?

Ans: In Equilibrium state, no net torque acts upon the current carrying loop. Mathematical form of torque is

$$\tau = BANi \, Cos\alpha$$

Where θ = angle between plane of the coil and magnetic field. By putting $\alpha = 90°$,

$$\tau = BANi \, Cos\alpha$$

$$\tau = BANi \, Cos\, 90° = 0$$

Hence torque will be zero when plane of the coil is oriented perpendicular ($\alpha = 90°$) to magnetic field. So in this state it will be in equilibrium.

Q 13.12 How does a current carrying coil behave like a bar magnet?

Ans: When current passes through a coil, magnetic field is setup around it. Direction of field can be determined by Right hand rule which states that "Imagine to grab the current carrying conductor in your right hand. Point your thumb in the direction of the current, then the curled fingers give the direction of magnetic field".

So magnetic field lines are such that they emerge from one face and terminate at the other behaving like a bar magnet.

Thus it can be said that current carrying coil behaves like a bar magnet.