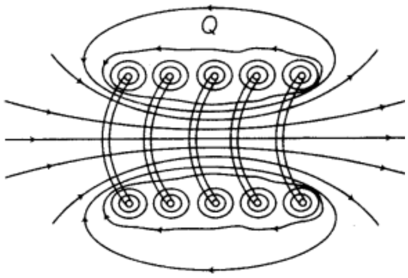
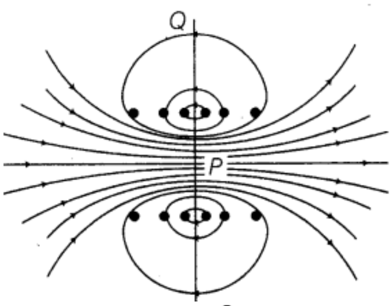
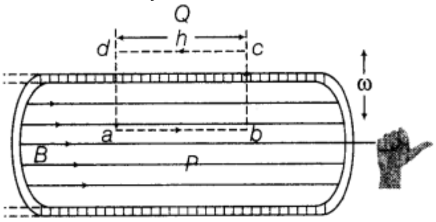
Magnetic Dipole & Magnetic Field Lines

2 Marks Questions

1.Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length. [Delhi 2014c]





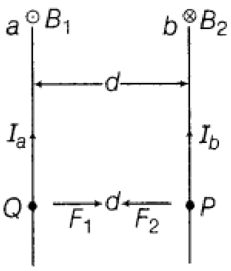


Applying Ampere's circuital law for the rectangular loop *abcd*,

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$$

$$Bh = \mu_0 I(nh)$$

$$B = \mu_0 nI \qquad \textbf{(1)}$$



a

Let a and b be two long straight parallel conductors. I_a and I_b are the current flowing through them and separated by a distance d. Magnetic field induction at a point P on a conductor b due to current I   passing through a is

2.(i) Two long straight parallel conductors a and b carrying steady currents I_a and I_b respectively are separated by a distance d. Write the magnitude and direction, what is the nature and magnitude of the force between the two conductors?

(ii) Show with the help of a diagram, how the force between the two conductors would change when the currents in them flow in the opposite directions. [Foreign 2014]

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$$B_1 = \frac{\mu_0 2I_a}{4\pi d}$$

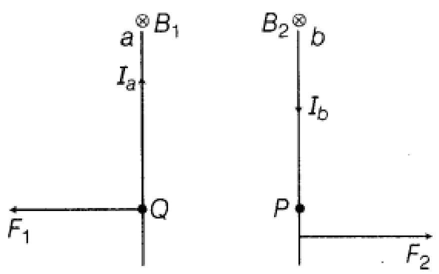
Now, unit length of b will experience a force as

$$F_2 = B_1 I_b \times 1 = B_1 I_b$$

$$\therefore \quad F_2 = \frac{\mu_0}{4\pi} \frac{2I_a I_b}{d}$$

Conductor a also experiences the same amount of force directed towards b. Hence, a and b attract each other. **(1)**

(ii)



Now, let the direction of current in conductor b be reversed. The magnetic field B_2 at point P due to current I_a flowing through a will be downwards. Similarly, the magnetic field B at point Q due to current I_b passing through b will also be downward as shown. The force on a will be, therefore towards the left. Also, the force on b will be towards the right. Hence, the two conductors will repel each other as shown.

3.A circular coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil. [All India 2012]

> The length of wire will be same in two cases as the same coil is unwound and rewound.

Length of the wire is same

$$\therefore \quad N_1 \times (2\pi R) = N_2 \times 2\pi \left(\frac{R}{2}\right)$$

[N_1 and N_2 = number of turns in two coils]

$$N_2 = 2N_1 \quad \textbf{(1/2)}$$

Now, the ratio of magnetic moments is given by

$$\frac{M_1}{M_2} = \frac{N_1 I A_1}{N_2 I A_2} = \frac{N_1 \times \pi R_1^2}{N_2 \times \pi R_2^2} \quad \textbf{(1/2)}$$

$$\frac{M_1}{M_2} = \left(\frac{N_1}{2N_1}\right) \times \left(\frac{R}{R/2}\right)^2 = \frac{1}{2} \times 4 = 2 \quad \textbf{(1/2)}$$

$$M_1 : M_2 = 2:1 \quad \textbf{(1/2)}$$

4.A circular coil of N turns and diameter d carries a current I. It is unwound and rewound to make another coil of diameter 2d, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil. [All India 2012]

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The length of wire will be same in two cases as the same coil in unwound and rewound.
Length of wire of coil 1 = Length of wire of coil 2

$$N_1 \times \pi d_1 = N_2 \times \pi d_2$$

$$N_1 \times \pi d = N_2 \times \pi \times 2d$$

$$N_2 = \frac{N_1}{2} \quad \text{where } N_1 = N$$

$$\Rightarrow \quad N_2 : N_1 = 1:2$$

$$\Rightarrow \quad N_1 : N_2 = 2:1 \quad \textbf{(1/2)}$$

Magnetic moment, $M = NIA$ **(1/2)**

$$\therefore \quad \frac{M_1}{M_2} = \frac{N_1 I A_1}{N_2 I A_2} = \frac{N_1 \pi d^2}{N_2 \pi (2d)^2}$$

$$\frac{M_1}{M_2} = \left(\frac{N_1}{N_2}\right) \times \frac{1}{4} = 2 \times \frac{1}{4} = \frac{1}{2} \quad \textbf{(1/2)}$$

$$\frac{M_1}{M_2} = \frac{1}{2}$$

$$\Rightarrow \quad M_1 : M_2 = 1:2 \quad \textbf{(1/2)}$$

5.Explain the following:

- Why do magnetic lines of force form continuous closed loops?
- Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field? [Foreign 2011]

(*i*) Magnetic lines of force come out from North pole and enter into the South pole outside the magnet and travels from South pole to North pole inside the magnet. So, magnetic lines of force form closed loop. **(1)**

(*ii*) The diamagnetic material gets slightly magnetised in a direction opposite to external field, therefore lines of force are repelled by diamagnetic material. **(1)**

NOTE When South pole of the magnet is viewed with the frame of reference inside the magnet would appear as North pole and similarly, North pole as South pole. Therefore, magnetic lines of force traversed from South pole to North pole inside the magnet.

6.A small compass needle of magnetic moment M and moment of inertia I is free to oscillate in a magnetic field It is slightly disturbed from its equilibrium position and then released. Show that it executes simple harmonic motion. Hence, write the expression for its time period. [HOTS, Delhi 2011C]

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As the needle is displaced from the equilibrium position, the torque will try to bring it back in equilibrium position hence, acceleration will be related with negative of angular displacement.

When compass needle of magnetic moment M and moment of inertia I is slightly disturbed by an angle θ from the mean position of equilibrium. Then, restoring torque begin to act the needle which try to bring the needle back to its mean position which is given by

$$\tau = -MB\sin\theta$$

Since, θ is small

So, $\sin\theta \approx \theta$

$\therefore$ $\tau = -MB\theta$

But $\tau = I\alpha$

where, α = angular acceleration

M = magnetic moment of dipole

$$\Rightarrow \quad I\alpha = -MB\theta$$

$$\alpha = -\left(\frac{MB}{I}\right)\theta$$

$\therefore$ $\alpha \propto -\theta$ **(1)**

$\Rightarrow$ Angular acceleration $\propto$ − angular displacement

$\Rightarrow$ Therefore, needle executed SHM.

Hence, the time period,

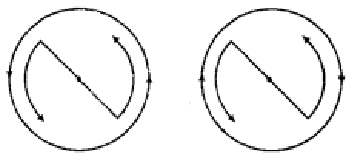
$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{MB}{I}}}$$

or $$T = 2\pi\sqrt{\frac{I}{MB}}$$ **(1)**

This is the required expression.

7.How does a circular loop carrying current behaves as a magnet? [Delhi 2011]

Ans.The current round in the face of the coil is in anti-clockwise direction, then this behaves like a North pole, whereas when it viewed from other sc le, then current round in it is in clockwise direction necessarily forming South pole of magnet.



Hence, current loop have both magnetic poles and therefore, behaves like a magnetic dipole

8.Deduce the expression for the magnetic dipole moment of an electron orbiting around the central nucleus. [All India 2010, Foreign 2009]

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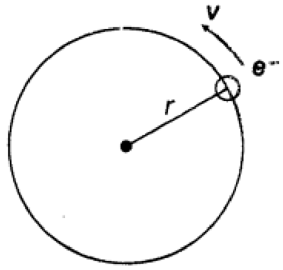
As we know that a moving charge always produces an electric current, so there will be electric current due to revolving electron, this is the current which produces magnetic field.

Let an electron revolves around the nucleus on a circular path of radius r with a uniform linear speed v.



Time period of electron is given by

$$T = \frac{2\pi r}{v}$$

$\therefore$ Electric current produced due to the orbital motion of electron is given by

$$I = \frac{-e}{T}$$

$$I = \frac{-e}{\left(\frac{2\pi r}{v}\right)}$$

$$I = -\frac{ev}{2\pi r} \qquad \text{...(i)}$$ **(1)**

Magnetic dipole moment is given by

$$M = IA = \left(\frac{-ev}{2\pi r}\right)\pi r^2$$

$$M = -\frac{evr}{2}$$

$$\Rightarrow \qquad M = -\frac{e}{2m}(mvr)$$

where, m = mass of electron.

$$\Rightarrow \qquad M = -\frac{e}{2m}L$$

where, $L = mvr$ and known as angular momentum,

$$M = -\frac{e}{2m}L$$

The direction of magnetic dipole moment is perpendicular to the plane of paper and directed inward. **(1)**

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