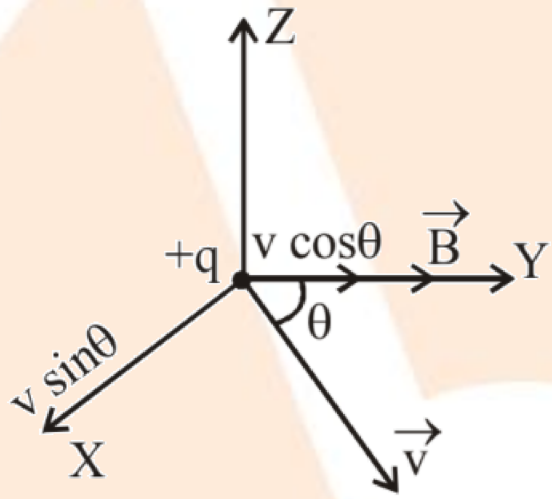
Revision Notes

Class - 12 Physics

Chapter 4 - Moving Charges And Magnetism

1. **Force on a moving charge:-**The source of magnetic field is a moving charge.



Suppose a positive charge q is in motion in a uniform magnetic field $\vec{B}$ with velocity $\vec{v}$.

n

$\therefore F \alpha qBv\sin\theta \Rightarrow F=kqBv\sin\theta \ [k = \text{constant}]$

Where in S.I. system, $k = 1$

$\therefore F=qB\sin\theta$ and $\vec{F}=q\left(\vec{v}\times\vec{B}\right)$

2. **Magnetic field strength $\left(\vec{B}\right)$:**

We can see that in the equation,
$F = qBv\sin\theta$, if $q = 1, v = 1,$

$\sin\theta = 1$ i.e. $\theta = 90^\circ$ then $F = B$.
Therefore magnetic field strength can be known as the force felt by a unit charge in motion with unit velocity perpendicular to the direction of magnetic field.

There are some special cases for this:

(1) If $\theta = 0^\circ$ or 180°, $\sin\theta = 0$

$\therefore F = 0$

A charged particle which is in motion parallel to the magnetic field, will be not experiencing any force.

(2) When $v = 0, F = 0$

At rest, a charged particle in a magnetic field will be not experiencing any force.

(3) When $\theta = 90^\circ$, $\sin\theta = 1$ then the force will be maximum

$F_{max.} = qvB$

A charged particle in motion perpendicular to the magnetic field will be experiencing maximum force.

3. **S.I. unit of magnetic field intensity:** The S.I unit has been found to be tesla (T).

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

When $q = 1C, v = 1m/s, \theta = 90^\circ$ That is, $\sin\theta = 1$ and $F = 1N$

Then $B = 1T$.

At a point, the strength of magnetic field can be called as $1T$ if a charge of $1C$ which have a velocity of 1 m/s while in motion at right angle to a magnetic field experiences a force of $1N$ at that point.

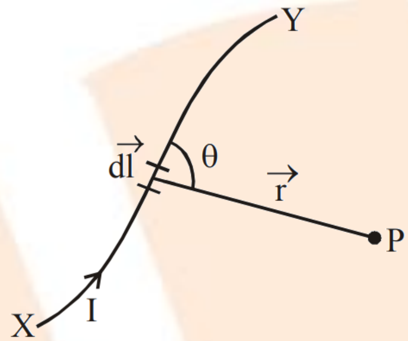
4. **Biot-Savart's law:–** The strength of magnetic flux density or magnetic field at a point P (dB) because of the current element dl will be dependent on**,**

(i) $dB \alpha I$

(ii) $dB \alpha dl$

(iii) $dB \alpha \sin\theta$

(iv) $dB \alpha \frac{1}{r^2}$,



When we combine them, $dB \alpha \frac{Idl\sin\theta}{r^2} \Rightarrow dB = k\frac{Idl\sin\theta}{r^2}$ [k = Proportionality constant]

In S.I. units, $k = \frac{\mu_0}{4\pi}$ where μ_0 can be called as permeability of free space.

$\mu_0 = 4\pi \times 10^{-7}\ TA^{-1}m$

$$\therefore dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2} \text{ and } \vec{dB} = \frac{\mu_0}{4\pi} I \frac{\left(\vec{dl} \times \vec{r}\right)}{r^3}$$

$\vec{dB}$ will be perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$ and will be directed inwards.

5. Applications of Biot-Savart's law:–

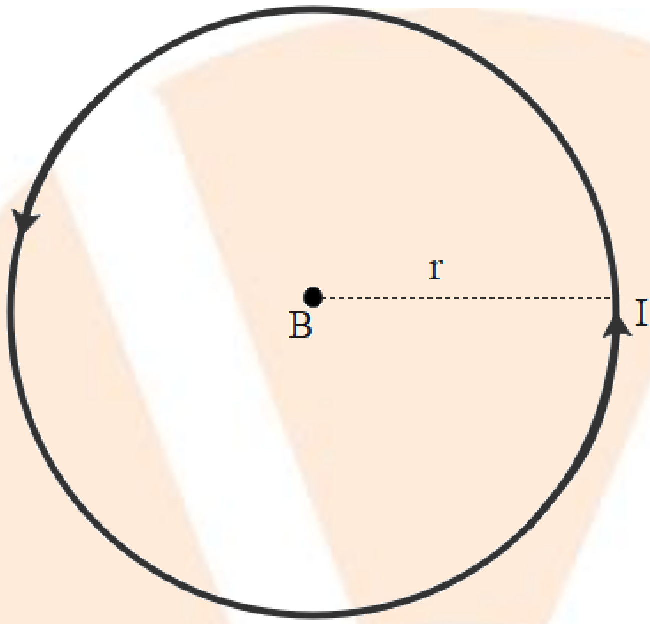
- Magnetic field (B) kept at the Centre of a Current Carrying Circular Coil of radius r .

$$B = \frac{\mu_0 I}{2r}$$

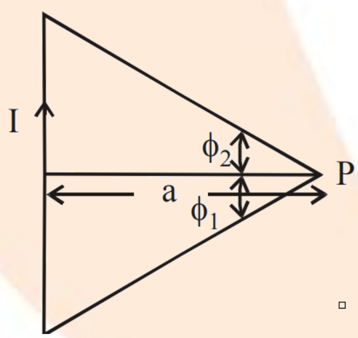
If there are n turns, then the magnetic field at the centre of a circular coil of n turns will be,

$$B = \frac{\mu_0 n I}{2r}$$

Here n will be the number of turns of the coil. I will be the current in the coil and r will be the radius of the coil.



- Magnetic field because of a straight conductor carrying current.

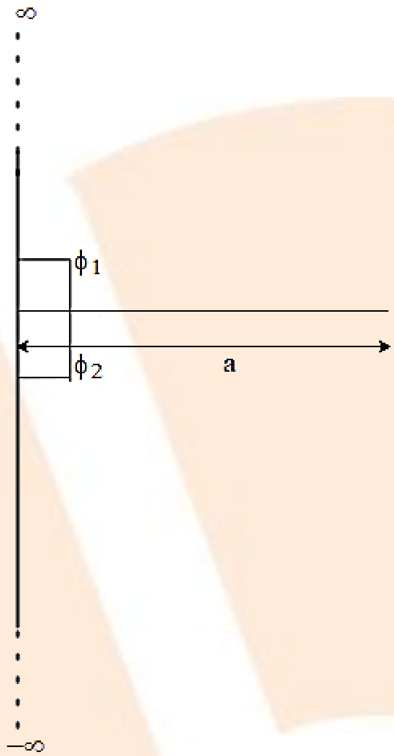


$$B = \frac{\mu_0 I}{4\pi a}\left(\sin\phi_2 + \sin\phi_1\right)$$

Here a will be the perpendicular distance of the conductor from the point where the field is to the measured.

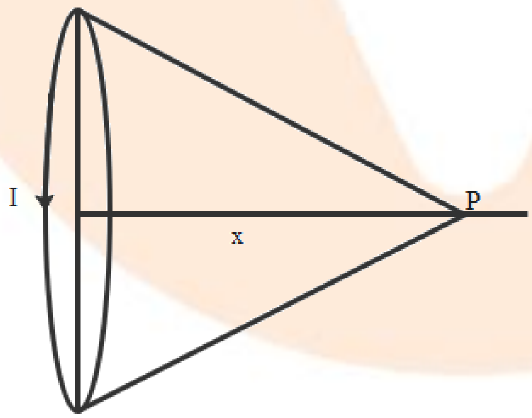
ϕ_1 and ϕ_2 will be the angles created by the two ends of the conductor with the point. In case of an infinitely long conductor, $\phi_1 = \phi_2 = \frac{\pi}{2}$

$$\therefore B=\frac{\mu_0}{4\pi}.\frac{2I}{a}$$



- At a point on the axis, magnetic field of a Circular Coil Carrying Current.

If point P is lying far away from the centre of the coil.

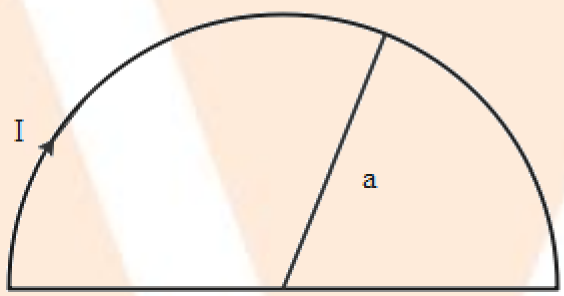


$$B=\frac{\mu_0}{4\pi}\frac{2M}{x^3}$$

Where $M = nIA = \text{magnetic dipole moment of the coil}$. x be the distance of the point where the field is needed to be measured, n be the number of turns, I
be the current and A be the area of the coil.

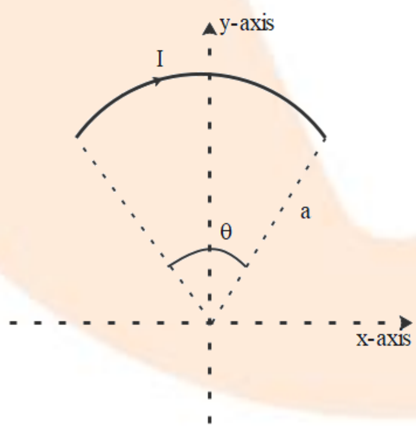
- Magnetic field at the centre of a semi-circular current-carrying conductor will be,

$$B = \frac{\mu_0 I}{4a}$$



- Magnetic field at the centre of an arc of circular current-carrying conductor which is subtending an angle 0 at the centre will be,

$$B = \frac{\mu_0 I \theta}{4\pi a}$$

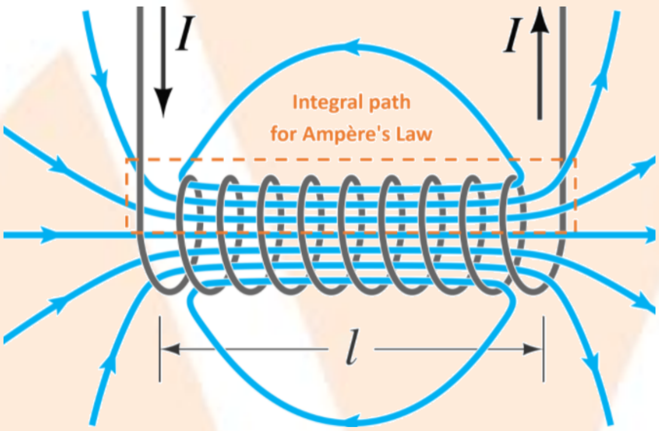


6. Ampere's circuital law:–

Around any closed path in vacuum line integral of magnetic field $\vec{B}$ will be μ_0 times the total current through the closed path. that is, $\oint \vec{B}.\vec{dl} = \mu_0 I$

7. Application of Ampere's circuital law:–

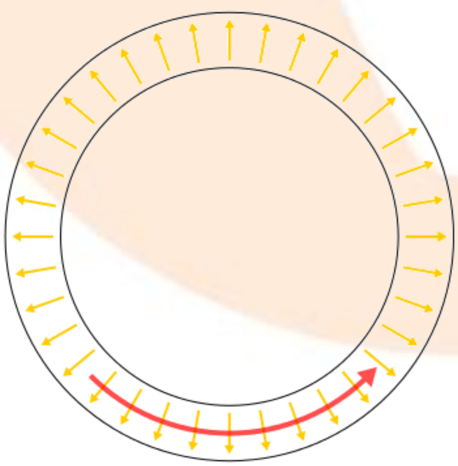
(a) Magnetic field because of a current carrying solenoid, $B = \mu_0 nI$



n be the number of turns per unit length of the solenoid.

In the edge portion of a short solenoid, $B = \frac{\mu_0 nI}{2}$

(b) Magnetic field because of a toroid or endless solenoid



Top view

$B = \mu_0 nI$

8. Motion in uniform electric field of a charged particle:–

Parabola is the path of a charged particle in an electric field.

Equation of the parabola be $x^2 = \frac{2mv^2}{qE} y$

Where x be the width of the electric field.

y be the displacement of the particle from its straight path.

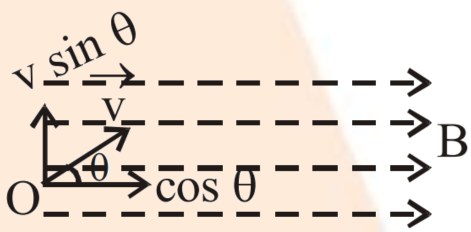
v be the speed of the charged particle.

q be the charge of the particle

E be the electric field intensity.

m be the mass of the particle.

9. In a magnetic field $(\vec{B})$ which is uniform, the path of a particle which is charged in motion with a velocity $\vec{v}$ creating an angle θ with $\vec{B}$ will be a helix.



The component of velocity $v\cos\theta$ will not be given a force to the charged particle, hence under this velocity in the direction of $\vec{B}$, the particle will move forward with a fixed velocity. The other component $v\sin\theta$ will create the force $F = qBv\sin\theta$, which will be supplying the needed centripetal force to the charged particle in the motion along a circular path having radius r.

$$\because \text{Centripetal force} = \frac{m(v\sin\theta)^2}{r} = Bqv\sin\theta$$

$$\therefore v\sin\theta = \frac{Bqr}{m}$$

Angular velocity of rotation $= w = \frac{v\sin\theta}{r} = \frac{Bq}{m}$

Frequency of rotation $= v = \frac{\omega}{2\pi} = \frac{Bq}{2\pi m}$

Time period of revolution $= T = \frac{1}{v} = \frac{2\pi m}{Bq}$

10. Cyclotron: This can be defined as a device we use for accelerating and therefore energize the positively charged particle. This can be created by keeping the particle, in an oscillating perpendicular magnetic field and a electric field. The particle will be moving in a circular path.

$\therefore$ Centripetal force = magnetic Lorentz force

$$\Rightarrow \frac{mv^2}{r} = Bqv \Rightarrow \frac{mv}{Bq} = r \leftarrow \text{radius of the circular path}$$

Time for travelling a semicircular path $= \frac{\pi r}{v} = \frac{\pi m}{Bq} = \text{constant}$.

When v_0 be the maximum velocity of the particle and r_0 be the maximum radius of its path then we can say that,

$$\frac{mv_0^2}{r_0} = Bqv_0 \Rightarrow v_0 = \frac{Bqr_0}{m}$$

Maximum kinetic energy of the particle

$$= \frac{1}{2}mv_0^2 = \frac{1}{2}m\left(\frac{Bqr_0}{m}\right)^2 \Rightarrow (K.E.)_{max.} = \frac{B^2q^2r_0^2}{2m}$$

Time period of the oscillating electric field $\Rightarrow T = \frac{2\pi m}{Bq}$.

Time period be the independent of the speed and radius.

Cyclotron frequency $= v = \frac{1}{T} = \frac{Bq}{2\pi m}$

Cyclotron angular frequency $= \omega_0 = 2\pi v = \frac{Bq}{m}$

11. Force acting on a current carrying conductor kept in a magnetic field will be,

$\vec{F} = I\left|\vec{l} \times \vec{B}\right|$ or $F = IlB\sin\theta$

Here I be the current through the conductor

B be the magnetic field intensity.

l be the length of the conductor.

θ be the angle between the direction of current and magnetic field.

(i) If $\theta = 0^\circ$ or 180°, $\sin\theta \Rightarrow 0 \Rightarrow F = 0$

$\therefore$ If a conductor is kept along the magnetic field, no force will be acting on the conductor.

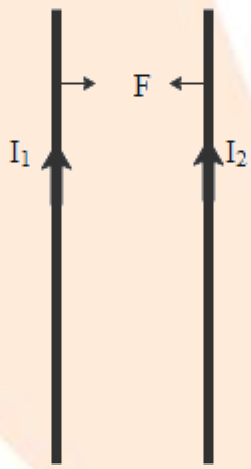
(ii) If $\theta = 90^\circ$, $\sin\theta = 1$, F will be maximum.

$F_{max} = IlB$

If the conductor has been kept normal to the magnetic field, it will be experiencing maximum force.

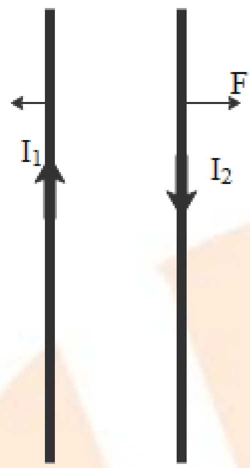
12. Force between two parallel current carrying conductors:–

(a) If the current will be in similar direction the two conductors will be attracting each other with a force



$$F = \frac{\mu_0}{4\pi} \cdot \frac{2I_1I_2}{r}$$ per unit length of the conductor

(b) If the current is in opposite direction the two conductors will be repelling each other with an equal force.



(c) S.I. unit of current is 1 ampere. (A).

1A can be defined as the current which on flowing through each of the two parallel uniform linear conductor kept in free space at a distance of 1m from each other creates a force of 2×10^{-7} N/m along their lengths.

13. Torque experienced on a current carrying coil kept in a magnetic field:–

$\vec{\tau} = \vec{M}\times\vec{B} \Rightarrow \tau = MB\sin\alpha = nIBA\sin\alpha$ where M be the magnetic dipole moment of the coil.

$M = nIA$

Where n be the number of turns of the coil.

I be the current through the coil.

B be the intensity of the magnetic field.

A be the area of the coil.

α will be the angle in between the magnetic field $\left(\bar{B}\right)$ and normal to the plane of the coil.

Special Cases will be:

(i) When the coil has been kept parallel to magnetic field $\theta = 0^\circ$,
$\cos\theta = 1$ then torque will be maximum.
$\tau_{max.} = nIBA$

(ii) When the coil is kept perpendicular to magnetic field, $\theta = 90^\circ$,
$\cos\theta = 0$
$\therefore \tau = 0$

14. Moving coil galvanometer: – This has been on the basis on the principle that if a coil carrying current has been kept in a magnetic field it is experiencing a torque. There is a restoring torque because of the phosphor bronze strip which is bringing back the coil to its normal position.

In equilibrium,

Deflecting torque = Restoring torque

$nIBA = k\theta$ [k = restoring torque/unit twist of the phosphor bronze strip]

$$I = \frac{k}{nBA}\theta = G\theta \text{ where } G = \frac{k}{nBA} = \text{Galvanometer constant}$$

$\therefore I \alpha \theta$

Current sensitivity of the galvanometer can be defined as the deflection made if the unit current has been passed through the galvanometer.

$$I_s = \frac{\theta}{I} = \frac{nBA}{k}$$

Voltage sensitivity can be explained as the deflection created if unit potential difference has been applied across the galvanometer.

$$V_s = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{nBA}{kR} \quad [R = \text{Resistance of the galvanometer}]$$

15. The maximum sensitivity of the galvanometer is having some conditions:-

The galvanometer has been defined to be sensitive if a small current develops a large deflection.

$$\because \theta = \frac{nBA}{k} I$$

$\because$ θ will be large if (i) n is large, (ii) B is large (iii) A is large and (iv) k is small.

16. Conversion of galvanometer into voltmeter and ammeter

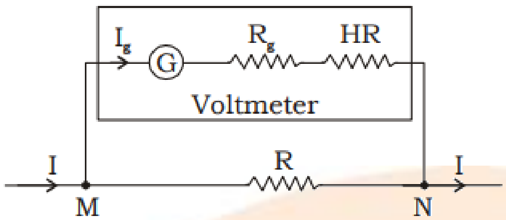
(a) A galvanometer has been converted to voltmeter by putting a high resistance in series with it.

Total resistance of voltmeter = $R_g + R$ where R_g be the galvonometer resistance.

R be the resistance added in series.

$$\text{Current through the galvanometer} = I_g = \frac{V}{R_g + R}$$

Here V is the potential difference across the voltmeter.

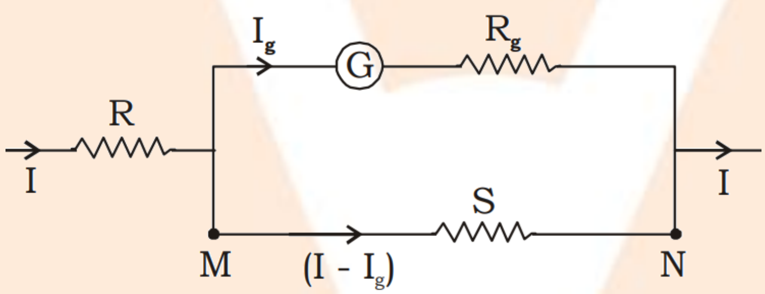


$$\therefore R = \frac{V}{I_g} - G$$

Range of the voltmeter: $0 - V$ volt.

(b) A galvanometer can be converted into an ammeter by the connection of a low resistance in parallel with it (shunt)

Shunt $= S = \left(\frac{I_g}{I - I_g}\right) R_g$ where R_g be the galvanometer's resistance.



I be the total current through the ammeter.
I_g be the current through the ammeter.
Effective resistance of the ammeter will be,

$$R = \frac{R_g}{R_g + S}$$

The range of the ammeter will be $0 - IA$. An ideal ammeter will be having zero resistance.