# MAGNETIC FIELD- LECTURE-19

CHAPTER- 4. MOVING CHARGE & MAGNETISM

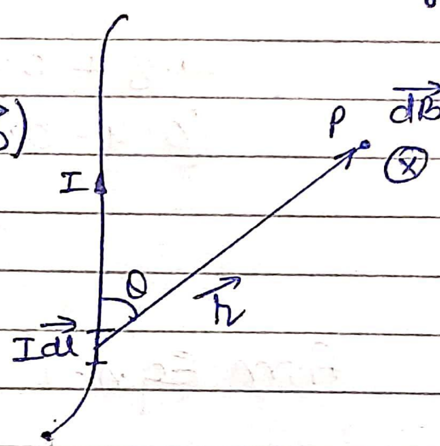
## BIOT-SAVERT LAW:

It states that the magnetic field due to a current element is proportional to the current (I), the element length $|\vec{dl}|$ and inversely proportional to the square of the distance $(r)$.

Its direction is perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$.

∴ According to Biot savert law.

Magnetic field due to element $(\vec{dB})$




$dB \propto I$ (current)

$dB \propto dl$ (element length)

$dB \propto \sin\theta$ (sin of angle)

$dB \propto \frac{1}{r^2}$ (distance)

$\Rightarrow dB \propto \frac{I\,dl\sin\theta}{r^2}$

$$\boxed{dB = \frac{\mu_0}{4\pi}\frac{I\,dl\sin\theta}{r^2}}$$

Where $\frac{\mu_0}{4\pi} = 10^{-7}$

$\mu_0$ = Absolute Permeability of free space $= 4\pi\times10^{-7}\ \frac{\text{Tesla-m}}{\text{Ampere}}$

Vector Form: $\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\vec{r}}{r^3}$

Direction of Magnetic field is given by Right hand screw rule.

⊗ ≡ Cross field ⇒ Direction ⊥ inward the plane.

⊙ ≡ Dot field ⇒ Direction ⊥ outward the plane

**SI unit of Magnetic Induction is Tesla or weber/square metre.**

**Note:** Magnetic field or Magnetic field induction and Magnetic flux density all are same physical quantity. ($\vec{B}$)

**2.** Magnetic intensity or Magnetizing force ($\vec{H}$)

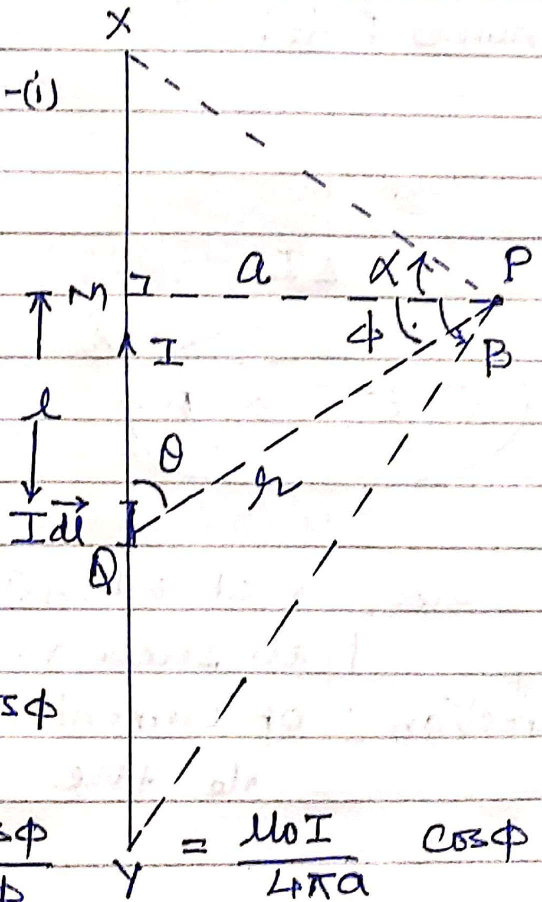
$$= \frac{\vec{B}}{\mu_0} \quad \text{Ampere-turn/meter}$$

## APPLICATIONS OF BIOT-SAVERT LAW

### (A) Magnetic field due to Straight Current carrying wire

using B-S Law

$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{r^2} \quad \text{---(i)}$$




In $\Delta$ QMP.

$$\tan\phi = \frac{l}{a}$$

$$l = a \tan\phi$$

$$dl = a \sec^2\phi \, d\phi$$

& $r = a \sec\phi$

Also $\theta + \phi = 90°$

$$\theta = 90 - \phi$$

$$\sin\theta = \sin(90-\phi) = \cos\phi$$

$$dB = \frac{\mu_0 I}{4\pi} \frac{a\sec^2\phi \, d\phi \times \cos\phi}{a^2 \sec^2\phi} = \frac{\mu_0 I}{4\pi a} \cos\phi \, d\phi$$

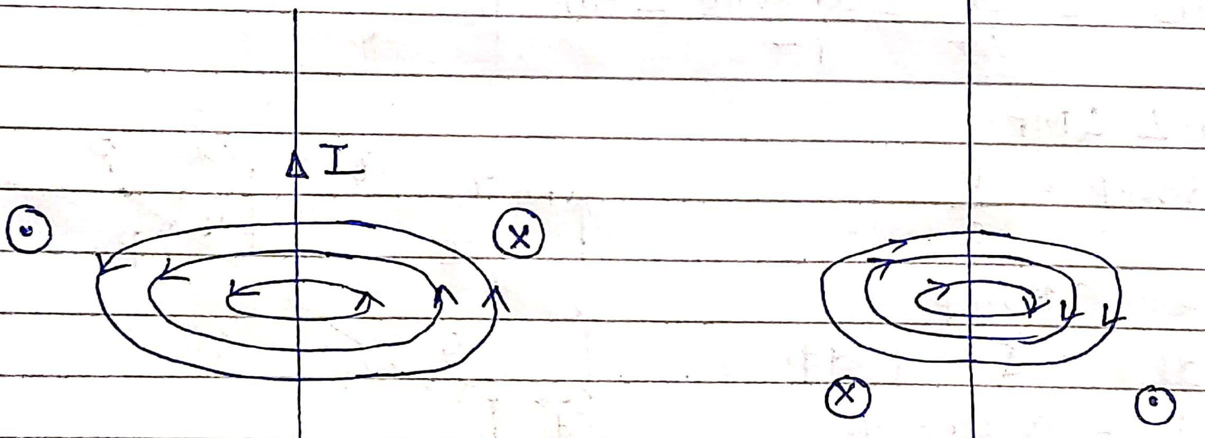
Integrating both side with proper limits-

$$\int_0^B dB = \frac{\mu_0 I}{4\pi a}\int_{-\beta}^{+\alpha} \cos\phi \, d\phi$$

$$B = \frac{\mu_0 I}{4\pi a}\left[\sin\phi\right]_{-\beta}^{+\alpha} = \frac{\mu_0 I}{4\pi a}\left[\sin\alpha - \sin(-\beta)\right]$$

$$\therefore \boxed{B = \frac{\mu_0 I}{4\pi a}\left[\sin\alpha + \sin\beta\right]}$$

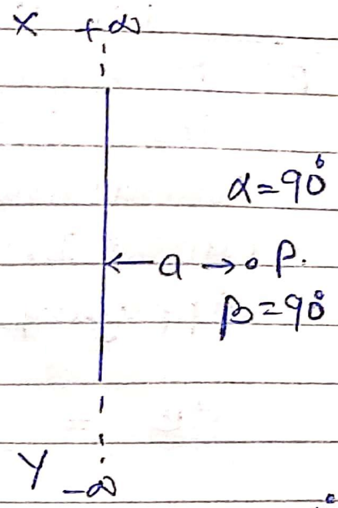
Direction of Magnetic field is given by Right hand Thumb Rule:




"It states that when conductor is held by Right hand in such a way that thumb points in the direction of current then curved fingers of hand indicate the direction of Magnetic field."

## Special Cases:

1. When length of wire is infinite and the point lies away from both the ends of wire.

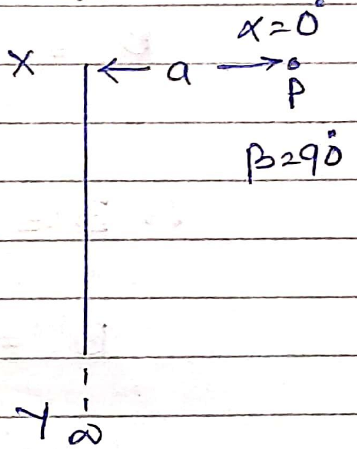



$\alpha = \beta = 90^\circ$

$$\therefore B = \frac{\mu_0 I}{4\pi a}\left[\sin 90^\circ + \sin 90^\circ\right]$$

$$\boxed{B = \frac{\mu_0 I}{2\pi a}}$$

2. In case of semi infinite wire i.e. when length of conductor is infinity and point lies near one end.

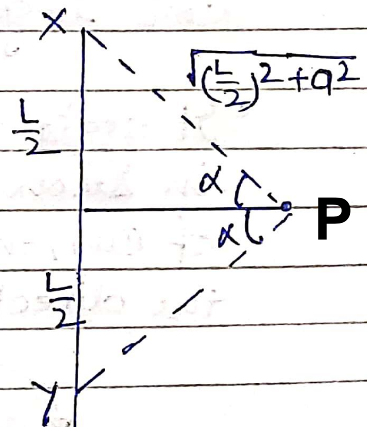



$\alpha = 0^\circ$ & $\beta = 90^\circ$

$$B = \frac{\mu_0 I}{4\pi a}\left[\sin 0^\circ + \sin 90^\circ\right]$$

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

3. When length of wire is finite and point lies on perpendicular bisector of wire.




$$\sin\alpha = \frac{L/\cancel{2}}{\frac{\sqrt{L^2+4a^2}}{\cancel{2}}} = \frac{L}{\sqrt{L^2+4a^2}}$$

$$\therefore \boxed{B = \frac{\mu_0 I}{4\pi a} \times 2\sin\alpha = \frac{\mu_0 I}{4\pi a} \times \frac{2L}{\sqrt{L^2+4a^2}}}$$