

# PHYSICS

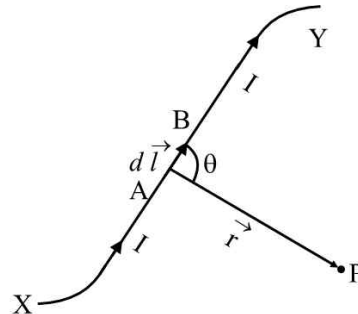
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## 01. Biot-Savart's Law

The Biot-Savart's Law deals with the magnetic field induction at a point due to a small current element.

“This Law is an equation that describes the magnetic field created by a current-carrying wire, and allows to calculate its strength at various points.”



In SI Units,

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

In vector form,

$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{I(d\vec{l} \times \vec{r})}{r^3}$$

Direction of  $\vec{dB}$

Right handed screw rule or Right Hand Rule.

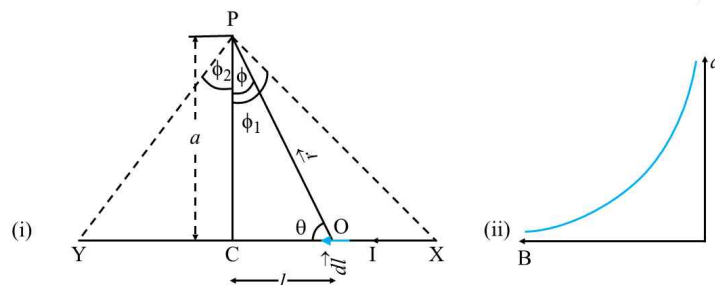
Biot Savart's law in terms of charge (q) and its velocity (v) is.

$$\vec{dB} = \frac{\mu_0}{4\pi} \frac{q(\vec{v} \times \vec{r})}{r^3}$$

Important features of Biot Savart's law

- (i) Biot Savart's law is valid for a symmetrical current distribution.
- (ii) This law is analogous to Coulomb's law in electrostatics.
- (iii) The direction of  $d\vec{B}$  is perpendicular to both  $I d\vec{l}$  and  $\vec{r}$ .

## 02. Magnetic Field Due to a Straight Wire Carrying Current



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

$$\cos \phi = \frac{a}{r} \quad \text{or} \quad r = \frac{a}{\cos \phi}$$

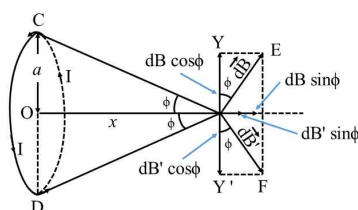
$$\tan \phi = \frac{1}{a} \quad \text{or} \quad l = a \tan \phi$$

$$dB = \frac{\mu_0}{4\pi} \frac{I(a \sec^2 \phi d\phi) \cos \phi}{\left(\frac{a^2}{\cos^2 \phi}\right)} = \frac{\mu_0}{4\pi} \frac{I}{a} \cos \phi d\phi$$

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

### 03. Magnetic Field at a Point on the Axis of a Circular Coil Carrying Current

Plane of the coil be perpendicular to the plane of the paper and current  $I$  be flowing in there coil in the direction shown.



$$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin 90^\circ}{r^2}$$

( $\because$   $a$  is small, therefore  $\theta = 90^\circ$ )

$$= \frac{\mu_0}{4\pi} \frac{I dl}{(a^2 + x^2)}$$

$$dB = dB' = \frac{\mu_0 I dl}{4\pi (a^2 + x^2)}$$

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I a^2}{(a^2 + x^2)^{3/2}}$$

#### Special cases

(i) **When point  $P$  lies at the centre of the circular coil**, then  $x = 0$ , we have

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I a^2}{a^3} = \frac{\mu_0}{4\pi} \frac{2\pi n l}{a}$$

which is the same as given by above equation.

(ii) **When point  $P$  lies far away from the centre of the coil**, then  $x \gg a$ . Now  $a^2 + x^2 = x^2$  as  $a^2$  can be neglected in comparison to  $x^2$ . From above equation, we have

$$B = \frac{\mu_0}{4\pi} \frac{2\pi n I a^2}{x^3} = \frac{\mu_0}{4\pi} \frac{2n I A}{x^3}$$

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