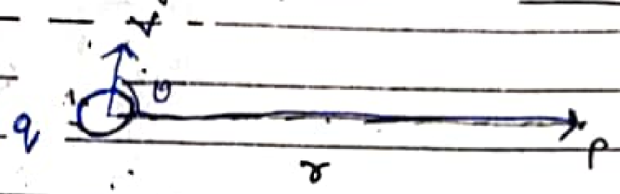
Magnetic field due to a point charge



$B \propto q$ — (i) $\qquad B \propto \frac{1}{r^2}$ — (iv)

$B \propto v$ — (ii)

$B \propto \sin\theta$ — (iii)

$$B \propto \frac{q v \sin\theta}{r^2}$$

$$B = k' \frac{q v \sin\theta}{r^2}$$ when $k' = \frac{\mu}{4\pi}$

In vector form $\qquad$ in free space $k' = \frac{\mu_0}{4\pi}$

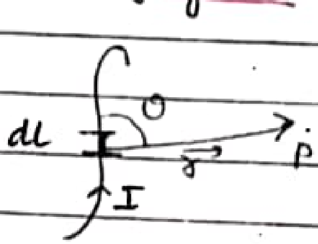
$$\boxed{\vec{B} = \frac{k' q (\vec{v} \times \vec{r})}{r^3}}$$

Direction of magnetic field is determined by cross product rule.

~~r axis~~

Magnetic field due to current carrying wire

Biot - Savart law



$B \propto I\,dl$ — (1)

$B \propto \sin\theta$ — (2)

$B \propto \frac{1}{r^2}$ — (3)

Head of r vector is at the point where we have to find field

(1), (2), (3)

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

$$\boxed{B = \frac{k' I \, dl \sin\theta}{r^2}}$$

In vector form,

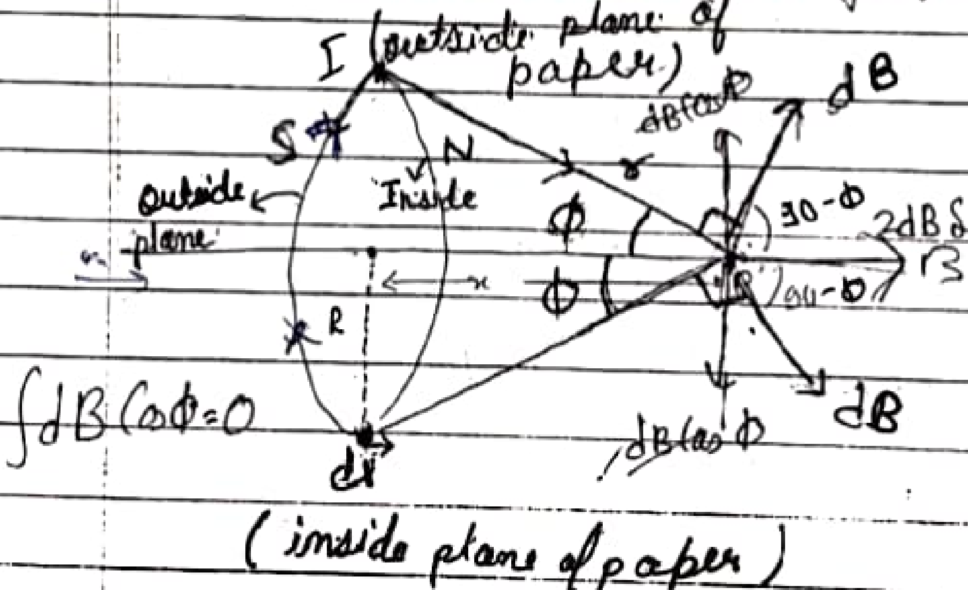
$$\boxed{\vec{B} = \frac{k' I \, (\vec{dl} \times \vec{r})}{r^3}}$$

Note: dl vector is always taken in direction of current.

: also direction of magnetic field is determined by right hand thumb rule or ~~of~~ cross product rule..

$\otimes$ inside $\odot$ outside.

★ Magnetic field at an axial point of a circular coil carrying current I.



$$dB = \frac{K'I\,dl\sin 90^\circ}{r^2}$$

$$2dB\sin\phi = \frac{K'I\,dl}{(R^2+r^2)}.$$

$$B = \int (dB)\sin\phi$$

$$B = \int \frac{K'(I\,dl)\sin\phi}{(R^2+x^2)}$$

$$B = \frac{K'I\sin\phi}{(R^2+x^2)}\int dl$$

$$= \frac{K'I}{(R^2+x^2)}\cdot\left[\frac{R}{\sqrt{R^2+x^2}}\right](2\pi R)$$

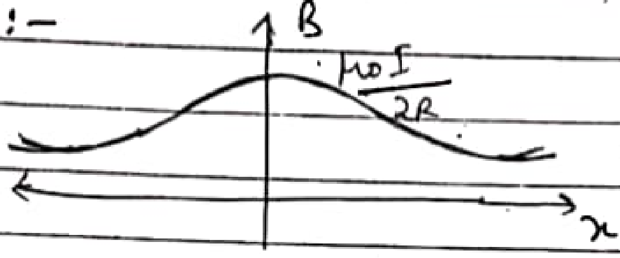
$$\boxed{B = \frac{K'(I)(2\pi R^2)}{(R^2+x^2)^{3/2}}}$$

At origin or at centre of ring.

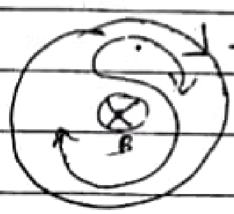
$$B = \frac{K' I\, 2\pi R^2}{R^3} = \frac{\pi\, 2\, \mu_0 I}{2\, 4\pi\, R} = \boxed{\frac{\mu_0 I}{2R}}$$

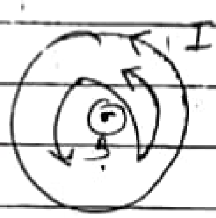
at center of ring

Graph:-



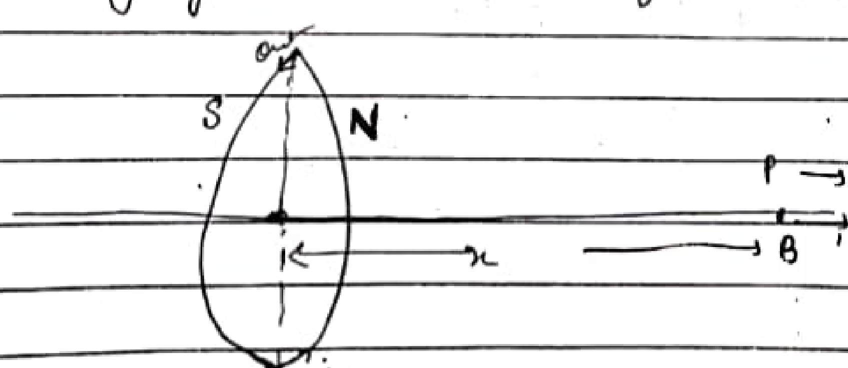
Direction of magnetic field is given by right-hand thumb rule. Hence, if we curl our fingers along the current (in direction of current) then the stretched thumb will point in direction of magnetic field on the axis of the closed loop.





If clockwise then inward   If anticlockwise outward

Hence we can treat a close loop current-carrying coil as a magnet as shown.



$\vec{B}$ at point P is

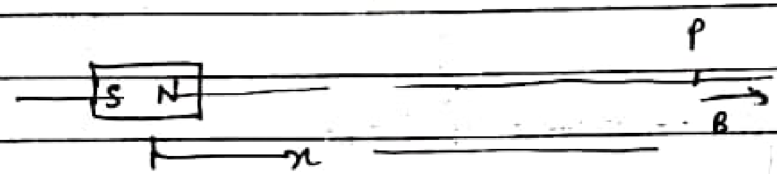
$$\vec{B} = \frac{k'(2I\pi R^2)}{(R^2+x^2)^{3/2}} \quad (\longrightarrow)$$

If $x >> R$

$$\vec{B} = \frac{2k'(I)\pi R^2}{x^3} \quad \text{— (1)}$$

Also, we know that for a magnetic dipole, $\vec{B}$ on its axis is

$$B = \frac{2K'M}{x^3} \quad \text{— (2)}$$



Comparing (1) and (2)

$$M = I\pi R^2$$

$$\boxed{M = IA}$$

magnetic dipole moment.

If there are N no of circular loops, having same area A.

$$M = NIA$$

Hence magnitude of magnetic dipole moment is product of current and area of loop. and its direction is from S to N.