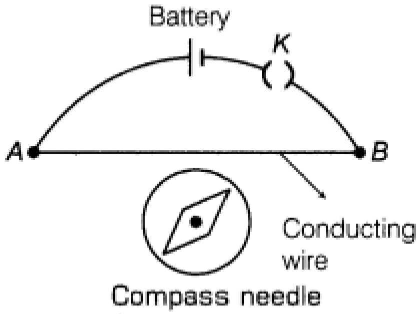
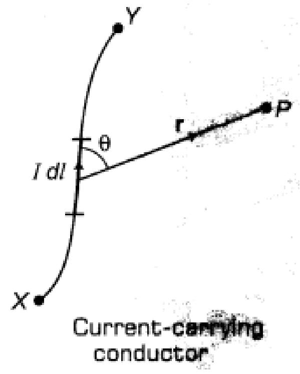
# Moving Charges and Magnetism

**1. The space** in the surroundings of a magnet or a current-carrying conductor in which its magnetic influence can be experienced is called magnetic field. Its SI unit is Tesla (T).
**2. Oersted experimentally** demonstrated that the current-carrying conductor produces magnetic field around it.




When key K is closed, then deflection occurs in the compass needle and vice-versa,
**3. Biot-Savart's Law** According to this law, the magnetic field due to small; current-carrying element dl at any nearby point P is given by

$$d\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{I d\mathbf{l}\ \hat{\mathbf{r}}}{|\mathbf{r}|^2} \quad \text{or} \quad dB = \frac{\mu_0}{4\pi} \cdot \frac{I dl \sin\theta}{r^2}$$




and direction is given by Ampere's swimming rule or right hand thumb rule.

where, $\frac{\mu_0}{4\pi} = 10^{-7}$ T-m/A

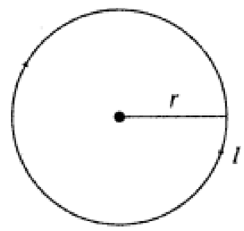
and $\mu_0$ = permeability of free space and $r$ = distance of point $P$ from current-carrying element.

**4.** The relationship between $\mu_0$, $\varepsilon_0$ and c is

$$\frac{1}{\mu_0 \varepsilon_0} = c^2$$

where, c is velocity of light, $\varepsilon_0$ is permittivity of free space and μ0 is magnetic permeability.
**5.** Magnetic field at the centre of a circular current-carrying conductor/coil.

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

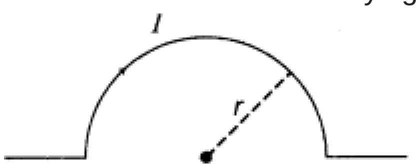



where, $r$ is the radius of a circular loop.

For $N$ turns of coil, $B = \frac{\mu_0 N I}{2r}$

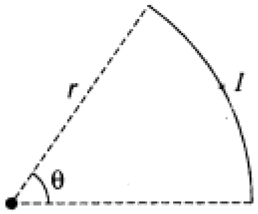
**6.** Magnetic field at the centre of semi-circular current-carrying conductor.

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

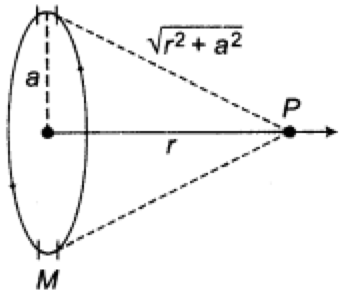



**7.** Magnetic field at the centre of an arc of circular current-carrying conductor which subtends an angle 0 at the centre.

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

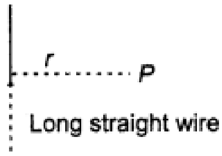



**8.** Magnetic field at any point lies on the axis of circular current-carrying conductor




$$B = \frac{\mu_0 I a^2}{2(r^2 + a^2)^{3/2}}$$

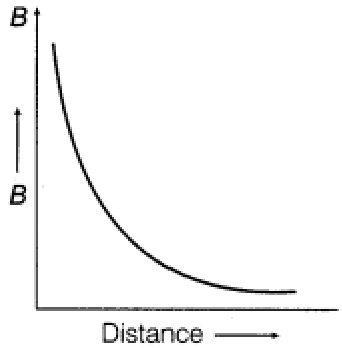
**9. Magnetic field** due to straight current-carrying conductor at any point P at a distance r from the wire is given by




$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r}$$

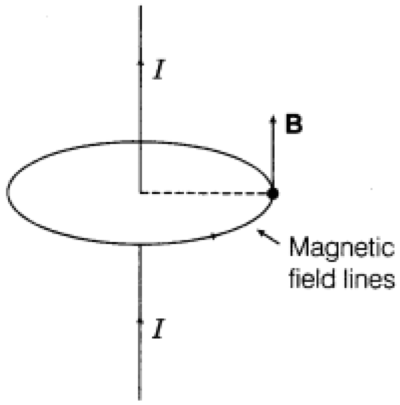
$\Rightarrow$ $$B \propto \frac{1}{r}$$

**10.** The following figure shows the graphical representation of variation of B with distance from straight conductor.




**11. Ampere's Circuital Law** The line integral of the magnetic field B around any closed loop is equal to $\mu_0$ times the total current I threading through the loop, i.e.

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




Magnitude of magnetic field of a straight wire using Ampere's law

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

**12. Maxwell introduced** the concept of displacement current.

Displacement current, $I_D = \varepsilon_0 \frac{d\phi_E}{dt}$

Displacement current flows in the space due to a variation in electric field.

$\Rightarrow$ $$\oint \mathbf{B} \cdot d\boldsymbol{l} = \mu_0 (I_C + I_D)$$

**13. Magnetic Field due to a Straight Solenoid**

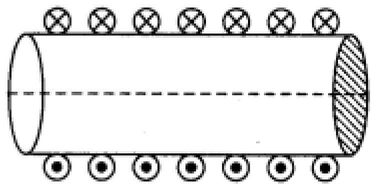
(i) At any point inside the solenoid,

$B = \mu_0 nI$

where, n = number of turns per unit length.

(ii) At the ends of the solenoid,

$B = 1/2\ \mu_0 nI$



**14. Magnetic Field due to Toroidal Solenoid**

(i) Inside the toroidal solenoid,

$B = \mu_0 nI$, here, $n = N/2\pi r$, N= total number of turns

(ii) In the open space, interior or exterior of toroidal solenoid,

B= 0