~~moving charges~~ MOVING CHARGES & ~~magnetism~~ MAGNETISM

[Short notes]

① oersted experiment
↳ magnetic field developed in the current carrying wire. → moving charges

② sources of fields

static charge → only electric field
moving charge → both EF & magnetic field are produced
current in wire → only MF is produced

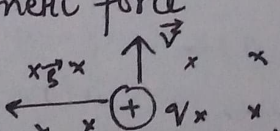
③ Net magnetic field
In any region MF is the vector sum of all the fields produced by all sources in region.

④ magnetic forces
- part of EM force
- Net EF on a charge particle

$\boxed{F = q\vec{E} + q(\vec{v} \times \vec{B})}$ → Lorentz force eq^n

⑤ Direction of magnetic force

$\vec{F}_m = q(\vec{v} \times \vec{B})$



method 1 ⟶ by cross product or Right Hand Thumb Rule.

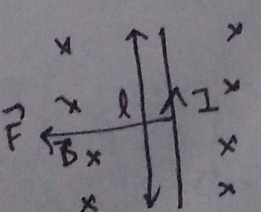
method 2 ⟶ By Right Hand Palm Rule
↳ $\vec{v}$ - Thumb
↳ $\vec{B}$ - fingers
↳ $\vec{F}$ - Palm face

method 3 ⟶ by Fleming's LHR

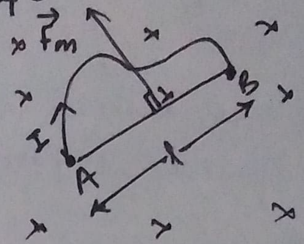
⑥ magnetic Force on a current carrying conductor

↳ Direction by RHPR

$\boxed{\vec{F} = I(\vec{l} \times \vec{B})}$



⑦ magnetic force on a Random shaped wire



$\boxed{F_m = BIl}$

⑧ magnetic force on a closed loop carrying current

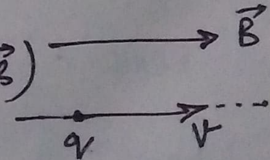
$\boxed{\vec{F}_m = 0}$

⑨ Moving charge in magnetic field

Case - I :

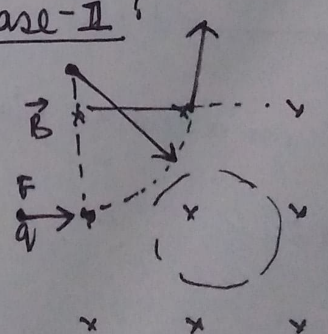
$F = q(\vec{v} \times \vec{B})$

$F = 0$



$\vec{v}$ is || to $\vec{B}$

Case - II :

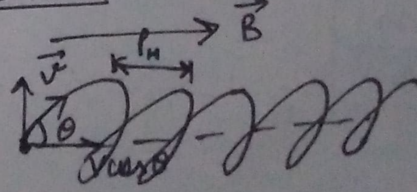


$F = qvB = \frac{mv^2}{R}$

$\boxed{R = \frac{mv}{qB}}$

- In a magnetic field the charge coming from outside always move outside the field

Case III :



$R_H = \frac{mv \sin\theta}{qB}$

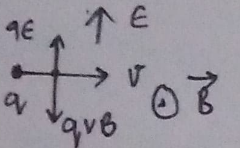
$P_H = \frac{2\pi mv \cos\theta}{qB}$

(10) Avg speed in MF for a moving charges

$$\boxed{\omega = \frac{qB}{m}}$$

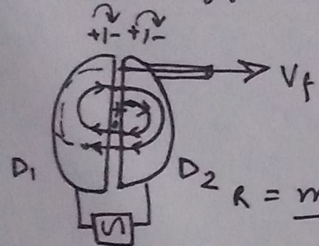
(11) Motion in combined EF & MF :-

$$\vec{F}_{EM} = q\vec{E} + q(\vec{v} + \vec{B})$$



$$\left[\begin{array}{l} qE = qvB \\ v = \frac{E}{B} \end{array}\right]$$

(12) Cyclotron : It uses both EF and MF to increase energy of charge particles.



$$R = \frac{mv\uparrow}{qB}$$

$$V_{exit} = \frac{qBR}{m}$$

$$K_{exit} = \frac{1}{2} m v_f^2$$

$$\boxed{K_{exit} = \frac{q^2 B^2 R^2}{2m}}$$

(13) W/D by MF (work done)

$W_{net} = 0$ in MF on a charge point

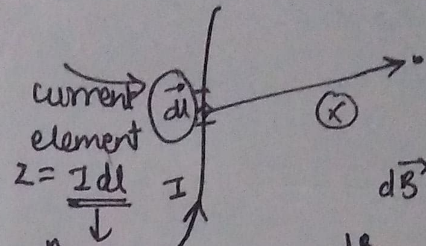
(14) Cyclotron frequency

$$\omega = \frac{qB}{m}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi m}{qB}$$

$$\boxed{T = \frac{2\pi m}{qB}}$$

(15) Biot Savart's Law



$z = Idl \downarrow$ Amp-m

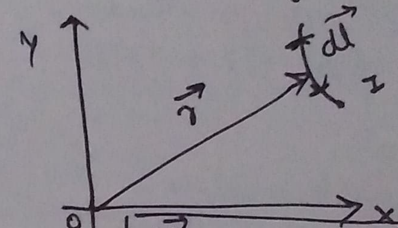
$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{(d\vec{l} \times \vec{r})}{r^3}$$

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

(16) magnetic field directn due to a current element

↙ RHTR ↘ RHPR

(17) Inverse of Biot - savart's law

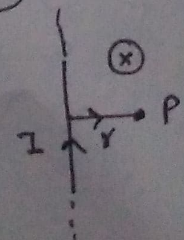


$$\boxed{d\vec{B}_0 = -\frac{\mu_0}{4\pi} \frac{I(d\vec{l} \times \vec{r})}{r^3}}$$

(18) Similarities in coulomb's law (EF) & Biot - savarts law (MF).

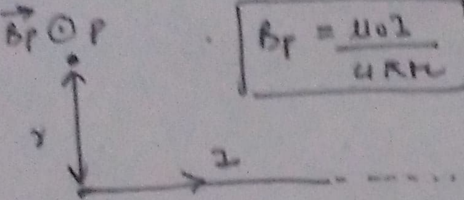
- Both are long range forces
- CL uses a scalar 'charge q' & BSL uses a vector source, 'current element $I\vec{dl}$'
- EF is along position vector from source & MF is perpendicular to position vector from source.
- MF changes with angle θ from current where as EF does not. $[B \propto \sin\theta]$

(19) MF due to a st. current carrying wire :



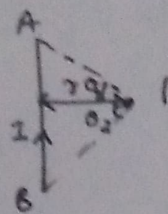
$$\boxed{B_P = \frac{\mu_0 I}{2\pi r}}$$

(20) MF due to semi ∞ wire



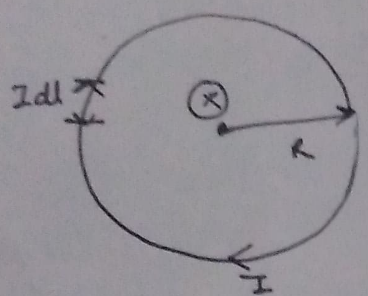
$$\boxed{B_P = \frac{\mu_0 I}{4\pi r}}$$

(21) MF due to a finite wire



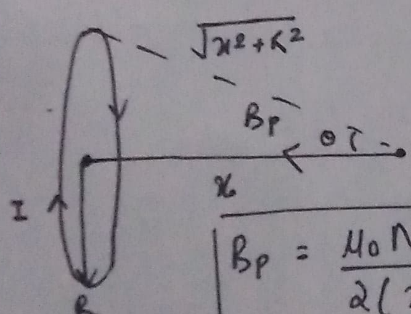
$$\boxed{B_P = \frac{\mu_0 I}{4\pi r}\left[\sin\theta_1 + \sin\theta_2\right]}$$

(22) MF due to a circular coil at it's centre :



$$\boxed{B_0 = \frac{\mu_0 I N}{2R}}$$ → no. of turns

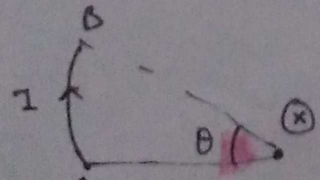
(23)



$$\boxed{B_P = \frac{\mu_0 N I R^2}{2(x^2+R^2)^{3/2}}}$$

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

(24) magnetic field due to a circular Arc:-

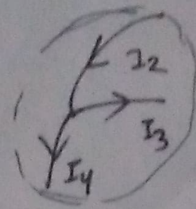


$$\boxed{B_0 = \frac{\mu_0 I \theta}{4\pi R}}$$

(24) Ampere's circuit law

↳ $\oint \vec{B}\cdot\vec{dl} = \mu_0\left(\Sigma I_{enclosed}\right)$

$= \mu_0\left[I_2 + I_3 - I_4\right]$



(25) MF due to long current carrying cylinder :

for r > R (outside)

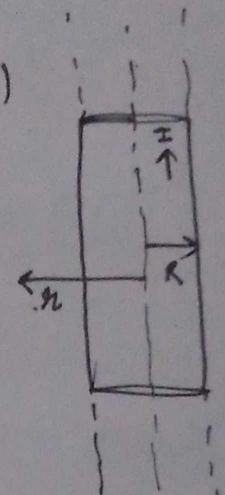
$$B_P = \frac{\mu_0 I}{2\pi r}$$

for r = R (surface)

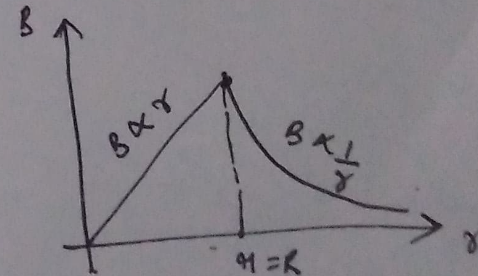
$$B_P = \frac{\mu_0 I}{2\pi r}$$

for r < R (inside)

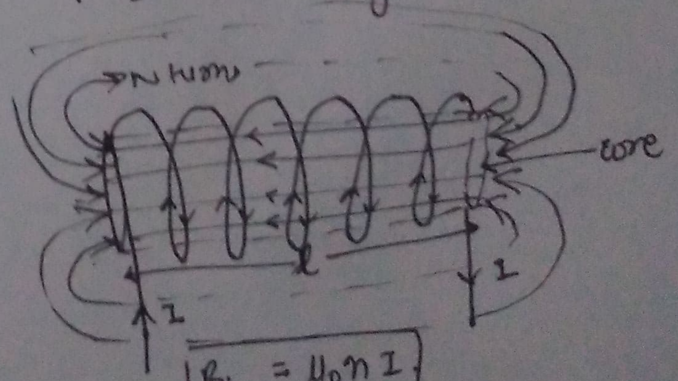
$$B_P = \frac{\mu_0 I}{2\pi R^2}$$



(26) variation curve of MF due to cylinder :-



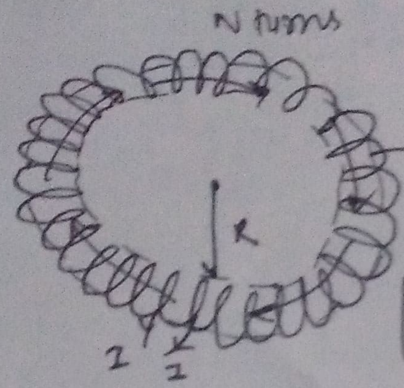
(27) MF due to long solenoid



$$\boxed{B_{in} = \mu_0 n I}$$

$n = N/l$

(28) MF due to a Toroid

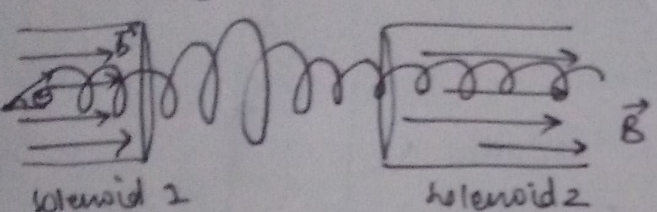


$$\boxed{B_{in} = \mu_0 n I}$$

$$\left[n = \frac{N}{2\pi r} \right]$$

(29) magnetic confinement

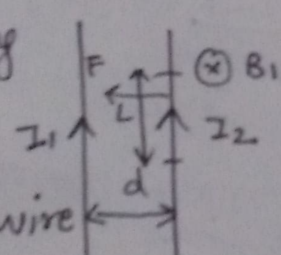
$R_n \propto \frac{1}{B}$



(30) Force betn 2 Parallel Wires

↳ ‖lel current carrying wire attract each other.

↳ Anti - Parallel current carrying wire repel each other.



$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

force on length l of I_2 -

$$F = B_1 I_2 l = \frac{\mu_0 I_1 I_2 l}{2\pi d}$$

(31) Roget's spiral

force betn parallel currents

$$F = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

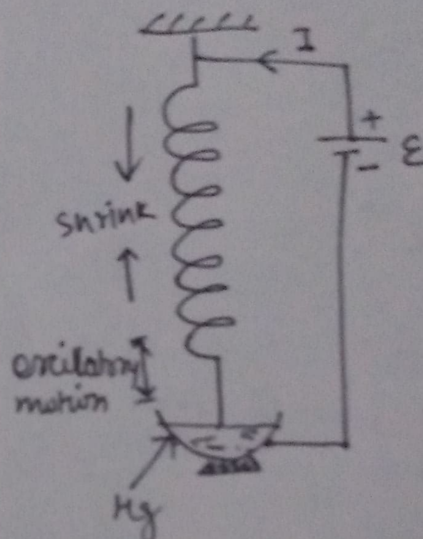
$$\boxed{F = 2 \times 10^{-7} N}$$

def. of Ampere

$I_1 = I_2 = 1A$

$d = 1m$

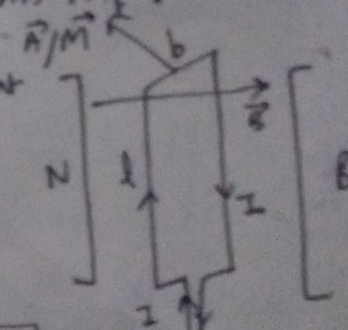
$L = 1\ m$



(32) Torque on a current loop in uniform mf:

magnetic moment of loop

$$\vec{M} = NI\vec{A}$$



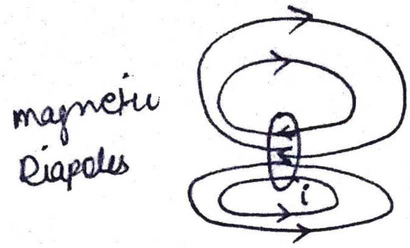
Torque on coil

$$\boxed{\vec{T} = \vec{m} \times \vec{B}}$$

$$\boxed{\vec{T} = mB\sin\theta}$$

$$\boxed{T = BINA\sin\theta}$$

(33) A small coil as a magnetic dipole :

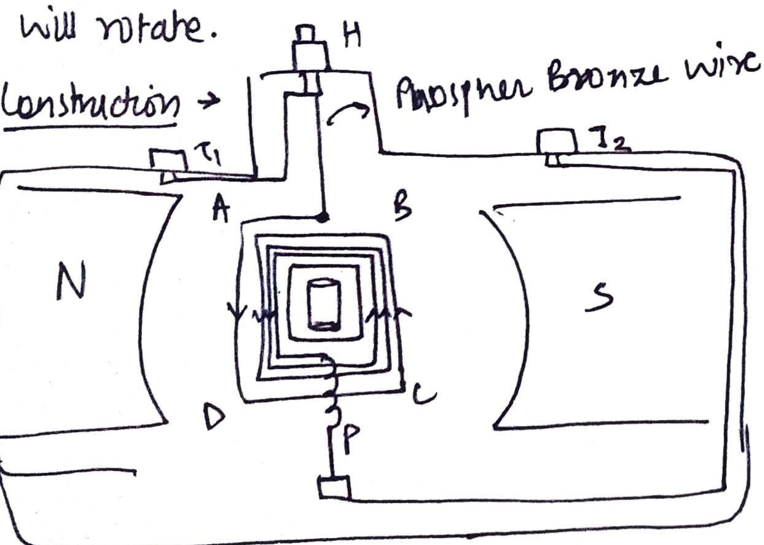


(34) Moving coil Galvanometer

↳ It is a device which is used to detect and measure small currents.

Principle → It is based on the fact that when a current carrying coil is placed in uniform magnetic field then it experiences Torque & it will rotate.

Construction →



It consist of a coil ABCD having large no. of turns of insulated Cu wire. The coil is wounded over a non-magnetic metallic frame which may be rectangular or circular in shape. The coil is suspended from a movable torsion (H) by means of Phosphor bronze strip in a uniform magnetic ~~strip~~ field produced by 'N' and 'S' poles of magnet

The lower end of the coil is connected to hair spring (P) connected to the terminal T_2 is soft iron core which may be spherical if the coil is circular and it may be cylindrical if the coil is rectangular.

In this we use radial magnetic field to produce max. Torque

Theory & working : let a coil having area of cross section carrying current I is lying in uniform magnetic field 'B'. Acc^n to principle it experience a Torque which is given by -

$$\tau = NIBA \cos\theta \qquad \theta = 0^\circ$$

$$\tau = NIBA \quad \text{—①}$$

let ϕ is the rotation (twist) produced & K is the restoring force per unit twist i.e.,

Total restoring force.

$$f = \phi K$$

At equilibrium,

total Restoring force = Torque

$$\phi K = NIBA.$$

$$\phi = \frac{NIBA}{K.}$$

This shows twist produced is directly proportional to current.

$$\boxed{\phi \propto I.}$$