Formula Sheet -04

Moving Charges and Magnetism

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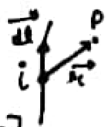
Moving Charges And Magnetism

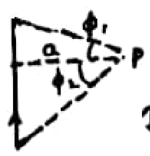
Oersted's Experiment :-
Observations
1. Compass show deflection near a current carrying wire.
2. If wire is over the needle, Current is from S → N, the North pole of compass deflects towards west.
   - SNOW
3. If direction of current reversed, then direction of compass also reversed.
   - Direction of North pole of compass is along direction of magnetic field.

SNOW :- EK variable change karne par dusra change hoga!
Doh bar change karne par kush bhi change nhi hoga.

Biot-Savarts Law :-


- $\vec{dB} = \frac{\mu_0}{4\pi}\frac{i}{r^3}(\vec{dl}\times\vec{r})$ [vector form]
- $|dB| = \frac{\mu_0}{4\pi}\frac{i\,dl\sin\theta}{r^2}$ [scalar form]
- $\mu_0 \to$ Permeability of free space/air/vaccum.
- $\frac{\mu_0}{4\pi} = 10^{-7}$
- Units of $\vec{B}$ = $\frac{N}{Am}$ = Tesla (T) = $\frac{Weber}{m^2}$

Direction of $\vec{B}$:-
1. Right Hand Thumb Rule.
2. Screw Rule or $(\vec{dl}\times\vec{r})$

$\vec{B}$ due to finite wire carrying 'I' :-


$B_p = \frac{\mu_0}{4\pi}\frac{I}{a}[\sin\phi_1 + \sin\phi_2]$

Direction = Inward.

For Infinite wires, $\phi_1 = \phi_2 = 90°$
$\therefore B_p = \frac{\mu_0}{4\pi}\frac{2I}{a}$

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

For semi-Infinite wire.
$\phi_1 = 0$, $\phi_2 = 90°$

$B_p = \frac{\mu_0}{4\pi}\frac{I}{a}$

For $\phi = 0$ or $180°$
$B_p = 0$

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$B_p = \frac{\mu_0}{4\pi}\frac{I}{a}[\sin\phi_2 - \sin\phi_1]$

When $\phi_2 > \phi_1$

Magnetic field at the
- Centre of circular loop of radius a.

  $B_c = \frac{\mu_0}{2}\frac{I}{a}$
- Semicular loop.

  $B_c = \frac{1}{2}\left[\frac{\mu_0}{2}\frac{I}{a}\right]$
- Quadrant loop.

  $B_c = \frac{\mu_0}{2}\frac{I}{a}\left[\frac{1}{4}\right]$

Magnetic field for N turns of loop at centre
$B_c = N B_c$
- N turns of loop means coil.

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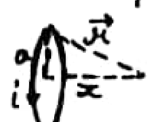
$B_p = \frac{\mu_0}{4\pi}\frac{I}{a}\theta$

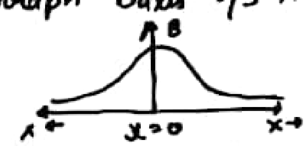
$\theta \to$ In radians

$180° \to \pi$ radian.

Magnetic field on the axis of circular loop.


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

- Note :- Direction of $\vec{B}$ is same on either side of the loop.
- $B_{Max} \Rightarrow$ At centre.
- $B_{MIN} \Rightarrow$ At infinity.
- Graph B_{axis} v/s X



- For N turns of loop,

$B = \frac{\mu_0}{2}\frac{Ia^2 N}{(a^2+x^2)^{3/2}}$

For $x >> a$
$B = \frac{\mu_0}{2\pi}\frac{Ia^2}{x^3}$

$= \frac{\mu_0}{4\pi}\frac{2IA}{x^3}$

A → Area of loop.

Ampere's Circuital law :-
$\oint B.dl = \mu_0 i_{inside}$.

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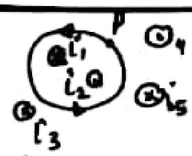


$\oint B.dl = \mu_0(i_2 - i_1)$
- At pt. P $\vec{B}$ is due to all the currents.

$\vec{B}$ due to Hollow cylindrical wire.
(i) Outside

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

(ii) Inside

$B = 0$

(iii) Surface

$B = \frac{\mu_0}{2\pi}\frac{i}{R}$

$\vec{B}$ due to solid cylindrical wire.
(i) Outside

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

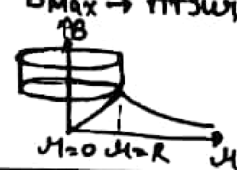
(ii) Inside

$B = \frac{\mu_0}{2\pi}\frac{ir}{R^2}$

(iii) Surface

$B = \frac{\mu_0}{2\pi}\frac{i}{R}$

$B_{Max} \to$ At surface.



$\vec{B}$ due to hollow cylinder of inner radius $\frac{R}{2}$ & outer R.

(i) Outside

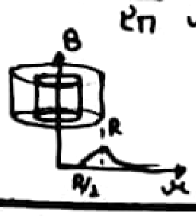
$B = \frac{\mu_0}{2\pi} \frac{I}{r}$

(ii) Inside

$B = 0$

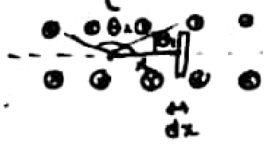
(iii) Between Inner & Outer Surface

$B = \frac{\mu_0}{2\pi} \frac{I}{r} \frac{(4r^2 - R^2)}{3R^2}$



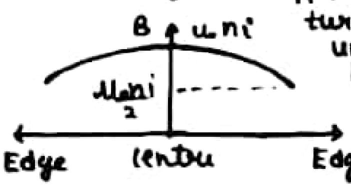
$\vec{B}$ due to a Solenoid :- of turns N

$B = \frac{\mu_0}{2} in [\cos\theta_2 - \cos\theta_1]$



- For ideal Solenoid : $|B| = \mu_0 in$
- $\vec{B}$ at one edge of Solenoid $|B| = \frac{\mu_0 in}{2}$

n → no. of turns per unit length.



- $B_{outside} = 0$

$\vec{B}$ due to Toroid :-

(i) In open Space interior to toroid :- $\vec{B} = 0$

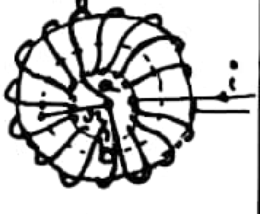
(ii) In open Space exterior to toroid :- $\vec{B} = 0$

(iii) For pt. inside toroid :-

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

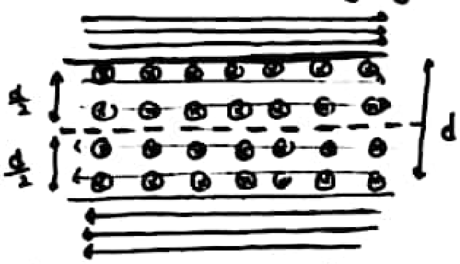
$r \rightarrow \frac{a+b}{2} \leftarrow$ avg. radius

- $B_{Max} = \frac{\mu_0 Ni}{2\pi a}$
- $B_{MIN} = \frac{\mu_0 Ni}{2\pi b}$



b → outer radius.
a → inner "
r → average "

Magnetic field due to large & thick Current carrying Sheet.



(i) Outside :- At distance y above axis.

$B = \frac{\mu_0 J d}{2}$ J → Current density $J = \frac{i}{A}$

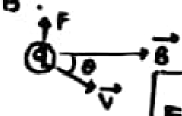
(ii) Inside :- $B = \mu_0 J y$

(iii) Axis or Centre :- $B = 0$

Force On a moving Charge in $\vec{B}$.

$|F| = qvB\sin\theta$

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



$\boxed{\theta = 0, F = 0}$

$\boxed{\theta = 90^\circ, F = qvB}$

Direction of Force.

(i) Fleming Left Hand Rule.

(ii) Right hand Palm rule.

Work done by Magnetic Force on Moving charge :-

$[v \perp F] \rightarrow [\vec{S} \perp \vec{F}]$

Velocity of Charge Displacement.

$W = \vec{F} \cdot \vec{S} = FS\cos 90^\circ = 0$

Work energy theorm,

Work done = Δ K.E

$0 = k_f - k_i$

$k_f = k_i$

$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2$

$|V_i| = |V_f|$

Note → Direction of velocity changes but magnitude of Speed remains constant.

Lorentz Force / Electromagnetic Force

$F_{Lorentz} = F_{electric} + F_{magnetic}$

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

$\theta = 90^\circ$

$F = qvB$

'q' charge will move in circular path.

Radius of Circular path.

$F_{magnetic} = F_{centripetal}$

$qvB = \frac{mv^2}{r}$

$\boxed{r = \frac{mv}{qB}}$ ← velocity

$\boxed{r = \frac{\sqrt{2mK}}{qB}}$

$\boxed{r = \sqrt{\frac{2mV}{qB^2}}}$ ← Voltage

Time-Period :-

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

ν Frequency $= \frac{1}{T}$

Angular (Frequency / velocity) :-

$\omega = \frac{2\pi}{T} = 2\pi\nu$

e^- : Proton : α-Particle

Mass :- $\frac{1}{1837}$: 1 : 4 (amu)

Charge :- −1 : 1 : 2 (e)

$V_\parallel$ ($\vec{v}$ parallel to $\vec{B}$)

→ Straight line path.

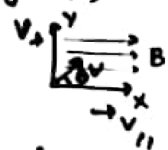
$V_\perp$ ($\vec{v} \perp \vec{B}$)

→ Circular path in a plane ⊥ to B.

When the initial velocity is at some angle (θ) to $\vec{B}$.

$V_\parallel = V\cos\theta$

$V_\perp = V\sin\theta$



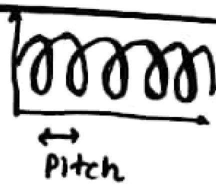
Motion ↳ Helical.

Radius $= \frac{mV_\perp}{qB}$

Time Period $= \frac{2\pi m}{qB}$

Pitch $= V_\parallel \times T$

$= V\cos\theta \times \frac{2\pi m}{qB}$



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Cyclatron Calculation

Frequency oscillator :-

$T = \frac{2\pi m}{qB}$ ← tq ko ek chakkar karne me kitna time lga.

↑ Same for all circles.

→ $f_{oscillator} = f_{circular\ motion}$

$= f = \frac{1}{T} = \frac{qB}{2\pi m}$

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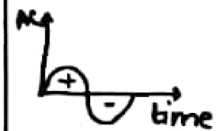


Time period of AC $= \frac{2\pi m}{qB}$

$f_{AC} = \frac{qB}{2\pi m}$.

$f = \frac{qB}{2\pi m}$ ← Cyclotron frequency OR Magnetic Resonance frequency.

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

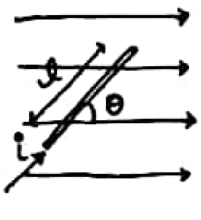
Max. K.E of accelerated charged particle

$K.E_{MAX} = \frac{q^2B^2R^2}{2m}$

Limitations of cyclotron :-

Cannot used to accelerate neutron, e^-s. $\left[m = \frac{m_0}{\sqrt{1 - v^2/c^2}} \right]$

Force on current carrying wire placed in $\vec{B}$.



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

Inward

$|\vec{F}| = ilB\sin\theta$

$|\vec{F}|_{MAX} = Bil$ [$\theta = 90°$]

$|F| = 0$ [$\theta = 0°$]

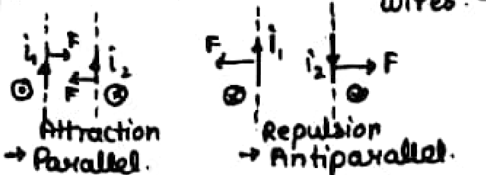
Direction of $\vec{F}$:-

1. Righthand palm rule.
2. Fleming's left hand rule.

If $\vec{B}$ is constant take displacement length to calculate force on wire.

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

Force b/w two // I carrying wires.



Attraction → Parallel.

Repulsion → Antiparallel.

$\vec{F}_{12} = -\vec{F}_{21}$

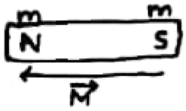
$|\vec{F}_{12}| = |\vec{F}_{21}|$

$\frac{F}{l} = \frac{\mu_0}{4\pi} \frac{2i_1i_2}{d}$

Magnetic Moment ($\vec{M}$)

m → Pole Strength

$\vec{M} = m(2l)$



$\vec{P} = q(2l)$

Note → Magnetic monopole do not exist independently.

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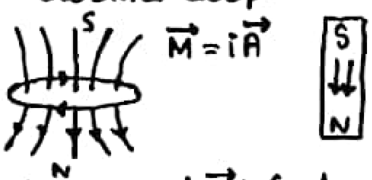
Clockwise → South pole

Anticlockwise → North pole.

Magnetic Moment of Current loop.



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

Direction of $\vec{M}$:- Curl your fingers in the direction of I, your thumb point in $\vec{A}$ or $\vec{M}$.

For N turns of loop,

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

Magnetic dipale moment of revalving e^-.

$M = \frac{evr}{2}$

Relation with angular momentum ($\vec{L}$)

$\left.\begin{array}{l} |\vec{M}| = \frac{e}{2m}|\vec{L}| \\ \vec{M} = -\frac{e}{2m}\vec{L} \end{array}\right\}$ For revolving e^- [Atom]

Bohr's Postulate :-

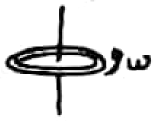
$M = n\left(\frac{eh}{4\pi m_e}\right)$

When n = 1

$M = \frac{eh}{4\pi m_e}$ ← Bohr's Magneton.

Magnetic Moment to Angular Momentum ratio due to Non-Conducting ring

$|M| = \frac{q\omega R^2}{2}$



$\frac{|M|}{|L|} = \frac{q}{2m}$

Current carrying loop in uniform $\vec{B}$.

(i) $\vec{M}$ is along $\vec{B}$ ($\theta = 0°$)

$F_{net} = 0$, $\tau_{net} = 0$

(ii) Loop is rotated at θ angle.

$F_{net} = 0$, $\vec{\tau}_{net} = \vec{M} \times \vec{B}$

$|\tau| = MB\sin\theta$

P.E of Magnetic dipole in uniform $\vec{B}$.

$W = -MB[\cos\theta_2 - \cos\theta_1]$

θ is angle b/w $\vec{M}$ & $\vec{B}$.

→ $U_\theta = -\vec{M} \cdot \vec{B}$

Moving Coil galvanometer:-

Torque on Current carrying coil placed in $\vec{B}$.

$\tau = NiAB\sin\theta$

N → no. of turns.

i → current in each turn.

A → Area of each coil.

B → Magnetic field.

θ → Angle b/w $\vec{B}$ & $\vec{M}$ or $\vec{A}$.

$\tau_{restoring} = C\phi$

C → Torsional constant

$NiAB\sin\theta = C\phi$

$i = \frac{C}{NAB}\phi$

Senstivity of Galvanometer :-

(i) Current Senstivity :- Produce large deflection for small current.

(ii) Valtage sensitivity :- More deflection for small Valtage.