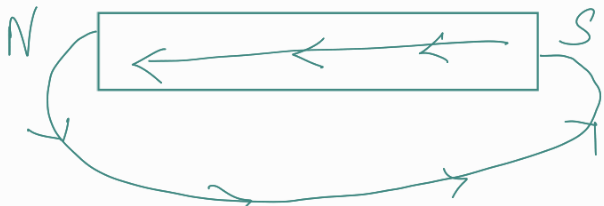
Theory Only

Magnetic Effects of Electric Current (Theory Only)



outside → N → S

inside → S → N

NOTE :- Magnetic Monopoles don't exist

Pole strength is independent of length but depends on Area

Magnetic Effects of Electric Currents.

Magnetic Dipole.

1) $\vec{M} = m\vec{l}$. $-m \xleftarrow{l} +m$

2) Pole strength is independent of length but dependent on Area.
 (a) $-m$ ▭ $+m$ → $-m$ ▭ $+m$ $-m$ ▭ $+m$
 (b) $-m$ ▭ $+m$ → $-m/2$ ▭ $+m/2$, $-m/2$ ▭ $+m/2$.

3) M. Force on moving Charged particle →
 if $\vec{v} \parallel \vec{B}$ or $\vec{v}$ ↿⇂ $\vec{B}$ ($\theta = 0°$ and $\theta = 180°$ respectively).
 ~~M.~~ Magnetic Force = 0.
 if $\vec{v} \perp \vec{B}$.
 then, $\vec{F}_B = q[\vec{v} \times \vec{B}]$. , $F_{max} = qvB$.
 $F_B = qvB\sin\theta$

(4) $dw = \vec{F}.\vec{ds}$
 $dw = \vec{F}.\vec{v}.dt$.

(5) If ~~force~~ F_B is always ⊥ to ~~mo~~ $\vec{v}$, then motion will UCM. Force is centripetal.

(6). $R = \frac{mv}{qB}$, $R = \frac{P}{qB}$, $R = \frac{\sqrt{2mKE}}{qB}$, $R = \frac{\sqrt{2m(q\Delta V)}}{qB}$

ΔV = accelerating voltage.

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

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

(7) Particle is projected at an angle θ with the magnetic ~~field~~.
 If $\vec{v} \perp \vec{B}$, the motion is circular in a plane ⊥ to M.F.
 $v_{\parallel} = v\cos\theta$ (doesn't make any change)
 $v_{\perp} = v\sin\theta$ (will make change to circular path)

Pitch $\vec{v}_{\perp}$ $\vec{v}_{\parallel}$

$r = \frac{mv_{\perp}}{qB}$

Pitch = $v_{\parallel} T$, $= \frac{v_{\parallel} 2\pi m}{qB}$.

8 velocity of particle at exit →
 $v = \frac{qBR}{m}$,

9 K.E of particle at exit :→
 $K.E = \frac{1}{2}mv^2 = \frac{1}{2}\cancel{m}\left(\frac{q^2B^2R^2}{m^{\cancel{2}}}\right)$
 $K.E = \frac{1}{2}\frac{q^2B^2R^2}{m}$

Note :→

(9).

Proton	α-particle
m	4m (mass)
q	2q (charge)

(10) Lorentz Force :→ $F = q\vec{E} + q(\vec{v} \times \vec{B})$. (Combination of electric and M. force).
 $F = q(\vec{E} + (\vec{v} \times \vec{B}))$.

Note :→ Electric force and M. force are frame dependent forces but Lorentz force is independent of frame of reference.

(11) Magnetic Force for current carrying straight wire :→
 $F = \int i(d\vec{l} \times \vec{B})$, $F = i L_{eff} B$.

(12) Pole strength
 $\vec{M} = q_m \times d$ → distance.
 Magnetic Moment, q_m → pole strength

(13) M. Moment of a current carrying loop :→
 $\vec{M} = i \times \vec{A}$ → ($\vec{A}$ is ⊥ to the plane of coil).

(14) Gyromagnetic Ratio :→
 $\vec{M} = \frac{q\omega R^2}{2}$. , $\boxed{\frac{M}{L} = \frac{q}{2m}}$ → only for uniform distribution
 $L = I\omega$ (I → Moment of inertia, L → Angular Momentum.)
 $\frac{M}{L}$ is Gyromagnetic Ratio.

Moment of Inertia
 (1) $I = MR^2$ (2) Ring $I = MR^2$ (3) along diameter $I = \frac{MR^2}{2}$
 Disc → $\frac{MR^2}{2}$, along Diameter = $\frac{MR^2}{4}$
 Solid sphere → $\frac{2}{5}MR^2$, Hollow sphere = $\frac{2}{3}MR^2$

Cyclotron

It is a machine which accelerates the charged particles or ions to high energy.

✱ frequency doesn't depend upon velocity

$P_1 : P_2 : P_3 = 1 : 3 : 5$

19. Force b/w 2 '$\parallel$' current carrying wires

$$f = \frac{\mu_0 i_1 i_2}{2\pi d} \times l.$$

if $\uparrow\uparrow \rightarrow f$ is attractive

if $\uparrow\downarrow \rightarrow f$ is repulsive

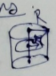
20. Ampere's law

A/c to this law, the line integral of M.F over a closed surface ($\oint \vec{B}\cdot d\vec{l}$) is μ_0 times the net I crossing the Area of the surface

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 \Sigma I.$$

Derivations

(1)



$J = \frac{I}{A} = \frac{I}{\pi R^2}$ — (i). $r < R$.

$B \cdot 2\pi r = \mu_0 (J\pi r^2)$.

$\boxed{\Rightarrow B = \frac{\mu_0 J r}{2}}$. $r \rightarrow$ is the distance from axis.

(2)

$\int \vec{B}\cdot d\vec{l} = B \mu_0 i_{en}$

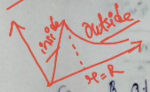
$J = \frac{I}{\pi R^2}$,

$\Rightarrow B \cdot 2\pi r = \mu_0 I$

$\Rightarrow I = J\pi R^2$

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

Graph



(3) B at Surface $= \frac{\mu_0 J \pi R^2}{2\pi R} = \frac{\mu_0 J R}{2} = \frac{\mu_0 I}{2\pi R}$.

$\boxed{(4)\ B_{axis} = 0.}$

Note :→ In, Hollow pipe there is no current / I enclosed, Hence, $B = 0$.

(5) Infinite current carrying sheet :→

$K \rightarrow$ current per unit width.

$B = \frac{\mu_0 K}{2}$. ('$\parallel$' to the sheet)

21. Solenoid

$\boxed{B = \mu_0 n i}$ ($n \rightarrow \frac{N}{L}$ i.e total turns per unit length).

At the end of solenoid,

$\boxed{B' = \frac{1}{2}B, \frac{\mu_0 n i}{2}}$

Note :→ $n = \frac{1}{d}$.

B Inside solenoid,

$B = \mu_0 \mu_r n I$.

$\boxed{\text{B outside solenoid is 0.}}$

Velocity selector :→

Region where uniform E.F and uniform M.F are present

Torque

(*) $\vec{\tau} = \vec{M} \times \vec{B} = MB\sin\theta$

$\theta = 0°$, Stable equilibrium

$\theta = 180°$, Unstable equilibrium

(*) $\tau = I\alpha$ (*) $\tau = \vec{r} \times \vec{F}$

15 Couple

$\tau = F \cdot L = ibBl = iAB = M \cdot B \sin\theta$

$\vec{\tau} = \vec{M} \times \vec{B}$

(16) Time period, $T = 2\pi \sqrt{\frac{I}{MB}}$. → I is moment of inertia.

$\boxed{\tau = I\alpha.}$

(17) P.E on the magnetic dipole moment :→

$\vec{U} = -\vec{M} \cdot \vec{B} = -MB\cos\theta$.

(minimum → $\theta = 0^{\circ}$
maximum → $\theta = 180$)

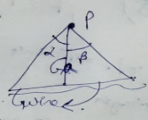
(18) Bio-Savart Law :→

$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \sin\theta}{r^2}$, $dB = \frac{\mu_0}{4\pi} \frac{I(\vec{dl} \times \vec{r})}{r^3}$

$B = \frac{\mu_0}{4\pi} \int \frac{I(\vec{dl} \times \vec{r})}{r^3}$.

M.F due to straight current carrying conductor

$B = \frac{\mu_0 i}{4\pi a} (\sin\alpha + \sin\beta)$.

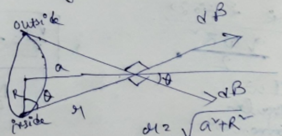


Note :→ (i) if wire is infinite,
then $\alpha = \beta = 90^{\circ}$

(ii) if wire is semi-infinite,
then, put $\alpha = 90$, $\beta = 0^{\circ}$

(iii) M.F along of the length will be 0.

M.f on the axis of loop



$B = \frac{\mu_0 i R^2}{2r^3}$

$B = \frac{\mu_0 i R^2}{2(a^2+R^2)^{3/2}}$.

$r = \sqrt{a^2+R^2}$

$\cos\theta = \frac{R}{r}$

$\boxed{B_{center} = \frac{\mu_0 i}{2R}}$

B_C of arc $= \frac{\mu_0 i}{2R}\left(\frac{\theta}{2\pi}\right)$

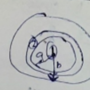
22 Toroid..

(1) Inside, $B = 0$.

(2) Outside, $B \cdot 2\pi r = \mu_0 i_{en}$

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

$r = r_{mean} = \frac{a+b}{2}$.



Note :→ In toroid, field is only in the cross section of the toroid.

23 Moving Coil Galvanometer :→

$F = -kx$, $\tau = -C\theta$ → Torsional constant

• at Equilibrium

$|\tau_B| = |\tau_C|$

$\Rightarrow MB\sin 90 = C\theta$

$\Rightarrow IABN = C\theta$.

$\Rightarrow \theta = \frac{IABN}{C}$.

Current Sensitivity

$C.S = \frac{\theta}{I} = \frac{ABN}{C}$.

N → double
C.S → Double

Voltage sensitivity

$V.S = \frac{\theta}{V} = \frac{\cancel{I}ABN}{\cancel{I}RC}$

$= \frac{ABN}{CR}$ → Resistance

N → double.
V.S → remain same.
R → double

$\boxed{\frac{C.S}{V.S} = R}$ → Resistance

(25) $I_G = 10^{-4}$ T

24 M.f due to moving charge :-

$B = \frac{\mu_0}{4\pi} \frac{qv\sin\theta}{r^2}$

P	deuteron	α
q	q	2q
m	2m	4m