Moving Charges & Magnetism

→ **Ampere's R. thumb rule** — Thumb indicates direction of current. Curling fingers indicates direction of magnetic lines.

flow Clockwise → ⊗ in

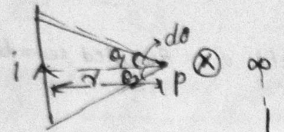
anticlockwise → ⊙ out

$\oint \vec{B}\cdot d\vec{l} = \mu_0 (I_1 + I_2 - I_3)$

→ **Biot - Savart's law** — $dB = \frac{\mu_0}{4\pi}\frac{i\,dl\sin\theta}{r^2}$

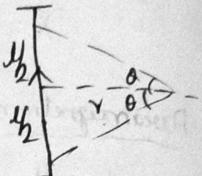
vector → $\frac{\mu_0}{4\pi}\frac{i\,d\vec{l}\times\vec{r}}{r^3}$

i) for finite wire



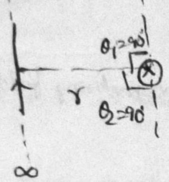
$B = \frac{\mu_0 i}{4\pi r}(\sin\theta_1 + \sin\theta_2)$

iii)



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

ii) infinite wire

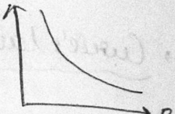


$B = \frac{\mu_0 i}{2\pi r}$

IV) for polygon of 'n' sides $B = \frac{\mu_0 i}{\pi L}\sin(\pi/n)\tan(\pi/n)$

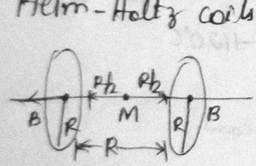
v) for circular coil $B = \frac{\mu_0 N i R^2}{2(x^2+R^2)^{3/2}}$ N - no. of turns

$\frac{\mu_0 N i}{2R} = B_{centre}$



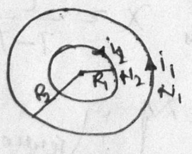
vi) Helm-Holtz coils

$\boxed{\frac{B_{axial}}{B_{central}} = \left(\frac{R^2}{x^2+R^2}\right)^{3/2}}$



$B_{MP} = \frac{8}{5\sqrt{5}}\frac{\mu_0 N i}{R}$

vii) Concentric coils:

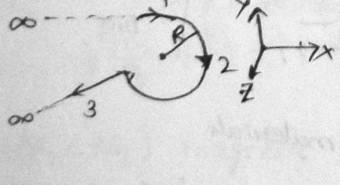


$B_1 = \frac{\mu_0 N_1 i_1}{2R_2}$ ⊙

$B_2 = \frac{\mu_0 N_2 i_2}{2R_1}$ ⊗

$B_{net} = B_1 - B_2$

Ex:



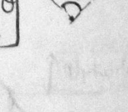
$B_1 = \frac{\mu_0 i}{4\pi R}(-\hat{k})$

$B_2 = \frac{3\mu_0 i}{8R}(-\hat{k})$

$B_3 = \frac{\mu_0 i}{4\pi R}(\hat{j})$

$B_1 + B_2 + B_3 = \frac{\mu_0 i}{8\pi R}(2(-\hat{k}) + 3\pi(\hat{k}) + 2\hat{j})$

$\boxed{B = \frac{\mu_0 i}{4\pi R}\theta}$



→ force experienced on a moving charge

$\vec{F_E} = q\vec{E}$ (particle either at rest or in motion)

$\vec{F_B} = q(\vec{V}\times\vec{B})$ (No force on stationary charged particle)

$|\vec{F_B}| = F_B = qVB\sin\theta$

$(F_B)_{max} = qVB$ (if $\vec{V}\perp\vec{B} \Rightarrow \theta = 90°$), $F_B = 0$ (if $V \neq 0$ then $\vec{V}\parallel\vec{B} \Rightarrow \theta = $

Pitch = $V_{\parallel} \times T$

clockwise flow i $\vec{B}$ ⊗ inside
anticlockwise flow i $\vec{B}$ ⊙ out

Time(T) = $\dfrac{2\pi m}{qB}$

→ when max force acted on particle. it moves in circular path.

$$mv^2/r = qVB \;,\; r = \frac{mv}{qB} = \frac{P}{qB} = \frac{\sqrt{2mKE}}{qB}$$

$$KE = \frac{B^2q^2r^2}{2M}$$

Energy per 1 rev of e^- in cyclotron $KE = 2 \times Vq$

→ Lorentz force $(\vec{F_L}) = \vec{F_E} + \vec{F_B} = q[\vec{E} + (\vec{V} \times \vec{B})]$

circular coils

$$\frac{B_{axial}}{B_{centre}} = \frac{(R^2)^{3/2}}{(x^2+R^2)^{3/2}}$$

for solenoid

$$B = \frac{\mu_0 N i}{2\pi a} = \mu_0 \mu_r n i_0$$

for toroid

$$B = \frac{\mu_0 N i_0}{2\pi a}$$

→ Magnetic moment $(M) = iA = \frac{q}{t}A = \frac{q}{T}\pi r^2 = \frac{qV}{2\pi r}\pi r^2 = \frac{qvr}{2}$

$$M_e = \frac{evr}{2} = \frac{er^2\omega}{2}$$

→ angular momentum $L = \vec{r} \times \vec{P} = Bq\left(\frac{mv}{Bq}\right)^2$

→ Force (F) = $q(\vec{V} \times \vec{B})$

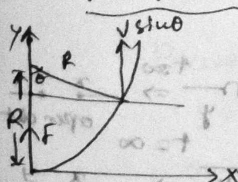
if $\vec{V} \parallel \vec{B}$ path of $\bar{e}$ is st. line

$\vec{V}$ lar $\vec{B}$ path of e is circle

pitch = $(V\cos\theta) \times T$

$\vec{V}$ inclined to $\vec{B}$ at θ the path is helical.

eqn of motion. $\bar{V} = V\cos\frac{Bqt}{m}\hat{i} + V\sin\frac{Bqt}{m}\hat{j}$

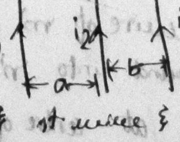


→ Force b/w 2 current carrying conductors

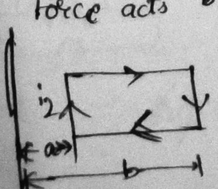
$$F = \frac{\mu_0 i_1 i_2 l}{2\pi d}$$

→ Force acts b/w 3 current carrying conductors

$$F_1 = \frac{\mu_0 l}{2\pi}\left(\frac{i_1 i_2}{a} - \frac{i_2 i_3}{b}\right)$$



→ Force acts b/w a current carrying st. wire & rectangular loop.

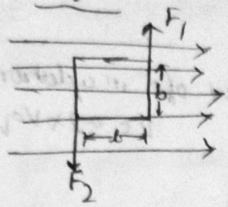


$$F = \frac{\mu_0 i_1 i_2 l}{2\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$$

→ Force acting on a current carrying wire placed in uniform magnetic field. $F = i(\vec{l} \times \vec{B})$

→ $B = \frac{\mu_0 i}{2R}\left(\theta/360\right)$

→ Torque



$T = Bi \sin 90° (bl)$

$T = BiA$

$T = BANi = MB$

$T = Ni\vec{A} \times \vec{B} = \vec{M} \times \vec{B}$

→ Moving coil galvanometer $T = C\theta = MH \sin\theta$

$NiBA = C\theta \Rightarrow i = (C/NBA)\theta$

$i = K\theta \Rightarrow i \propto \theta$

sensitivity $(S) = \frac{d\theta}{di} = \frac{NBA}{C}$

$di = \left(\frac{C}{NBA}\right) d\theta$

Tangent galvanometer: $i = k \tan\theta$, $i \propto \tan\theta$

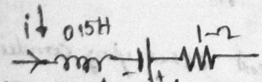
$di = k \sec^2\theta \, d\theta$

$K = \frac{2rB_H}{\mu_0 n}$ $S = \frac{d\theta}{di} = \frac{1}{k\sec^2\theta} = \frac{\mu_0 n \cos^2\theta}{2rB_H}$

B for solenoid $B = \mu_0 ni$

for toroid $B = \mu_0 \frac{ni}{2\pi r}$

EMF Battery polarity



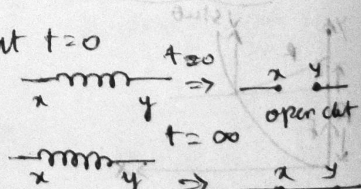
$i = 5A$

$\frac{di}{dt} = 10 A/s$ $\mathcal{E} = L\, di/dt$

$V_x - V_y = 5 - 15 - 5 = -15V$

at $t=0$ → open ckt

$t = \infty$ → plain wire



→ If wire of m turn is unwound & rewound into n turn then

Ex: at centre of coil

$B = \frac{\mu_0 m I}{2R/n} \Rightarrow B_{centre} = \frac{\mu_0 mnI}{2R}$