Magnetic effect of current ①

① Biot-savart law.

$$\boxed{d\vec{B} = \frac{\mu_0}{4\pi} \frac{I(d\vec{l}\times\vec{r})}{|\vec{r}|^3}} \quad \boxed{dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\sin\theta}$$

$\boxed{\mu_0/4\pi = 10^{-7}}$

② formulae of field for wire.

$$\boxed{B = \frac{\mu_0}{4\pi}\frac{I}{r}(\sin\alpha + \sin\beta)}$$

③ $\log_e 2 = 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \dots$

④ m.field for polygon of n sides

$$\boxed{B_{centre} = \frac{\mu_0 n I}{\pi l}\sin(\pi/n).\tan(\pi/n)}$$

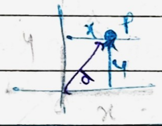
n → total sides, l → side length.

⑤ Neutral point (for two ∥el wires)

$$\boxed{x = \frac{I_1 r}{(I_1+I_2)}}$$

near small magnitude of I.

for 2 ⊥er wires



neutral point → $\boxed{y = \left(\frac{I_x}{I_y}\right)x}$

$$\boxed{B_p = \frac{\mu_0}{2\pi d}(x^2+y^2)^{1/2}}$$

⑥ Field at centre of arc

$$\boxed{B_c = \frac{\mu_0}{4\pi}\frac{I}{R}(\theta)}$$

- point lies at axial of wire contributes zero magnetic field.

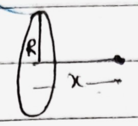
⑦ field at the centre of symmetrically located diag. $\boxed{R \propto \theta}$

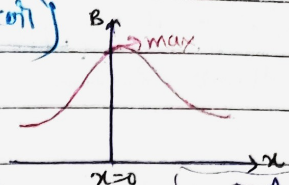
$$I_1R_1 = I_2R_2 \rightarrow \boxed{I_1\theta_1 = I_2\theta_2} \text{ ***}$$

$$\boxed{\frac{I_1 \rho r \theta_1}{A} = \frac{I_2 \rho r \theta_2}{A}}$$

②

Field at the axis of Ring. (current carrying coil)





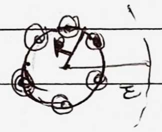
① $B_{axis} = \frac{\mu_0}{4\pi}\frac{2M}{(R^2+x^2)^{3/2}}$ $\quad \boxed{M = I\times A = I\times\pi R^2}$

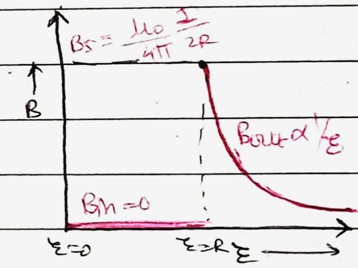
→ field at axial of bar magnet

② $B_{centre} = \frac{\mu_0}{4\pi}\frac{I}{R}2\pi \rightarrow \boxed{\frac{\mu_0 I}{2R}}$

$$\rightarrow \boxed{B_{axis} = \frac{B(centre)}{\left(1+\frac{x^2}{R^2}\right)^{3/2}}}$$

Hollow pipe





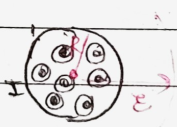
① $B_{out} = \frac{\mu_0}{4\pi}\frac{2I}{r}$

② on the surface : $(r=R)$ → $\boxed{\frac{\mu_0}{4\pi}\frac{2I}{R}}$

③ Inside $(r<R)$

$B_{inside} = 0$, $I_{inc} = 0$

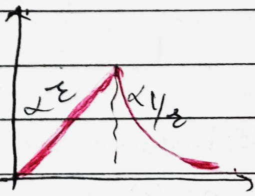
solid pipe : thick pipe



① $B_{out} = \frac{\mu_0}{4\pi}\frac{2I}{r}$ $\quad \boxed{B_{out} = B_s \times R/r}$

② on the surface $(r=R)$

$B_s = \frac{\mu_0}{4\pi}\frac{2I}{R}$



③ $B_{inside} = \boxed{B_s \times \frac{r}{R}}$

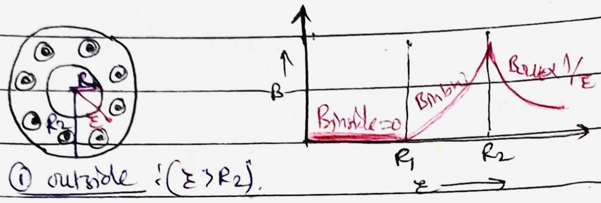
Gauss theorem = Ampere's law
Biot-Savart's law = Coulomb's law

(8) Ampere's law

$$\boxed{\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}}$$

$B\,dl\cos\theta = \mu_0 I_{enc}$

* Annular pipe.



(1) outside : $(r > R_2)$

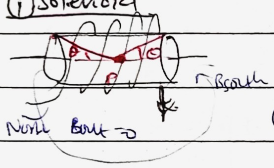
$B_{out} = \frac{\mu_0}{4\pi}\frac{2I}{r}$

(2) $\boxed{B_{in\,b/w} = \frac{\mu_0}{4\pi}\frac{2I}{r}\frac{(r^2-R_1^2)}{(R_2^2-R_1^2)}}$ → partial Area / → Total Area

(3) $B_{inside} = r < R_1 \Rightarrow \boxed{0}$ → imp

Solenoid & Toroid

(1) Solenoid



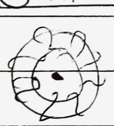
(1) $\boxed{B_{centre} = \mu_0 n I}$ $\quad \theta_1=\theta_2=0$

(2) $\boxed{B_{end\,p} = \frac{1}{2}\mu_0 n I}$ → $n = \frac{N}{L}$

(3) at general ~~point~~ 'O'

$$\boxed{B = \frac{1}{2}\mu n I(\cos\theta_1 + \cos\theta_2)}$$

(2) Toroid.



$\boxed{B_{axis/inside} = \frac{\mu_0 N I}{2\pi r_{av}}}$ $\quad n = \frac{N}{l}$

$2\pi r_{av}$ → mean circumference length

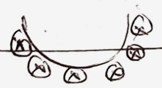
$B_{interior}$ and $B_{ext} = 0$

(9) Field due to thin sheet of ∞ length & width

$\boxed{B = \frac{1}{2}\mu_0 J}$ $\qquad J = I/A = J/\pi R^2$

current density

(10) Field at the axis of cylinder having semicircular cross-section



$$\boxed{B = \frac{1}{\pi}\mu_0 J}$$

(11) spiral $\qquad \boxed{B = \frac{\mu_0 N I}{2(b-a)}\log(b/a)}$

CH-2 Motion of charged particle in M. field

(1) $\boxed{\vec{F}_m = q(\vec{V}\times\vec{B})}$

a) circular path $\qquad \theta = 90^\circ \quad (\vec{V}\perp\vec{B})$

$\boxed{F_{max} = qvB}$

$\Rightarrow \boxed{r = \frac{mV}{qB}} = \boxed{\frac{\sqrt{2mK}}{qB}} = \boxed{\frac{\sqrt{2mqV}}{qB}}$ $\quad$ K.E final

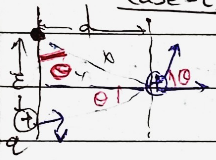
if $k_i \neq 0$

$$\boxed{r = \frac{\sqrt{2mqV + k_i}}{qB}}$$

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

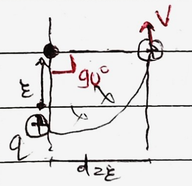
i) Deviation in circular region.

case-i) : $\boxed{d < r}$



$\boxed{\sin\theta = d/r}$ $\qquad \boxed{t = \frac{\theta m}{qB}}$

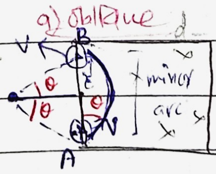
case (ii) $\boxed{d = r}$



$\boxed{\theta = \frac{\pi}{2}}$ $\qquad \boxed{time = \frac{\pi m}{2qB}}$

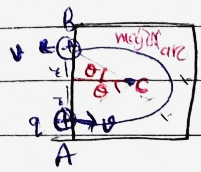
case iii) $\boxed{d > r}$

a) oblique



$\boxed{deviation = 2\theta}$

time $= \frac{2\theta m}{qB}$ $\qquad AB = 2r\sin\theta$



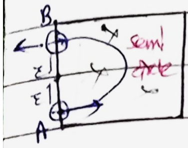
$\Rightarrow$ deviation $= 2\pi - 2\theta$

$\Rightarrow$ time $= \frac{(2\pi-2\theta)m}{qB}$

$\Rightarrow \boxed{AB = 2r\sin\theta}$

$$B_{axial} = \frac{2\mu_0 M x}{4\pi (x^2 - l^2)^2} \Rightarrow B_{axis} = \frac{2\mu_0 M}{4\pi x^3}$$

$$B_{equatorial} = \frac{-\mu_0 M}{4\pi (x^2 + l^2)^{3/2}} \Rightarrow B_{eq} = \frac{-\mu_0 M}{4\pi x^3}$$

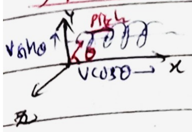


$AB = 2r$

deviation $= \pi$

time $= \frac{\pi m}{qB}$

b) Helical path



① $\text{Radius} = \frac{mv_\perp}{qB}$

② Time pd. $\frac{2\pi m}{qB}$

③ Pitch = speed × time $= v_{\parallel} \times T$

cyclotron

① Total work done

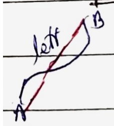
$$N\,2qEd = K_{max}$$

(2 times work is done by e.f. at entry and leaving site).

② $R = \frac{\sqrt{2mK}}{qB}$ $\qquad K_{max} = \frac{q^2 B^2 R^2}{2m}$

② Force on current carrying conductor.

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



$$F = I(l_{eff})B\sin\theta$$

③ Force b/w ‖el & ⊥er wires.

‖el wires

$$F_1 = F_2 = \frac{\mu_0 2 I_1 I_2 \times l}{4\pi r}$$

$$\text{Force/length} = \frac{\mu_0}{4\pi}\frac{2I_1 I_2}{r}$$

⊥er wires

$$F = \frac{\mu_0}{4\pi} 2 I_1 I_2 \log_e\left[\frac{d+l}{d}\right]$$

④ Motion of charged particle in M. & E. field.

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

when $B \perp v \perp E$ $\qquad \vec{E} = \vec{B} \times \vec{v}$

⑤ moving coil galvanometer

$$NIBA = C\phi$$

a) current sensitivity $\Rightarrow \frac{\phi}{I} \Rightarrow \frac{NAB}{C}$

C = torsional const. / spring const

ϕ = angle of devn / deflection

b) Voltage sensitivity $\Rightarrow \frac{\phi}{V} = \frac{NAB}{RC}$ $\qquad \frac{\text{scn current}}{R}$

Moving charges & Magnetism

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q(\vec{v} \times \vec{r})}{|r|^3} \qquad B = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}$$

a) Revolving sphere.

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

$$B = \frac{\mu_0}{4\pi}\frac{q\omega}{r}$$

$\frac{v}{r} = \omega$

b) orbital motion of e^-

$$B = \frac{\mu_0}{4\pi}\frac{ev}{r^2} \text{ or } \frac{\mu_0}{4\pi}\frac{e\omega}{r}$$

2nd law of kepler

$$\frac{A}{t} = \frac{L}{2m}$$

★ magnetic dipole moment of revolving charge.

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

called gyromagnetic ratio

value for e^- is 8.8×10^{10} C/kg

⑥ Bohr's magneton.

$$\mu = \frac{eh}{4\pi m} \Rightarrow \text{for } e^- \; 9.27 \times 10^{-24}\ \text{Am}^2$$

$M = NIA$ → closed body

$M = \frac{qL}{2m}$ → point charge → $\boxed{L = I\omega}$

$M = m \times l_p$ → bar magnet

magnetic mom, pole strength

* Force b/w moving charges.

$$\boxed{F_m = \frac{\mu_0}{4\pi} \frac{q_1 q_2}{r^2} \cdot v_1 v_2} \qquad \boxed{\mu_0 \varepsilon_0 = \frac{1}{c^2}}$$

Bar magnet.

① $\boxed{M = m \times l_p}$ pole strength $[Am^2]$

Am × m

magnetic moment

② $$\boxed{M_{new} = M \frac{\sin(\theta/2)}{(\theta/2)}}$$

* Earth magnetism *

① α = angle of declination

α at centre of earth is $11.5°$.

② $$\boxed{\tan\delta = \frac{B_V}{B_H}} \qquad \boxed{B_E = \sqrt{B_V^2 + B_H^2}}$$

③ Relⁿ b/w false angle of dip & True angle of dip.

$$\boxed{\tan\delta' = \frac{\tan\delta}{\cos\theta}}$$

θ = angle b/w m.meridian & plane other than m.meridian

δ' = inclination of needle in plane other than m.meridia

δ = inclination of angle in magnetic meridian

④ Tangent law

$$\boxed{B_{ext} = B_H \tan\theta}$$

⑤ Tangent Galvanometer.

$$\boxed{\frac{\mu_0 N I}{2R} = B_H \tan\theta}$$

⑥ vibration magnetometer

$$T = 2\pi\sqrt{\frac{I}{MB_H}} \qquad \boxed{T' = T/n} \quad \boxed{I' = \frac{I}{n^3}} \quad \boxed{M' = M/n}$$

$$\boxed{\frac{M_1 \text{(large)}}{M_2 \text{(small)}} = \frac{T_d^2 - T_s^2}{T_d^2 + T_s^2}}$$

T sender, T difference

magnetic fied (B) ⇒ $\boxed{\mu = \frac{B}{\mu_{med}}}$

magnetising (H) $= \frac{B}{\mu_0}$

magnetic properties

$\boxed{2\sqrt{2} = 2.8}$

① Permeability

$$\boxed{\text{Relative permeability } (\mu_r) = \frac{\mu_{med}}{\mu_0}}$$

② Intensity of magnetising field (H) or magnetising field

$$\boxed{\vec{H} = \frac{\vec{B}_{ext}}{\mu_0}} \qquad \boxed{B = \mu_r B_0}$$

$[B \propto \mu]$

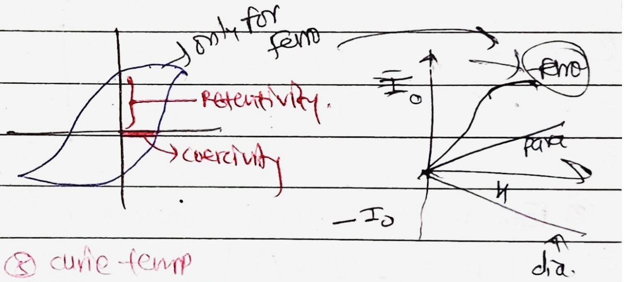
③ Intensity of magnetisation (I) polarisation

$$\vec{I} = \frac{\vec{B}_M}{\mu_0} = \frac{\vec{B}_{ind}}{\mu_0} = \frac{M}{A} = \frac{M}{V}$$

dipole ~~magnetic~~ moment — $\boxed{M = mN}$ — ~~dipole moment~~ pole strength

④ magnetic susceptibility (χ_m)

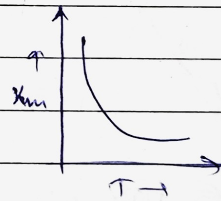
$$\boxed{\chi_m = \frac{I}{H} = \frac{B_{ind}}{B_{ext}}}$$



⑤ curie temp

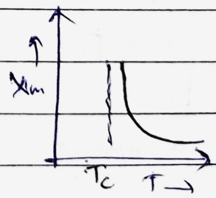
for Paramagnetic,

$$\boxed{\chi_m = \frac{C}{T}}$$



for ferro.

$$\boxed{\chi_m = \frac{C}{(T - T_c)}}$$



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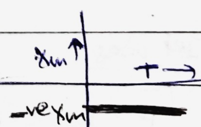

* Relⁿ b/w permeability & susceptibility

$$\boxed{\mu_r = 1 + \chi_m}$$