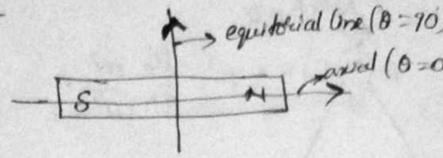
Magnetism & matter

→ **Magnetic poles:**



i) Poles are of equal strength i.e at ends

Magnetic length $= \frac{5}{6} \times (2l)$ (geometric length)

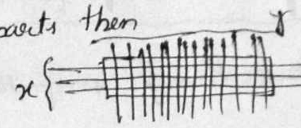
→ **Magnetic moment (M):**

$M = m \times 2l$ (pole strength) ($SI - Am^2$), vector quantity ($S \longrightarrow N$).

i) If magnet is cut into 'n' equal ||el parts to axis

$$\left.\begin{aligned} m' &= m/n \\ L' &= 2l \end{aligned}\right\} M' = M/n$$

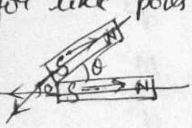
ii) If magnet is cut into 'x' ||el & 'y' ⊥ar parts then



$$\left.\begin{aligned} m' &= m/x \\ L' &= 2l/y \end{aligned}\right\} M = \frac{M}{xy}$$

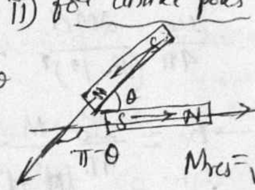
→ **Resultant magnetic moment:**

i) for like poles:

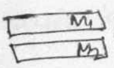


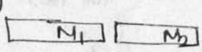
$$M_{res} = \sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$$

ii) for unlike poles:



$$M_{res} = \sqrt{M_1^2 + M_2^2 - 2M_1M_2\cos\theta}$$

iii)  ($\theta = 180'$) $M_{res} = M_1 - M_2$

iv)  ($\theta = 0'$) $M_{res} = M_1 + M_2$

v) for 'n' identical bar magnets form a closed polygon resultant magnetic moment is zero.

→ **Bending of magnets:**

i) If thin magnet is bent at its midpoint with an angle θ.

$M' = M\sin(\theta/2)$. $\quad L' = 2l\sin(\theta/2)$

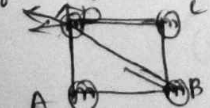
ii) If wire is bent to form an arc of Cle makes angle 'θ'.

$$M' = \frac{2M\sin(\theta/2)}{\theta}$$

→ **Coulomb's inverse square law:**

$$F = \frac{\mu}{4\pi}\frac{m_1 m_2}{d^2}, \quad \mu = \mu_0\mu_r, \quad \mu_r = \frac{\mu}{\mu_0}$$

for square



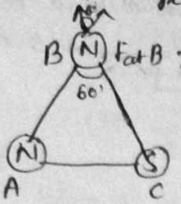
$$F' = \frac{\mu_0}{4\pi}\frac{m^2}{a^2}\left[\sqrt{2} + 1/2\right]$$

for eq. Δle

$$F' = \sqrt{3}\,\frac{\mu_0}{4\pi}\frac{m^2}{a^2}$$

→ for eq. Δ^{le} having 2 dissimilar poles

1 North pole



$F_{at\,B} = F' = \frac{\mu_0}{4\pi}\frac{m^2}{a^2}$

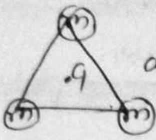
→ **Magnetic Field Induction**

$$\vec{B} = \frac{\vec{F}}{m}$$

i) due to north pole only

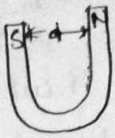
$$\vec{B} = \frac{\mu_0}{4\pi}\frac{m}{d^2} \quad N \longrightarrow S$$

ii) B at centre of eq. Δ^{le} having identical poles



at G, $B_G = 0$

iii) for horse shoe magnet



$$B = 8\frac{\mu_0}{4\pi}\frac{m}{d^2}$$

→ **Magnetic lines of force :**

Never intersect.

→ passes through magnetic substances, closed curves.

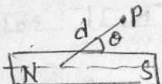
⇒ **Magnetic flux for only non uniform field (ϕ)** : $\phi : \vec{B}\cdot\vec{A}$

for bar magnet

i) axial → $B_a = \frac{\mu_0}{4\pi}\frac{2Md}{(d^2-l^2)^2}$, for $(l<<<d)$ $B_a = \frac{\mu_0}{4\pi}\frac{2M}{d^3}$

ii) equitorial → $B_e = \frac{\mu_0}{4\pi}\frac{M}{(d^2+l^2)^{3/2}}$ for $(l<<d)$ $B_e = \frac{\mu_0}{4\pi}\frac{M}{d^3}$.

B at any angle θ



$$B = \frac{\mu_0}{4\pi}\frac{M}{d^3}\sqrt{3\cos^2\theta+1}$$

Null points : $(m_1 < m_2)$ pole strengths

for $x = \frac{d}{\sqrt{\frac{m_2}{m_1}} \pm 1}$ $\left(\begin{matrix}+ \text{ for like} \\ - \text{ for unlike}\end{matrix}\right)$ from m_1 , from $m_2 = d \mp x$ $\left(\begin{matrix}- \text{ for like} \\ + \text{ for unlike}\end{matrix}\right)$

if $(M_1 < M_2)$ magnetic moments

$$x = \frac{d}{\left(\frac{M_2}{M_1}\right)^{1/3} \pm 1}$$

→ Couple ($\vec{C}$) ⇒ $\vec{C} = \vec{M}\times\vec{B}$

$\vec{C} = MB\sin\theta$

i) in uniform magnet field only couple & no net force. (only rotatory)

ii) vice versa but both (couple & force) in non uniform field. (Rotational & translation)

→ Potential energy (U) $= -\vec{M}\cdot\vec{B}$

i) if $\vec{M}$ ||el to $\vec{B}$ PE is min (stable eq.)

ii) if $\vec{M}$ anti ||el to $\vec{B}$ PE is max (unstable eq.)

→ Work done $(W) = MB(\cos\theta_1 - \cos\theta_2)$

Potential (magnetic) $V = \frac{\mu_0}{4\pi}\frac{M\cos\theta}{r^2}$

→ Time period of oscillation $T = 2\pi\sqrt{\frac{I}{MB_H}}$ where I = moment of inertia

T changes only if magnet is cut into 'n' lar length parts $T' = T/n$

→ Intensity of magnetisation (I): $I = \frac{M}{V} = \frac{m}{a}$.

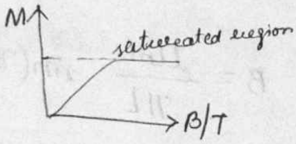
→ Magnetic susceptibility (χ): ratio of I to magnetising field (H).

$\chi = \frac{I}{H}$, $B = \mu_0(H+I)$, $\mu_r = 1+\chi$

→ Paramagnetism: i) absence of external magnetic field e⁻s oriented randomly due to thermal agitation

$(H_{\text{at low}})\ M \propto B \propto 1/T$ (H = magnetising field)

at high H



→ Curie's law: $\chi \propto \frac{1}{T_{(\text{absolute})}}$ $\chi = \frac{C}{T}$ Above curie temp.

Ferro → para

Para → dia

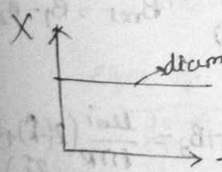
No effect on dia

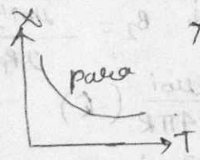
not applicable for ferromagnetic materials

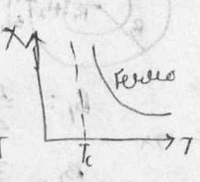
→ Curie temp. for Ni − 358°C, Fe − 770°C, Co − 1120°C

→ Curie-weiss law:

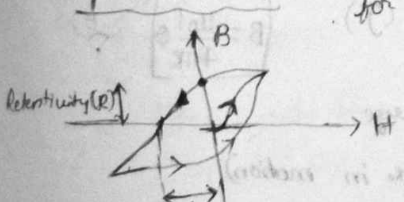
for ferromagnetic materials $\chi = \frac{C}{T - T_c}$ (C → curie const.)







Hysteresis Loop: for ferromagnetic materials



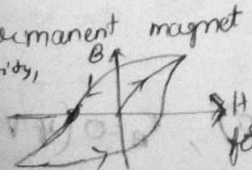
due to friction, heat is produced, area (A) of loop is a measure of loss of energy.

$R_{\text{Soft Fe}} > R_S$; $C_{SFe} < C_S$; $A_{SFe} < A_S$

S = steel

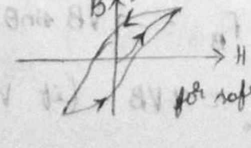
Permanent magnet

large retentivity, coercivity



for steel

electromagnets



less coercivity, retentivity

for soft iron