Formula Sheet -05

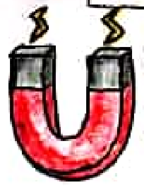
Magnetism and Matter

Sheet Credit: Umme Rumaan

PHYSICSWALLAH Lakshya Batch

Ch-05 : Magnetism & Matter

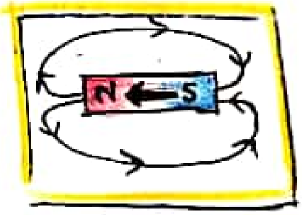
[FORMULAE SHEET]



Bar magnet as a magnetic Dipole:

$\boxed{\vec{M} = m(2l)}$ S to N ; SI unit: Am^2

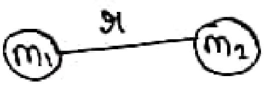
N → +q



SI unit of magnetic Field: Tesla (T)

$$\boxed{1T = \frac{1N}{1Am} = \frac{1Weber}{m^2} = 10^4 \text{ Gauss}}$$

Coulomb's law of magnetic Force:

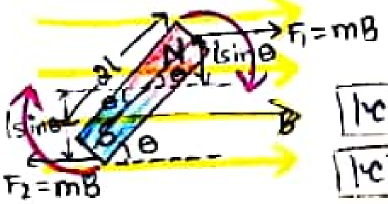


$$\boxed{F = \frac{Km_1m_2}{r^2}}$$ where, $\boxed{K = \frac{\mu_0}{4\pi}}$

Magnetic Fields due to a Monopole:

$$\boxed{B_A = \frac{Km}{r^2}}$$

Torque on a Bar magnet (magnetic Dipole) in a uniform magnetic field:

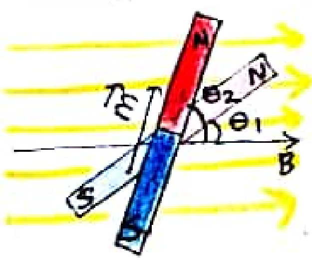


$\boxed{\vec{\tau} = \vec{M} \times \vec{B}} = MB\sin\theta$

$\boxed{|\tau|_{max} = MB}$ when $\theta = 90°, 270°$

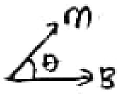
$\boxed{|\tau|_{min} = 0}$ when $\theta = 0°, 180°$

Potential Energy of a Bar magnet (magnetic dipole) in a magnetic Field (uniform):



Assumption

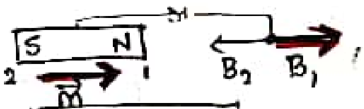
When $\vec{m} \perp \vec{B}$, i.e., $\theta = 90°$, then $\boxed{U_{90°} = 0}$ → min



$U_{\theta_2} \Rightarrow \boxed{U_\theta = -\vec{m}\cdot\vec{B}}$ $\boxed{U_{0°} = -mB}$ $\boxed{U_{180°} = +mB}$

Magnetic Field due to a magnetic Dipole:

- On the axis:

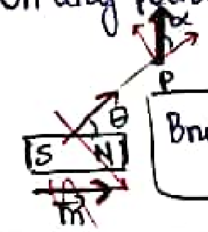


$$\boxed{\vec{B_a} = \frac{2K\vec{m}}{r^3}}$$

- On the equatorial line:

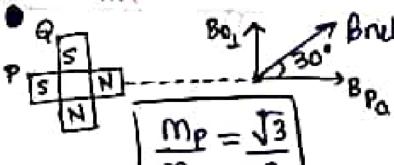
$$\boxed{\vec{B_\perp} = \frac{-K\vec{m}}{r^3}}$$

- On any point $P(r,\theta)$: $\tan\alpha = \frac{1}{2}\tan\theta$



$$\boxed{B_{net} = \frac{Km}{r^3}\sqrt{3\cos^2\theta + 1}}$$

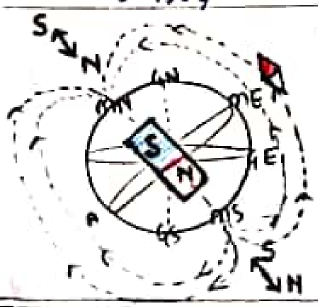
-



$$\boxed{\frac{m_P}{m_Q} = \frac{\sqrt{3}}{2}}$$

When $\theta = 0°$, $F_{net} = 0$, $\tau = mB\sin 0° = 0$; $U = -mB\cos 0° = -MB$ ⇒ minimum : stable Equilibrium ✓

When $\theta = 180°$, $F_{net} = 0$, $\tau = mB\sin 180° = 0$; $U = -mB\cos 180° = +mB$ ⇒ Maximum : Unstable Equilibrium ✓

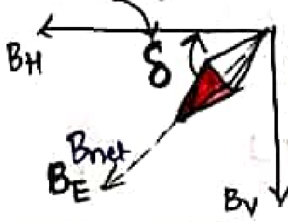


Angle of Dip or Magnetic Inclination (δ or I)

At magnetic equator (ME), $\delta = 0$

At magnetic poles, $\delta = 90°$

At any place, $\boxed{\tan\delta = \frac{B_V}{B_H}}$

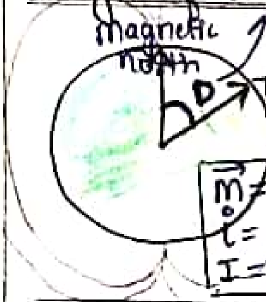


$\boxed{B_E = \sqrt{B_H^2 + B_V^2}}$

$B_H = B_E\cos\delta$

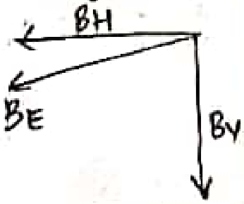
$B_V = B_E\sin\delta$

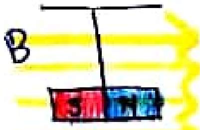
Angle of Declination (D):



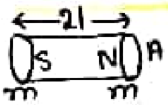
$\vec{M} = 6.4 \times 10^{21}\ Am^2$
$l = 5 \times 10^{?}\ A$
$I = 72\ A/m$

★ Most of the time, we consider only Horizontal component (B_H) of earth's magnetic field, ∵, at most places only B_H is present.



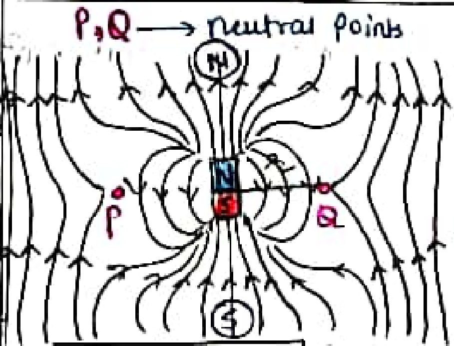


$$\boxed{T = 2\pi\sqrt{\frac{ml^2}{12MB}}}$$

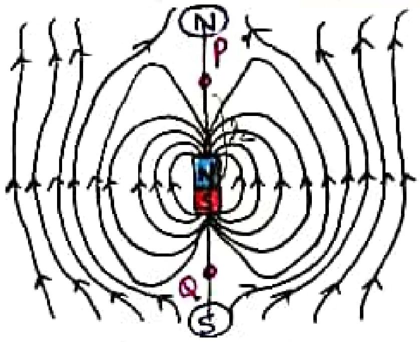


$$\boxed{I = \frac{m}{A}}$$

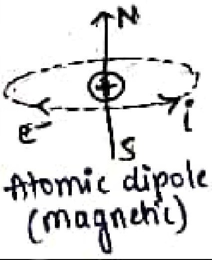
P, Q ⟶ neutral points



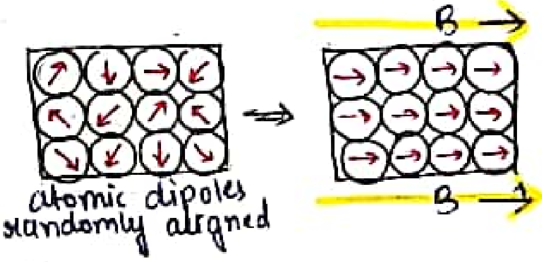
$$\boxed{B_H = \frac{\mu_0}{4\pi}\frac{M}{r^3}}$$



$$\boxed{B_H = \frac{\mu_0}{4\pi}\frac{2M}{r^3}}$$



Atomic dipole (magnetic)



atomic dipoles randomly aligned

Magnetisation (I):

$$\boxed{\vec{I} = \frac{\vec{M}}{V}}$$

$\vec{M}$ – magnetic moment

V – Volume

SI unit: A/m

Magnetic Intensity or Magnetising Field (H):

$$\boxed{B_{net} = \mu_0 (H + I)}$$

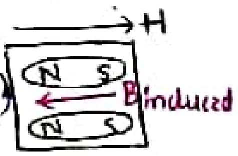
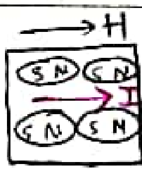
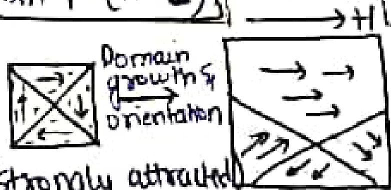
Magnetic Susceptibility (χ)

$$\boxed{I = \chi H}$$

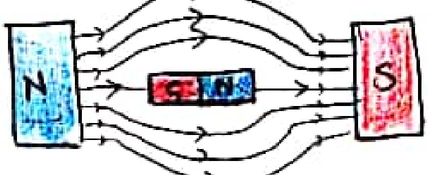
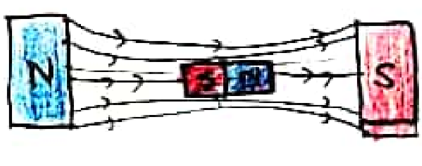
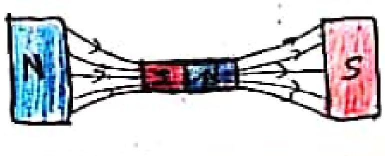
• $\boxed{\mu_0 = 4\pi \times 10^{-7}}$

Absolute permittivity (μ_0), magnetic permeability (μ_m) & Relative permittivity (μ_r)

$\boxed{\mu_0 = \frac{B_0}{H}}$ • $\boxed{\mu_m = \frac{B_m}{H}}$ • $\boxed{\mu_m = \mu_0(1+\chi)}$ $\boxed{\mu_r = 1 + \chi}$ • $\boxed{\mu_r = \frac{\mu_m}{\mu_0} = \frac{B_m}{B_0}}$

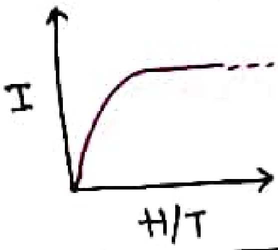
DIAMAGNETIC ⇅	PARAMAGNETIC ⇅	FERROMAGNETIC ⇅
$\chi \to -ve$; $I \to -ve$; $\mu_r < 1$ $\boxed{B_m = \mu_0 (H - I)}$	$\chi \to +ve$; $I \to +ve$; $\mu_r > 1$ $\boxed{B_m = \mu_0 (H + I)}$	$\chi \to +ve$; $I \to$ large +ve $\mu_r >>>> 1$ $\boxed{B_m = \mu_0 (H + I)}$
(Repelled by H) 	(Weakly attracted to H) 	 (Strongly attracted)

In Non-uniform magnetic Field,

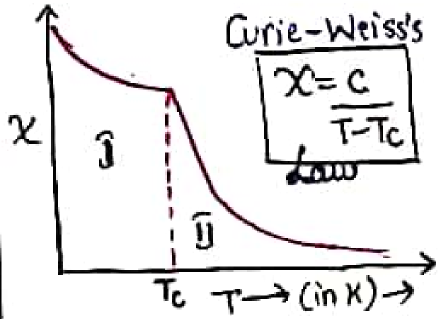
these tends to move from stronger part to weaker one.	these tends to move from weaker part to stronger part.	they move quickly from weaker part to stronger one
		

Curie's law for Paramagnetic : $\boxed{\chi = \frac{C}{T}}$ C - curie's constant, T - temperature $\Rightarrow \boxed{\frac{\chi'}{\chi} = \frac{T}{T'}}$

I v/s H/T graph for Paramagnetic:



Graph for χ with T for ferromagnetic:



Curie-Weiss's Law $\boxed{\chi = \frac{C}{T - T_c}}$

Region I - Paramagnetic
$\chi \propto \frac{1}{T-0} \propto \frac{1}{T}$

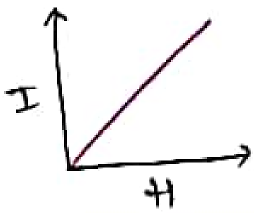
Region II - Ferromagnetic
$\chi \propto \frac{1}{T - T_c}$

T_c - Curie Temperature or Curie's Point.

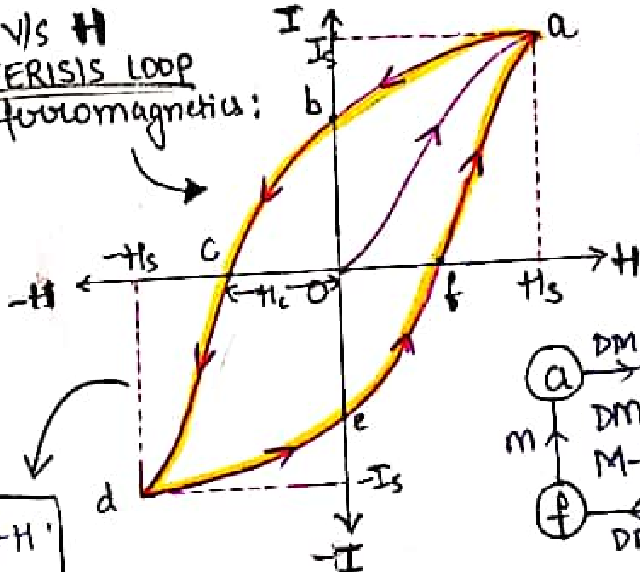
Hysterisis [Greek]

(n.) lagging or delayed

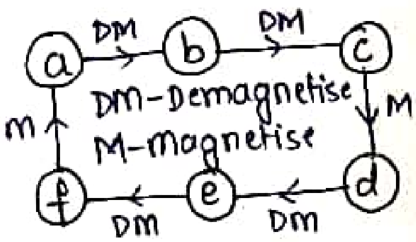
I v/s H graph for paramagnetic:



I v/s H HYSTERISIS LOOP for ferromagnetics:



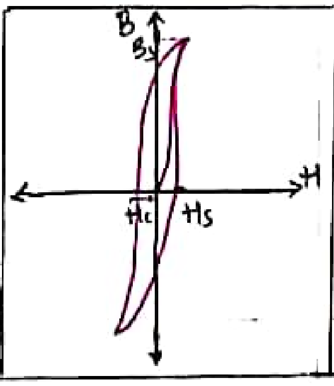
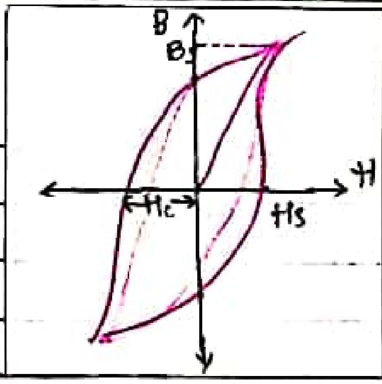
a, d → Saturation points
oe, ob → retentivity
of, oc → coercivity



DM - Demagnetise
M - magnetise

$$\frac{\text{Energy lost}}{\text{cycle} \times \text{Volume}} = \mu_0 \times \text{Area of 'I-H' loop}$$

B v/s H graph - similar to I v/s H graph

	Soft Ferromagnetic materials:-	Hard Ferromagnetic Materials:-
B v/s H Graph		
Coercivity	Low	high
Energy loss	Small	Large
Retentivity	High	low
Permeability	High	low
Susceptibility	High	low
Example	Soft iron core, Mu metal (Ni, Fe)	Steel, AlNiCo
Used in	Cores of Electromagnets, & Transformers	making permanent magnets