LAKSHYA BATCH

JEE

MAGNETISM AND MATTER
MAGNETIC MATERIALS

LECTURE - 6

GOALS OF THE DAY

CBSE Remove

1. FIELD DUE TO REVOLVING ELECTRON
2. MAGNETIC MATERIALS
3. HYSTERISIS

Mains

ELECTRON REVOLVING IN ATOM:

What we Know from Bohr's Model.

$r_n = \frac{a_0 n^2}{Z}$ $\quad a_0 = 0.529\,\mathring{A}$.

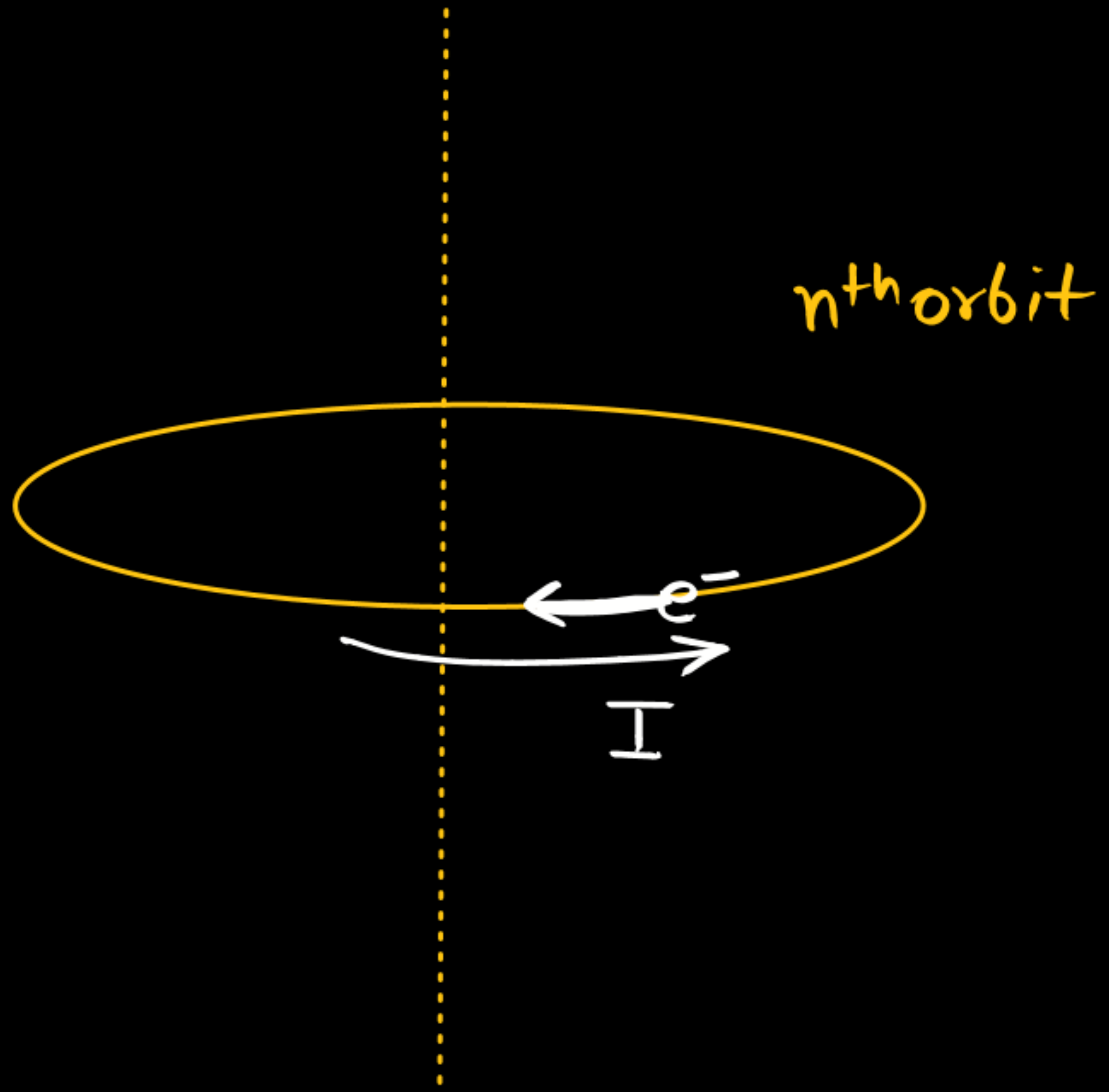
$v_n = \frac{v_0 Z}{n}$ $\quad v_0 = 2.2 \times 10^6\ m/s$.

$r_n \propto \frac{n^2}{Z}$

$v_n \propto \frac{Z}{n}$

Z = Atomic Number

n = Principal Q. No.



ELECTRON REVOLVING IN ATOM:

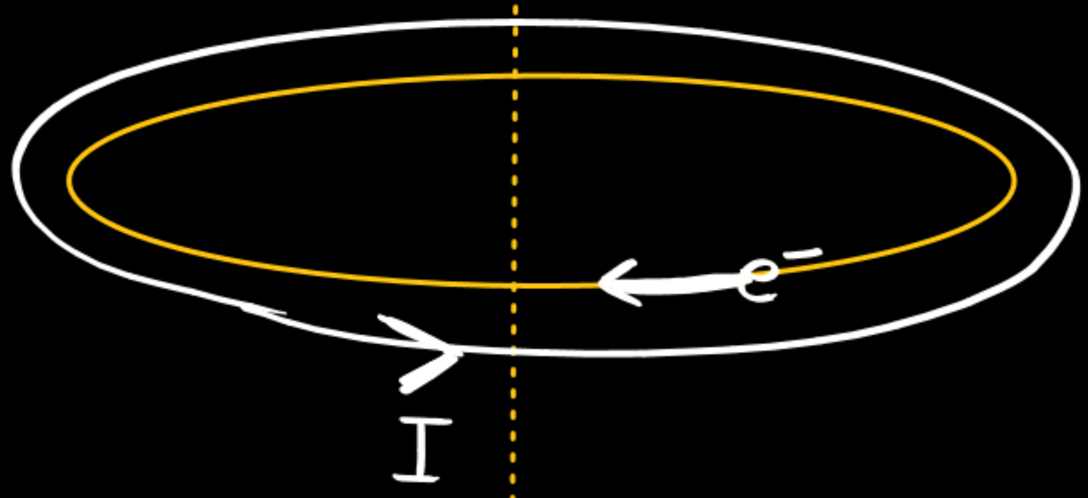
Time Period of Revolution in n^{th} orbit :-

$v_n = \frac{v_0 Z}{n}$ = Constant

$r_n = \frac{a_0 n^2}{Z}$

$T_n = \frac{2\pi r_n}{v_n}$ $T_n \propto \frac{r_n}{v_n} \propto \frac{n^2 n}{Z \times Z}$

$$T_n \propto \frac{n^3}{Z^2}$$



frequency in n^{th} orbit :-

$\nu_n = \frac{1}{T_n}$

$$\nu_n \propto \frac{Z^2}{n^3}$$

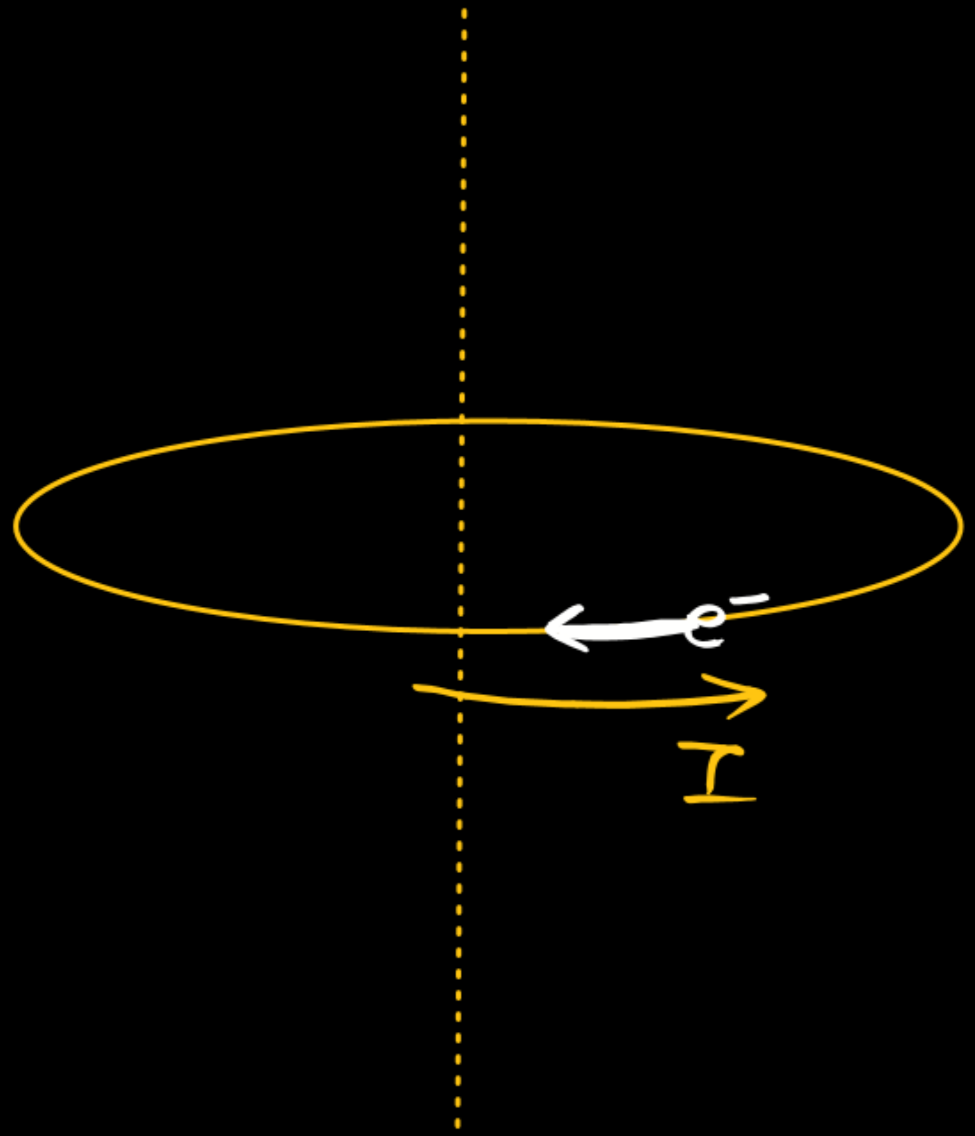
ELECTRON REVOLVING IN ATOM:

Angular frequency in n^{th} orbit :-

$$\omega_n = \frac{2\pi}{T_n} = 2\pi \nu_n \quad \therefore \quad \boxed{\omega_n \propto \frac{Z^2}{n^3}}$$

Current developed in n^{th} orbit :-

$$\text{Current} = \frac{q}{\text{Time}} = q\nu \qquad \boxed{I_n \propto \frac{Z^2}{n^3}}$$



ELECTRON REVOLVING IN ATOM:

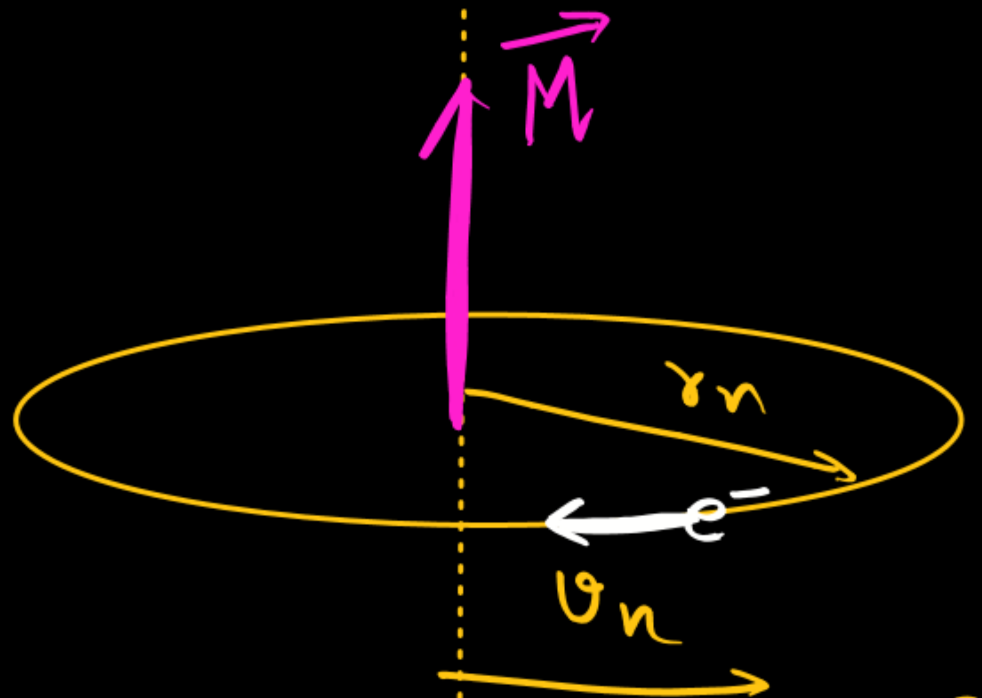
$r_n = \frac{a_0 n^2}{Z}$

Magnetic field developed due to e^-

Rotation in n^{th} orbit.

$B_n = \frac{\mu_0 I}{2 r_n}$ $B_n \propto \frac{I}{r_n} \propto \frac{Z^2 \times Z}{n^3 \, n^2}$

$\boxed{B_n \propto \frac{Z^3}{n^5}}$



$I_n \propto \frac{Z^2}{n^3}$

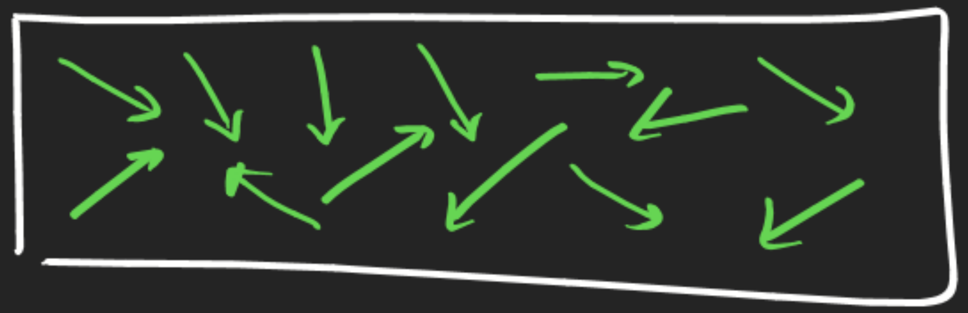
Magnetic Moment developed due to rotation of e^- in n^{th} orbit.

$M = I_n A_n = I_n (\pi r_n^2)$ $M_n \propto \frac{Z^2}{n^3} \cdot \frac{n^4}{Z^2} \propto n$

$\boxed{M = \mu_B n}$ → Bohr's Magnetron.

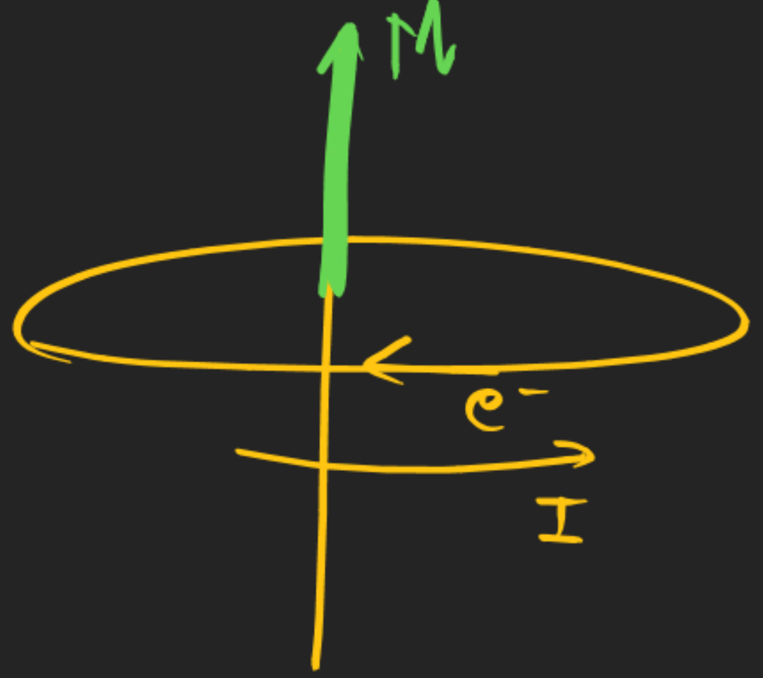
Magnetic Materials

(Randomisation)



$M_{net} = 0$

Non-Magnetic



Naturally There are Some Materials.

(Natural Magnets)

When we apply External MF they attain Magnetic Properties.

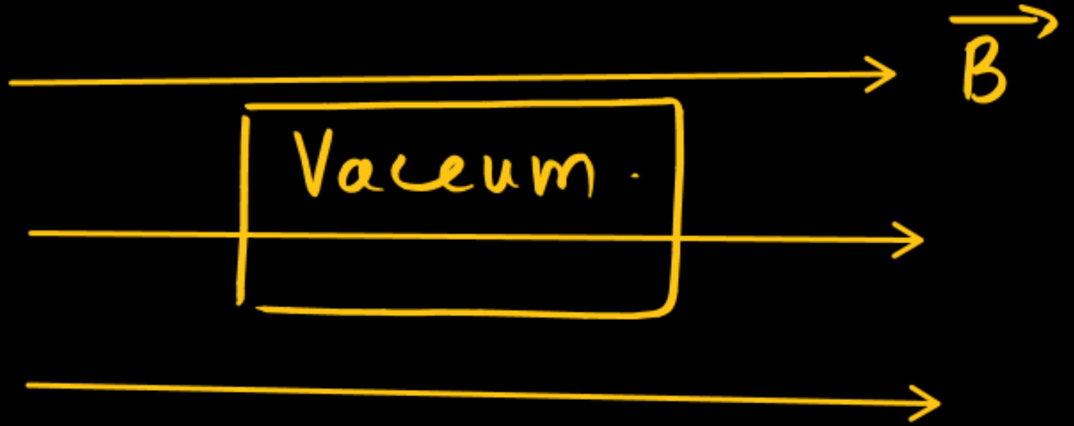
- Diamagnetic
- Paramagnetic
- ferromagnetic.

IMPORTANT TERMS

a) Relative Permeability (μ_r).

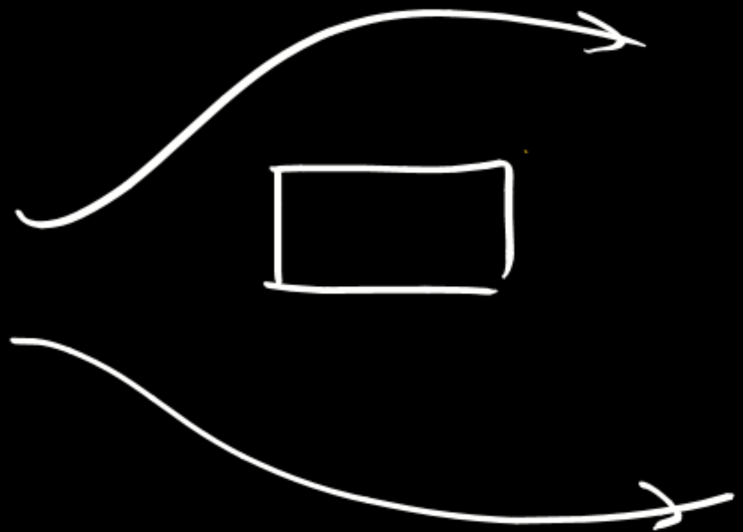
$$\mu_r = \frac{\mu_{medium}}{\mu_{vaccum}} = \frac{B_m}{B_0}$$

Region



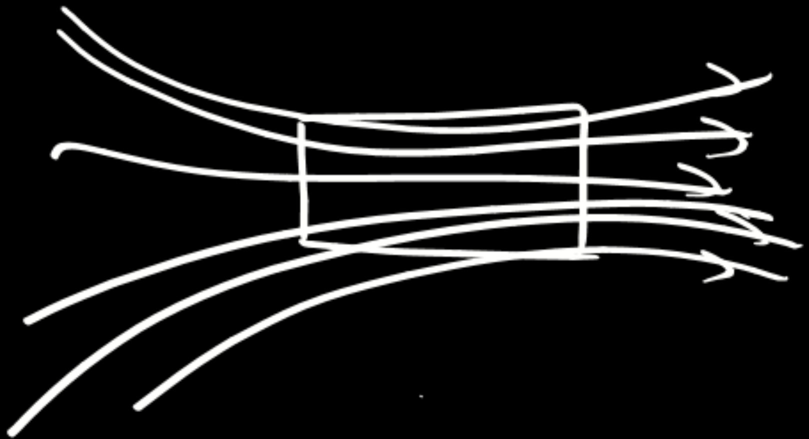
$\mu_r < 1$

Those Materials which Repel External Mf



(Diamagnetic)

$\mu_r > 1$



Those Material which attract MFL

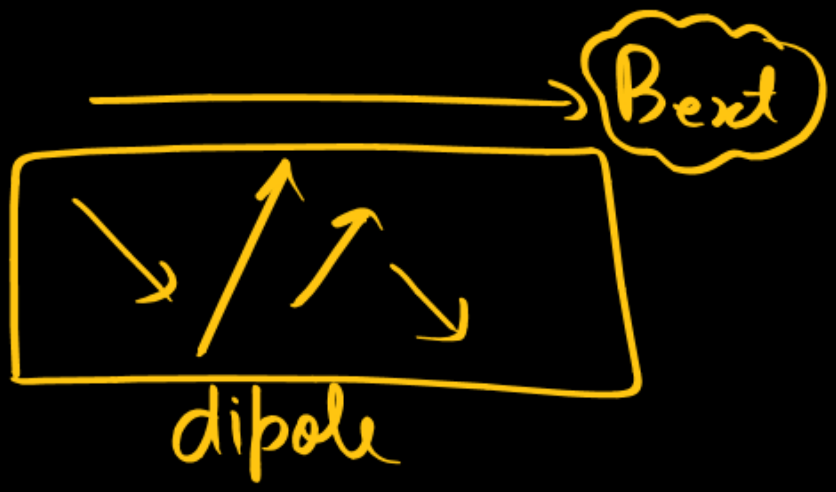
"Paramagnetic"

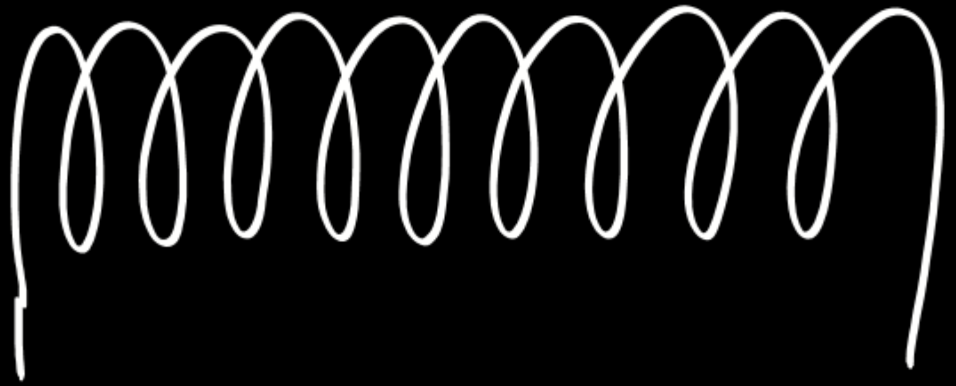
"Ferromagnetic".

IMPORTANT TERMS

b) Magnetising Force OR Magnetising Intensity. $(H) = nI$.

This is Representation of Strength of External field





In Stable

$\longrightarrow B$

Stable Equilibrium pt.

$$H = nI = \left(\frac{A}{cm}\right)$$

$$B = \mu_0 H$$

$$B = \mu_0 nI$$

"H"

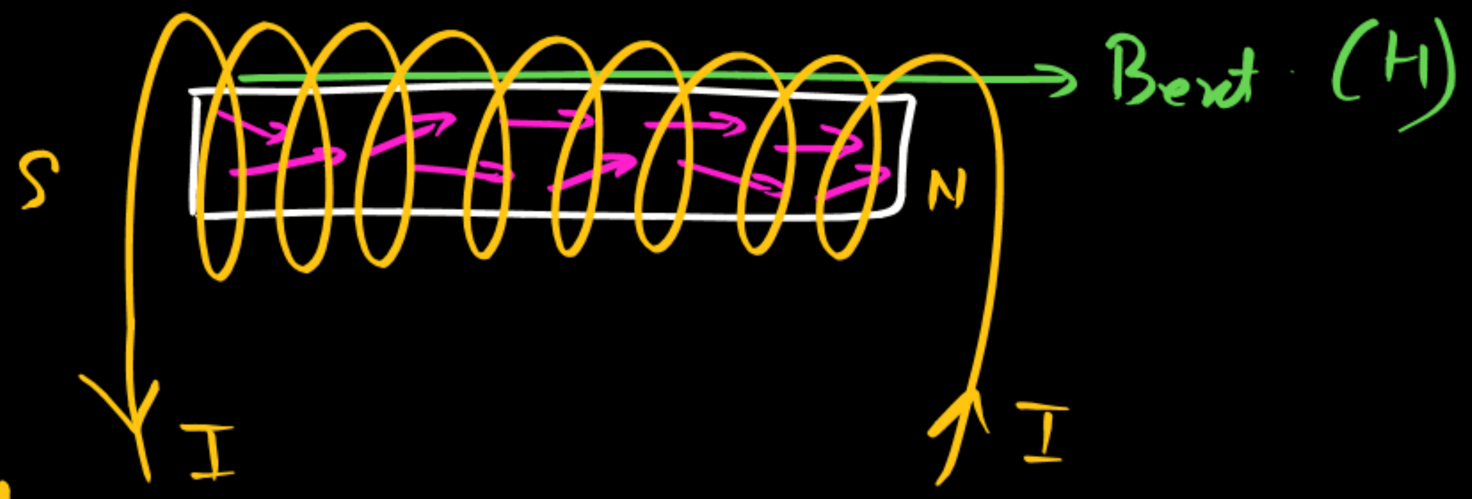
IMPORTANT TERMS

c) Intensity of Magnetisation (I). {Extent of Magnetisation inside Material}

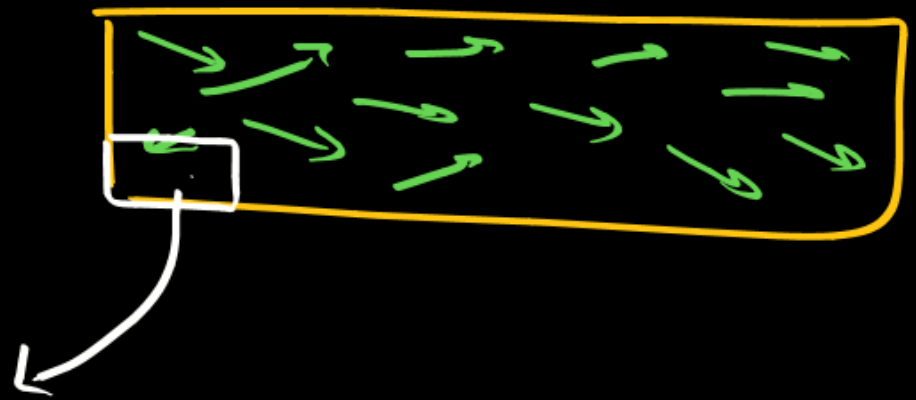
(field developed inside Material)

Non-Magnetised Material

$\vec{M} = I \cdot A$
$= A \cdot m^2$



Outcome



$$I = \frac{\text{Magnetic Moment}}{\text{Volume}} = \frac{|\vec{M}|}{\text{Volume}}$$

M = Magnetic Moment

m = Pole Strength $\vec{M} = m l$.

$$= \frac{m l}{l^3} = \frac{m}{l^2}$$

Volume

$$\text{unit} = \frac{Am}{m^2} = \frac{A}{m}$$

IMPORTANT TERMS

d) Magnetic Susceptibility. (χ). (Z_i)

(Ease of Magnetisation)

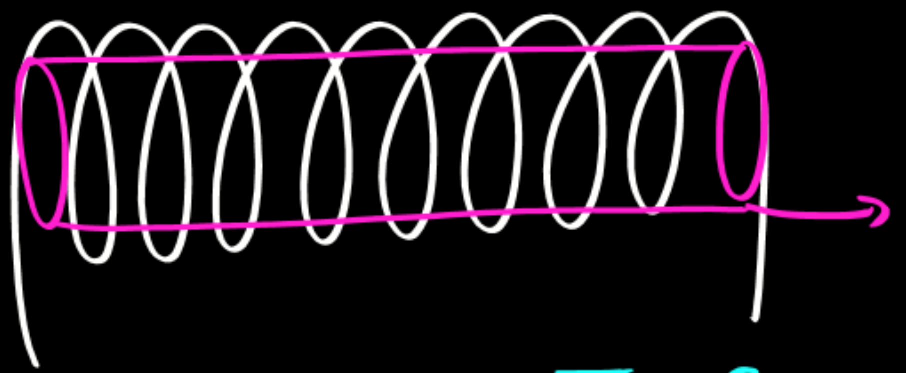
$$\chi \propto I$$

$$\propto \frac{1}{H}$$

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

IMPORTANT TERMS

(*) Relation Between B, I, H.



I_0 = Current

we Know

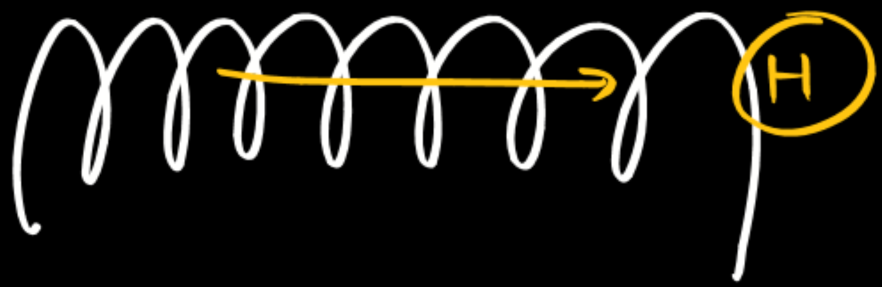
$H = n I_0$

$B = \mu_0 H.$

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

$I = \chi H$

No Material

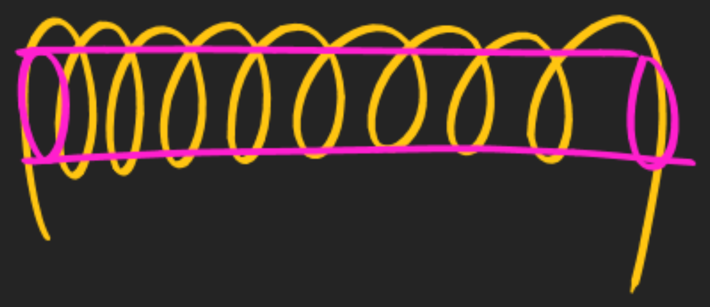


In this Region

$B_{Total} \propto (I + H).$

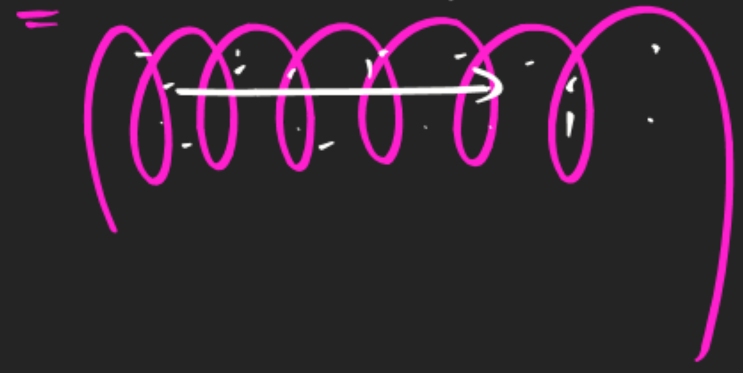
$B_T = \mu_0 (I + H) = \mu_0 (\chi H + H)$

$$B_T = \mu_0 (1+\chi) \cancel{H} = \mu_m \cancel{H}$$



$$\frac{\mu_m}{\mu_0} = 1+\chi$$

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



If Medium is not present $(I = 0)$

$$B = \mu_0 (\cancel{I} + H)$$

$$\boxed{B = \mu_r H}$$

$$B_{solenoid} = \mu_m n I$$
$$= \mu_m H$$

(a) $B = \mu_0 (H + I)$ when medium is present

when Medium is not there

$I = 0$

$B = \mu_0 H$

(b) $\chi = \frac{I}{H}$

(c) $\mu_r = 1 + \chi$

(d) $B = \mu H = \mu_0 \mu_r H$

Here : μ = magnetic permeability,

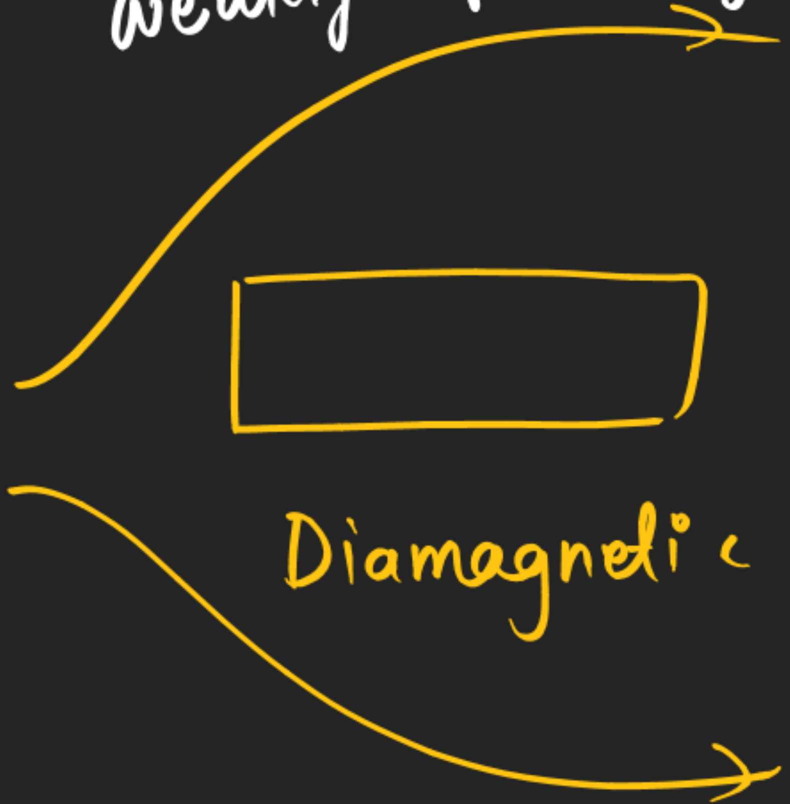
H = magnetizing force,

I = Intensity of magnetization

μ_r = relative magnetic permeability,

χ = magnetic susceptibility

weakly repelled by MF.



Diamagnetic

$\mu_r < 1$

$\mu_r = 1 + \chi$

$\chi = -ve$

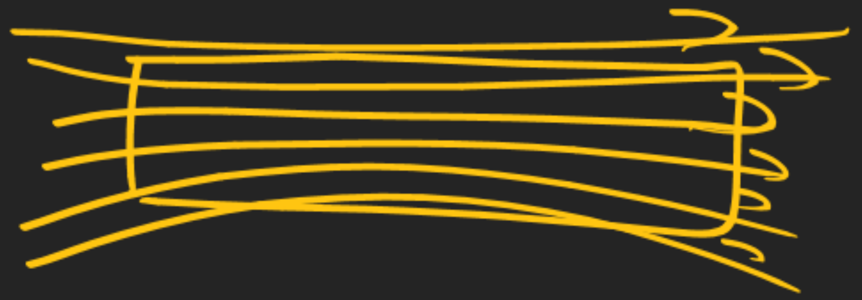
Attract MF

Paramagnetic

$\mu_r > 1$

$\chi = +ve$

highly attract MF.

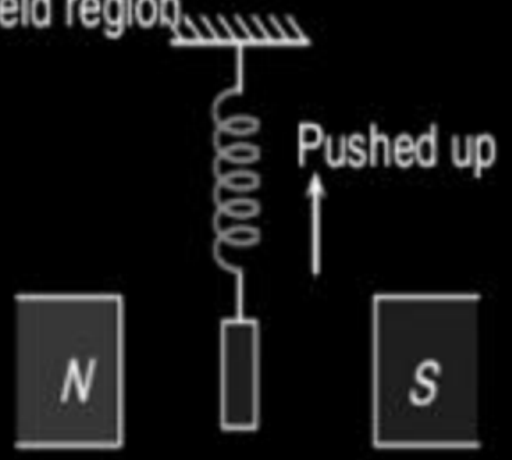
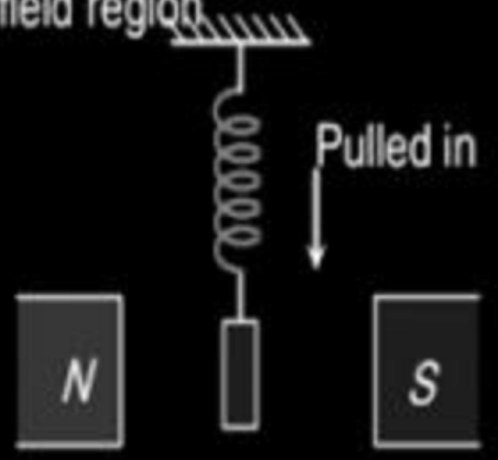
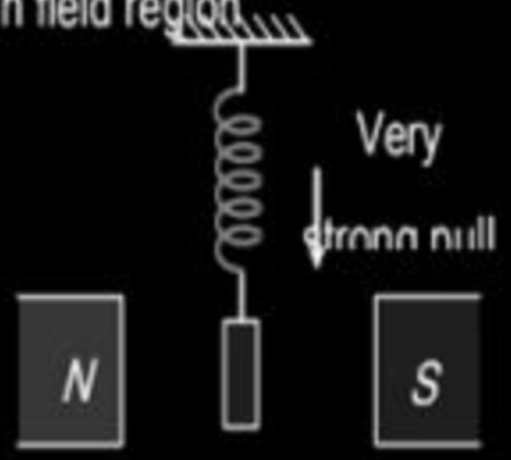


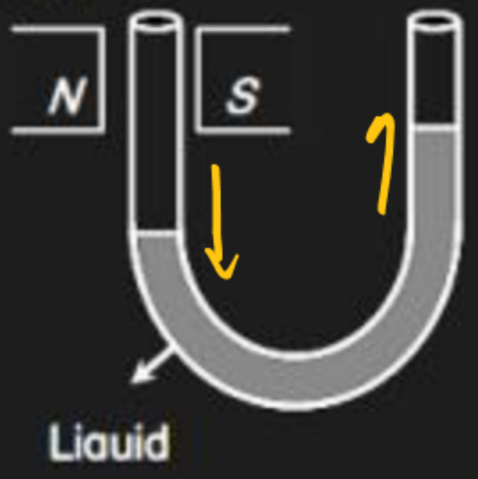
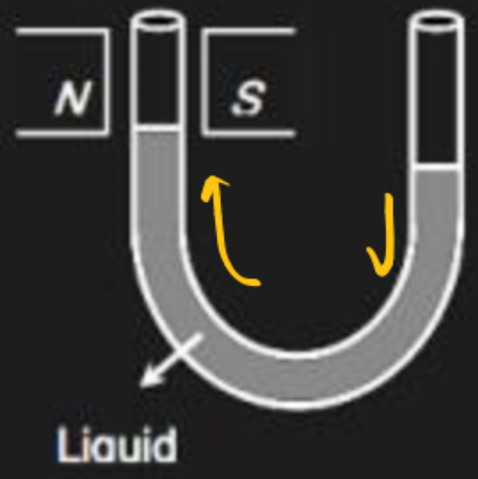
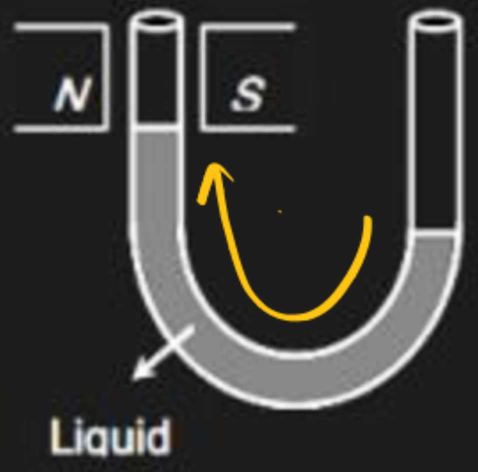
Ferromagnetic

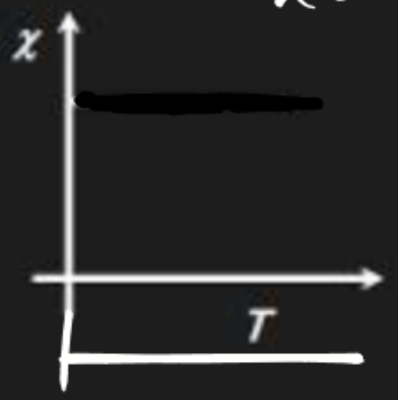
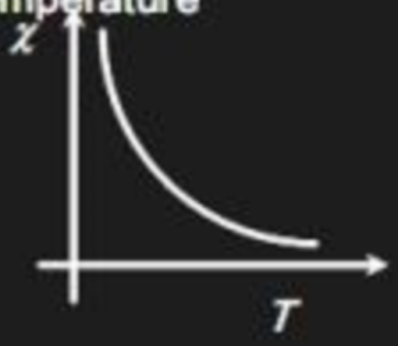
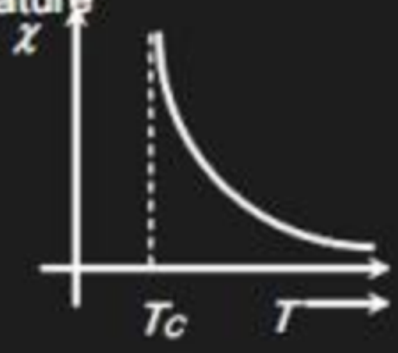
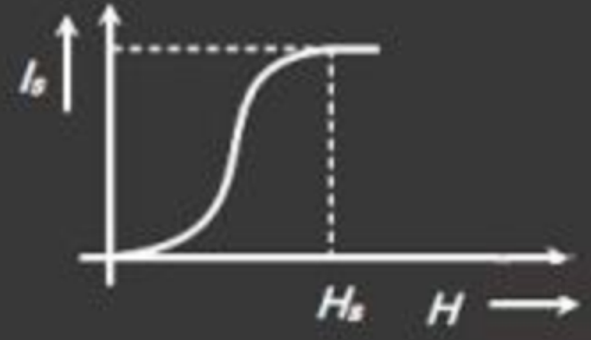
$\mu_r >> 1$

χ = highly positive

COMPARATIVE STUDY OF MAGNETIC MATERIALS :

Property	Diamagnetic substances	Paramagnetic substances	Ferromagnetic substances
Cause of magnetism	Orbital motion of electrons	Spin motion of electrons	Formation of domains
Explanation of magnetism	On the basis of orbital motion of electrons	On the basis of spin and orbital motion of electrons	On the basis of domains formed
Behaviour In a non-uniform magnetic field	These are repelled in an external magnetic field *i.e.* have a tendency to move from high to low field region 	These are feebly attracted in an external magnetic field *i.e.*, have a tendency to move from low to high field region 	These are strongly attracted in an external magnetic field *i.e.* they easily move from low to high field region 

State of magnetisation 	These are weekly magnetised in a direction opposite to that of applied magnetic field	These get weekly magnetised in the direction of applied magnetic field	These get strongly magnetised in the direction of applied magnetic field
When the material in the form of liquid is filled in the *U*-tube and placed between pole pieces.	Liquid level in that limb gets depressed 	Liquid level in that limb rises up 	Liquid level in that limb rises up very much 
On placing the gaseous materials between pole pieces	The gas expands at right angles to the magnetic field.	The gas expands in the direction of magnetic field.	The gas rapidly expands in the direction of magnetic field
The value of magnetic induction B	$B < B_0$ (where B_0 is the magnetic induction in vacuum)	$B > B_0$	$B >> B_0$

Magnetic susceptibility χ	Low and negative $\lvert\chi\rvert \approx 1$	Low but positive $\chi \approx 1$	Positive and high $\chi \approx 10^2$
Dependence of χ on temperature Next Class.	Does not depend on temperature (except *Bi* at low temperature) $\chi = -ve$ 	On cooling, these get converted to ferromagnetic materials at Curie temperature 	These get converted into paramagnetic materials at Curie temperature 
Relative permeability (μ_r)	$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$ $\mu_r = 10^2$
Intensity of magnetisation (*I*)	*I* is in a direction opposite to that of *H* and its value is very low	*I* is in the direction of *H* but value is low	*I* is in the direction of *H* and value is very high.
I-*H* curves			

Magnetic moment (M)	Very low (≈ 0)	Very low	Very high
Examples	Cu, Ag, Au, Zn, Bi, Sb, $NaCl$, H_2O air and diamond *etc.*	Al, Mn, Pt, Na, $CuCl_2$, O_2 and crown glass	Fe, Co, Ni, Cd, Fe_3O_4 *etc.*

Link :

https://simphy.com/weblets/earth-magnetic-field-simulation-3d/

Thank You Lakshyians