Formula Sheet -05

Magnetism and Matter

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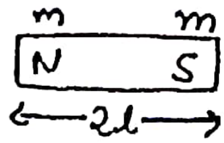
MAGNETISM AND MATTER

① Magnetic dipole moment

$\boxed{\vec{M} = m(2l)}$ South to North



SI unit → Am^2

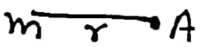
② Magnetic induction or magnetic induction field or Mag. flux density

$\boxed{\phi = B.A}$ $\boxed{\frac{\phi}{A} = B}$

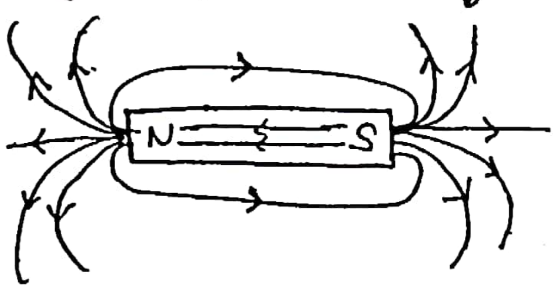
→ Units : Tesla (T) = $NA^{-1}m^{-1}$ = $weber/m^2$ = 10^4 Gauss (G)

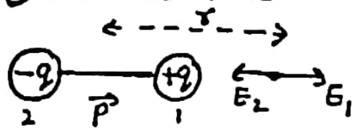
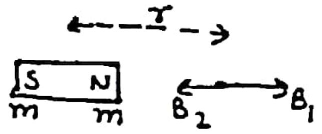
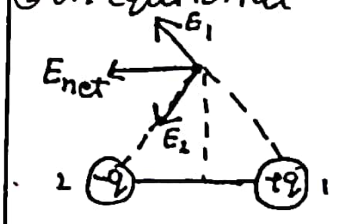
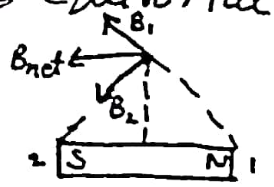
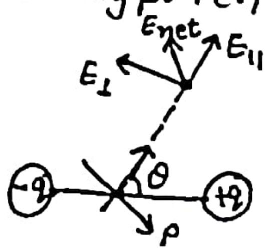
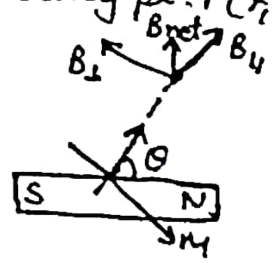
③

Coulomb's Law of Electric force	Coulomb's Law of Magnetic field
$F = \frac{kq_1q_2}{r^2}$ $k = \frac{1}{4\pi\epsilon_0}$ like charge → Repel Unlike " → Attract	$F = \frac{km_1m_2}{r^2}$ $k = \frac{\mu_0}{4\pi}$ like poles → Repel Unlike " → Attract

$\vec{E}$ due to a point charge	$\vec{B}$ due to a monopole
 $E_A = \frac{kq}{r^2}$ $k = \frac{1}{4\pi\epsilon_0}$ +q → away −q → towards	 $M_A = \frac{km}{r^2}$ $k = \frac{\mu_0}{4\pi}$ North → away South → towards

★ Magnetic field lines :-



$\vec{E}$ due to an electric dipole	$\vec{B}$ due to a magnetic dipole.
ⓐ on the axis  $\vec{E_a} = \frac{2k\vec{P}}{r^3}$ along $\vec{P}$	ⓐ on the axis  $\vec{B_a} = \frac{2k\vec{M}}{r^3}$ along $\vec{M}$
ⓑ on equitorial  $E_\perp = \frac{-k\vec{P}}{r^3}$	ⓑ equitorial  $B_\perp = \frac{-k\vec{M}}{r^3}$
ⓒ on any pt. $P(r,\theta)$  $E_{net} = \frac{kP}{r^3}\sqrt{3\cos^2\theta+1}$ $\tan\alpha = \frac{1}{2}\tan\theta$	ⓒ on any pt. $P(r,\theta)$  $B_{net} = \frac{kM}{r^3}\sqrt{3\cos^2\theta+1}$ $\tan\alpha = \frac{1}{2}\tan\theta$

(4) Torque on a BAR magnet (Magnetic Dipole) in a uniform $\vec{B}$.

$\boxed{F_{net} = 0}$ $\boxed{\tau_{net} = MB\sin\theta}$ $\boxed{\vec{\tau} = \vec{M} \times \vec{B}}$ $\boxed{\tau_{max} = MB \quad \tau_{min} = 0}$ $\theta = 90^\circ, 270^\circ$; $\theta = 0^\circ, 180^\circ$

(5) Potential Energy of a magnetic dipole in a uniform $\vec{B}$.

$WD = \Delta U = U_f - U_i$ $\boxed{U_\theta = -MB\cos\theta}$ $\boxed{U_\theta = -\vec{M}\cdot\vec{B}}$

At $\theta = 0^\circ$, $F_{net} = 0$, $\tau_{net} = 0$, $U = -MB$ → stable equlibrium

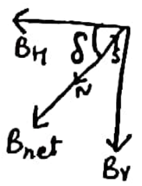
At $\theta = 180^\circ$, $F_{net} = 0$, $\tau_{net} = 0$, $U = MB$ → unstable eq/b.

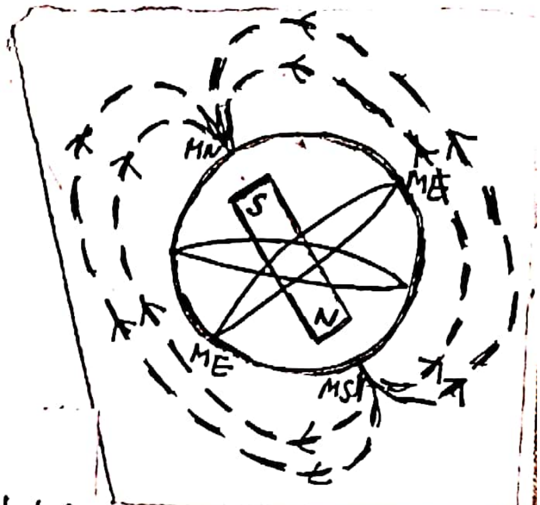
(6) At magnetic equator $\boxed{\delta = 0^\circ}$ Needle is aligned with horizontal

At magnetic poles $\boxed{\delta = 90^\circ}$ Needle is aligned ⊥ to horizontal.

→ $\boxed{B_H = B_E\cos\delta}$; $\boxed{B_V = B_E\sin\delta}$

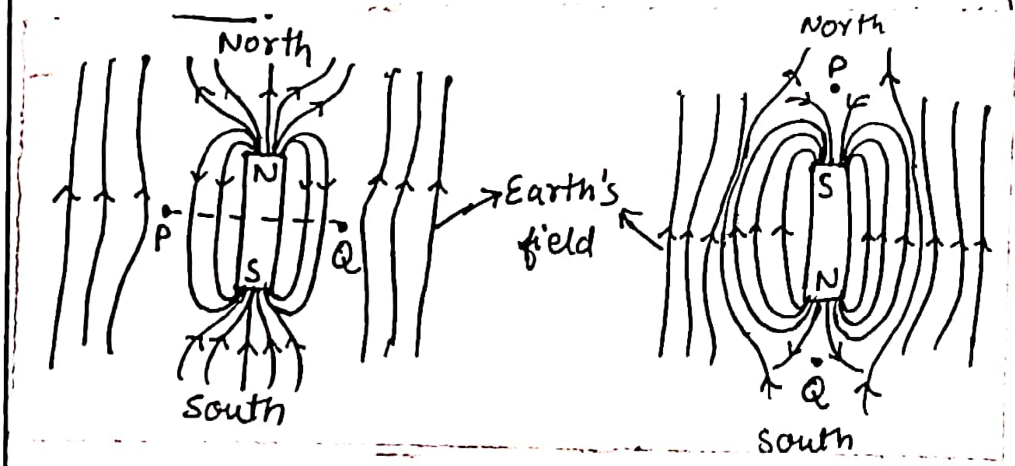
$\boxed{B_E = \sqrt{B_H^2 + B_E^2}}$; $\boxed{\tan\delta = \frac{B_V}{B_H}}$





(7) Neutral point :-

is a point at which the $\vec{B}$ of magnet is equal and oppo. to B_H of earth's magnetic field. The net $\vec{B}$ at neutral pt. is zero.



P & Q are neutral points

P is equitorial pt. for magnet

$B_H = B_M = \frac{k\vec{M}}{r^3}$

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

P & Q are neutral pt.

P is axial pt. for magnet

$B_H = B_M = \frac{k\,2M}{r^3}$

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

(8) Magnetic Moment of an atom is due to :

→ Orbital motion of e^-

→ Spin motion of e^-

→ Magnetic moment of nucleus

(9) Magnetization ($\vec{I}$)

$\boxed{\vec{I} = \frac{\vec{M}}{V}} \xrightarrow{\text{unit}} A/m$

(10) Magnetizing field ($\vec{H}$) is due to :-

→ External factor : Magnetizing field ($\vec{H}$)

→ Internal factor : Magnetization (I)

(11) Magnetic Suspectibility(χ)

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

$H\uparrow \Rightarrow I\uparrow$

Solenoid with core :- $\boxed{B_{net} = \mu_0(H+I)}$ $\boxed{B_m = \mu_m H}$ $\boxed{\mu_m = \mu_0(1+\chi)}$

Solenoid in vaccum :- $\boxed{B_{net} = B_0 = \mu_0 H}$ $\mu_0 \rightarrow$ absolute permeability

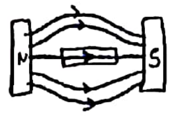
(13) Relative permeability :- $\boxed{\mu_r = 1+\chi}$ $\boxed{\mu_r = \frac{B_m}{B_0}}$

(14) Diamagnetism :- No magnetic moment and no atomic dipole

Ex:- Bi, Cu, Au, Quartz, Hg, H_2O, air, etc $\boxed{M_{net} = 0}$

→ There is a small induced magnetism (-ve) $\xrightarrow{\ \ } H$ $\boxed{I \leftarrow}$

$\vec{B}_m = \mu_0(\vec{H}+\vec{I})$ $\boxed{B_m = \mu_0(H-I)}$



→ μ_r slightly less than 1. $\because \mu_r = 1+\chi \rightarrow$ small -ve

→ temp. independent

(15) Paramagnetism :- Magnetic Moment ✓, Induced magnetism → small

Ex. Al, Pt, Cr, Mn, $CuSO_4$, O_2 (STP) $\cdot$ $H\uparrow \Rightarrow T\downarrow \Rightarrow$ alignment ↑

→ There is a small +ve induced magnetism

$\mu_r = 1+\chi \rightarrow$ small +ve, $\mu_r \rightarrow$ slightly greater than 1.

→ temp. dependent. $\boxed{I = \chi H}$

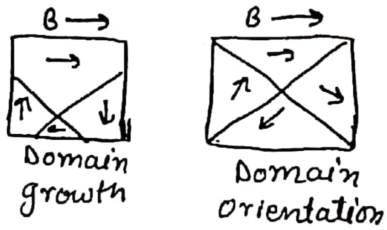
★ $\boxed{\chi = \frac{C}{T}}$ C → curie's constt. T → kelvin [for paramagnetic only]

(16) Ferromagnetism :- Atomic dipoles ✓

Ex. → Fe, Ni, Co, Alloys like Alnico etc.

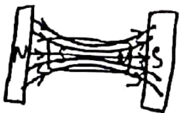
When ext^n $\vec{B}$ is applied two thing occurs :-

① Domain Growth ② Domain Orientation (Torque wala khel)



→ Magnetisation is large +ve $\therefore \chi \rightarrow$ large +ve $= 10^3$

→ $\mu_r >>> 1$ $\Rightarrow$ Temp ↑, I ↓, χ ↓



→ At curie point ferromagnetics passes over to paramagnetics.

(17) When non-uniform magnetic field :-

Diamagnetic → tends to move from ~~weak~~ strong to weak $\vec{B}$.

Paramagnetic → tends to move from weak to strong $\vec{B}$.

Ferromagnetism → strongly moves from weak to strong $\vec{B}$.

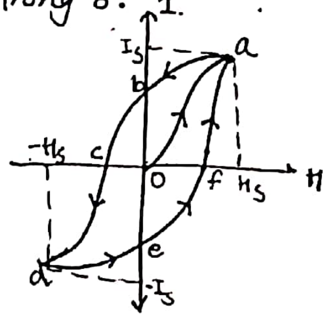
(18) Hysteresis :-

oe → retentivity

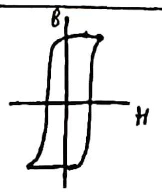
of → Coercitivity

-ve H requires to make I → zero

$$\begin{array}{ccccc} & & \text{demagnetisat}^n & & \\ a & \rightarrow & b & \rightarrow & c \\ \uparrow \text{mag}^n & & & & \downarrow \text{mag. oppo.} \\ f & \leftarrow & e & \leftarrow & d \\ & & \text{demagnetised} & & \end{array}$$



Energy loss per cycle per unit volume = Area of B-H loop = $\mu_0 \times$ Ar of I-H loop

Soft Ferromagnetic material	Hard Ferromagnetic Material
→ Low coercivity → Small Energy loss → High Retentivity → High Permeability → High susceptibility ★ Ex. → Electromagnets, soft iron core, mu metal, Ni-Fe alloy, core of transformers. 	→ High Coercitivity → Large Energy Loss → Low retentivity → Low permeability → Low susceptibility ★ Ex → Permanent magnets, Steel, Alnico