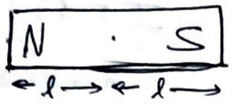
① Magnetic Induction

$$\boxed{\phi = BA} \quad \text{or} \quad B = \frac{\phi}{A}$$

② Magnetic length



$$\boxed{2l = \frac{5}{6} \times (\text{Geometric length})}$$

$l \rightarrow$ half length of magnet.

③ Magnetic moment:

i) In magnitude,

$$\boxed{M = m \times 2l}$$

ii) In vector

$$\boxed{\vec{M} = m\,(2\vec{l})}$$

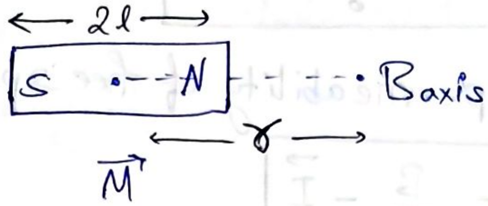
④ Pole strength

$$\boxed{m = \frac{M}{2l}}$$

⑤ Torque acting on Bar magnet:

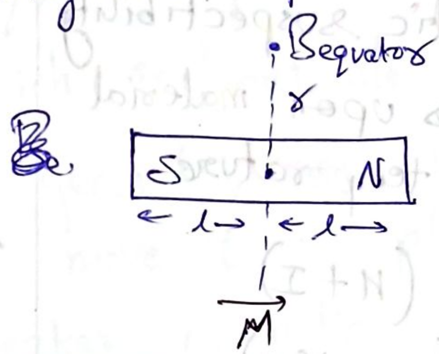
$$\boxed{\vec{\tau} = \vec{M} \times \vec{B} = MB\sin\theta}$$

⑥ Magnetic induction (B) at a point along the axis of a magnetic dipole:



$$\boxed{B_{axis} = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}}$$

⑦ Magnetic induction (B) at a point along the equator of a Magnetic dipole:



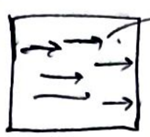
$$\boxed{B_{equator} = \frac{\mu_0}{4\pi}\frac{M}{(r^2 + l^2)^{3/2}}}$$

⑧ Magnetic induction for a short Bar Magnet ($r >>> 2l$)

1) $$\boxed{B_{axis} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}}$$

2) $$\boxed{B_{equator} = \frac{\mu_0}{4\pi}\frac{M}{r^3}}$$

3) $$\boxed{B_{axis} = 2B_{equator}}$$



$B_{net} \propto B_{internal} + B_{external}$

$B_{net} \propto I + H$

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

$\mu_0 \rightarrow$ permeability of free space.

$$\boxed{\vec{H} = \frac{B}{\mu_0} - \vec{I}}$$

$\Rightarrow \vec{H} \uparrow \Rightarrow I \uparrow$

$I \propto H$

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

χ = Magnetic suspectibility
→ Depends upon material & temperature..

$$B_{net} = \mu_0 (H + I)$$
$$= \mu_0 (H + \chi H)$$
$$= \underbrace{\mu_0 (1 + \chi)}\, H$$

$$\boxed{B_{net} = \mu_m H}$$

$$\boxed{\mu_m = \mu_0 (1 + \chi)}$$

↳ permeability of material

Relative permeability (μ_r)

$$\boxed{\mu_r = \frac{\mu_m}{\mu_0}} \begin{array}{l} \rightarrow \text{of Material} \\ \rightarrow \text{vaccum} \end{array}$$

→ H (Magnetising field intensity) in Vaccum

$$B_0 = \mu_0 (H + I)$$
$$= \mu_0 (H + \cancel{I})$$
$$= \mu_0 H + \cancel{\mu_0 I}^{\,0} \quad (I = 0)$$
$\because$ In vaccum

$$B_0 = \mu_0 H$$

→ H (Magnetising field intensity in Material)

$$B_m = \mu_0 (H + I)$$
$$= \mu_0 H + \mu_0 I$$
$$= \mu_0 H + \mu_0 \chi H$$
$$B_m = \mu_0 (1 + \chi) H$$
$$B_m = \mu_m H$$
$$\mu_m = \mu_0 (1 + \chi)$$

$$\mu_r = \frac{\mu_m}{\mu_0} = \frac{B_m/H}{B_0/H} = \frac{B_m}{B_0}$$

$$\mu_r = \frac{\mu_m}{\mu_0} = \frac{\mu_0 (1 + \chi)}{\mu_0} = (1 + \chi)$$

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

Note :- $H = nI$

$n \rightarrow$ No. of turns per unit length
$I \rightarrow$ Current

Note :- H & I have same unit & dimensions $[L^{-1}A]$

For Paramagnetic material,

$$I \propto \frac{B_0}{T}$$

$$I = C\frac{B_0}{T} \quad C = \text{curie constant}$$

$$\chi H = C\frac{\mu_0 H}{T} \quad \left(\because I = \chi H \ \& \ B_0 = \mu_0 H\right)$$

$$\boxed{\chi = \frac{C\mu_0}{T}}$$

When a paramagnetic liquid is placed in a U tube manometer with a magnet kept in close vicinity of one of the arms, it is observed that the liquid rises into the arm close to the magnet.

(11) Magnitude of earth's magnetic field at a given place

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

V → vertical

H → Horizontal

If a diamagnetic liquid is filled in a U-tube and one arm of the U-tube is placed in an external magnetic field. the liquid is pushed in the arm which is outside the field.

In general, these materials try to move to a place of weaker magnetic field

(12) Earth's magnetic field.

1) $B_H = B\cos\delta$

2) $B_V = B\sin\delta$

3) $\tan\delta = \frac{B_V}{B_H}$

δ → Angle of dip

OR

Magnetic (field) inclination

* Magnetic monopole don't exist

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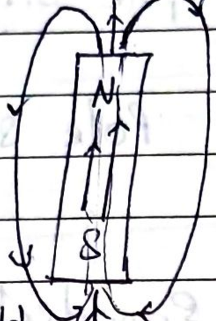
Magnetic field lines

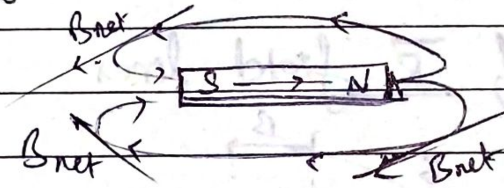
Imaginary lines drawn in region of 'space-time' along which a 'free north pole' would move, if followed to.

Bar magnet

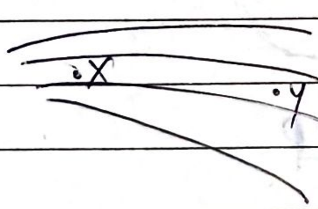


① Magnetic field lines form closed loops
$N \rightarrow S$ outside magnet
$S \rightarrow N$ Inside magnet

② The tangent at any point gives the direction of net magnetic field at that point

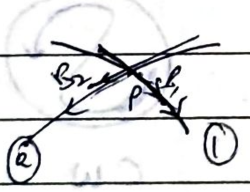


③ Closer the field lines (denser) ⇒ stronger the field $(\vec{B})$



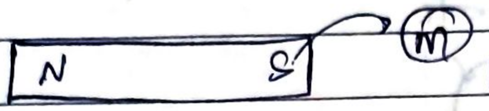
$(\vec{B})_x > (B)_y$

④ Two magnetic field lines, do not intersect each other



if they intersect then at point of intersection there will be two tangents & hence two direction of $\vec{B}$ which is WRONG.

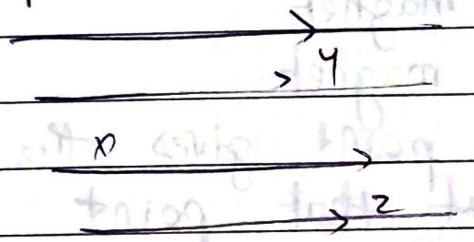
⑤ Pole strength



m pole strength

$$\boxed{\text{Number of field lines} \propto \text{Pole strength}}$$

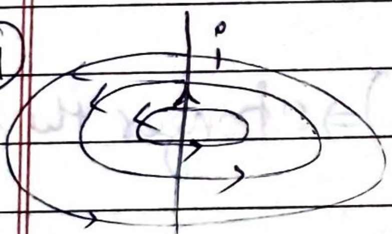
⑥ Straight, parallel & Equidistant field lines represent Uniform magnetic field



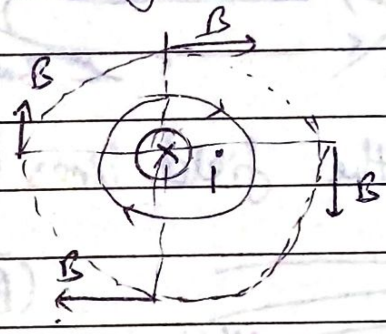
$$(B)_x = (B)_y = (B)_z$$

Some diagrams of $\vec{B}$ field lines

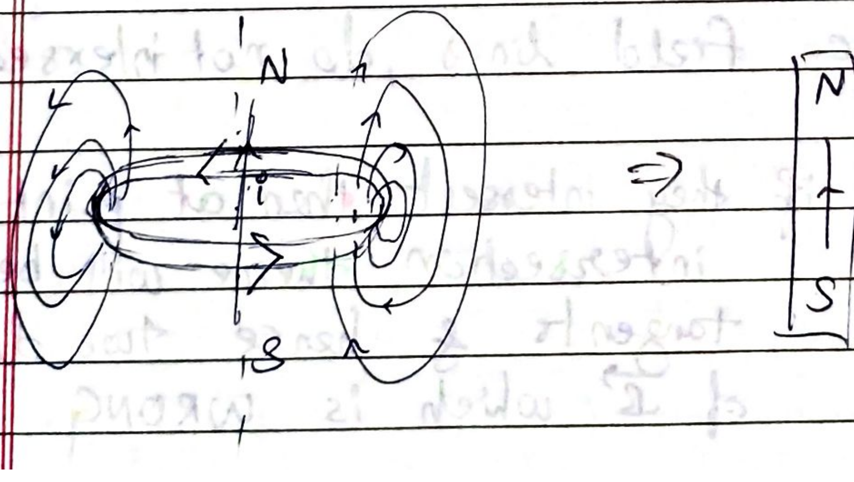
①



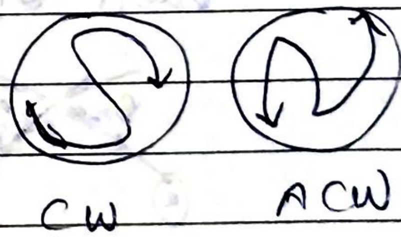
②



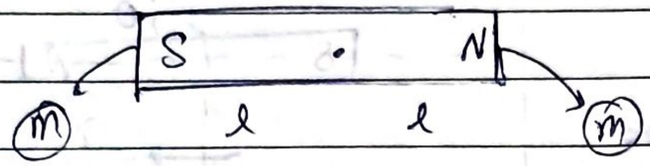
③ Current carrying coil loop



Magnetic Dipole



Bar Magnet
or
Magnetic Dipole



(m) → pole strength
+q → North jaise
−q → South jaise

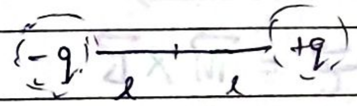
Electric Dipole

① $\vec{E}$ field due to point charge q

q - - - r - - - . $E = \frac{kq}{r^2}$

$k = \frac{1}{4\pi\varepsilon_0}$ (away from +q & towards −q)

② Electric Dipole Moment

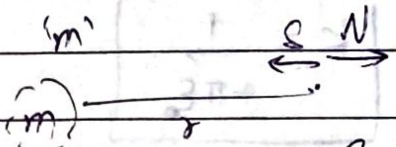


$\vec{p} = q \times 2l$

from −q to +q

Magnetic Dipole

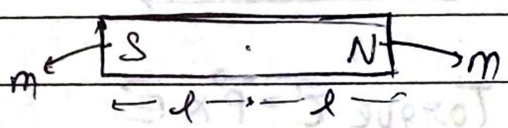
① $\vec{B}$ field due to monopole



$B = \frac{km}{r^2}$ → pole strength

$k = \frac{\mu_0}{4\pi}$ (away from N pole & towards S pole)

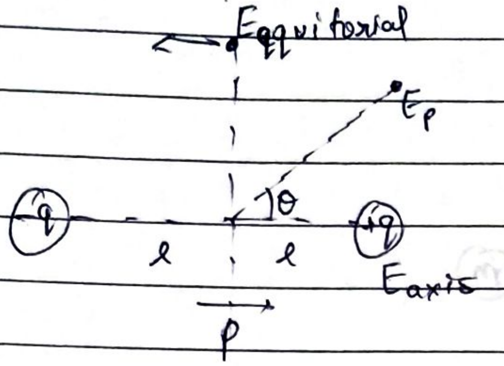
② Magnetic Dipole moment



$\vec{M} = m \times 2l$

from S to N pole

③ $\vec{E}$ field due to electric dipole



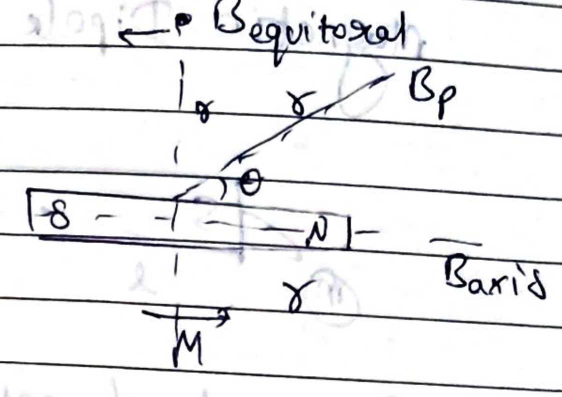
$$E_{axis} = \frac{2kP}{r^3} \text{ (along } \vec{P}\text{)}$$

$$E_{equitorial} = \frac{kP}{r^3} \text{ (opp to } \vec{P}\text{)}$$

$$E_p = \frac{kP}{r^3}\sqrt{1+3\cos^2\theta}$$

$$\boxed{k = \frac{1}{4\pi\varepsilon_0}}$$

③ $\vec{B}$ field due to magnetic Dipole



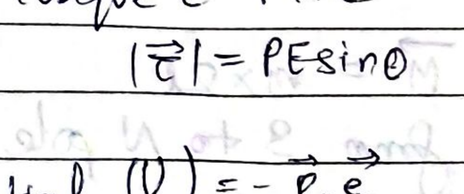
$$B_{axis} = \frac{2kM}{r^3} \text{ (along } \vec{M}\text{)}$$

$$B_{equitorial} = \frac{kM}{r^3}$$

$$B_p = \frac{kM}{r^3}\sqrt{1+3\cos^2\theta}$$

$$\boxed{k = \frac{\mu_0}{4\pi}}$$

④ Electric Dipole in Uniform Electric field



Torque $\vec{\tau} = \vec{P} \times \vec{E}$

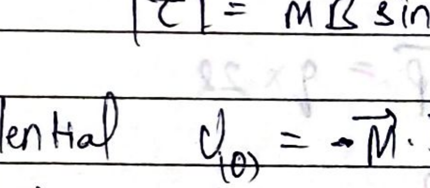
$|\vec{\tau}| = PE\sin\theta$

Potential Energy $(U) = -\vec{P}\cdot\vec{E}$

$|U_\theta| = -PE\cos\theta$

$\boxed{W_{ext} = \Delta U}$

④ Magnetic Dipole in Uniform magnetic field



Torque $\vec{\tau} = \vec{M} \times \vec{B}$

$|\vec{\tau}| = MB\sin\theta$

Potential Energy $U_{(\theta)} = -\vec{M}\cdot\vec{B}$

$|U_\theta| = -MB\cos\theta$

Work by external $= \Delta U$

Magnetism

$\rightarrow \boxed{m_{orb} = IA}$

unit: Am^2

$\rightarrow m_{orb} = \frac{evr}{2}$ $\rightarrow L = m_e v r$

$\rightarrow m_{orb} = \frac{eL}{2m_e}$

The ratio $\boxed{\frac{e}{2m_e}}$ $\Rightarrow$ gyromagnetic ratio

The quantity $\boxed{\frac{eh}{4\pi m_e}}$ $\Rightarrow$ Bohr's Magneton

$e \rightarrow 1.6 \times 10^{-19}$ C

$h \Rightarrow 6.626 \times 10^{-34}$

$m_e = 9 \times 10^{-31}$ kg

$B.M = 9.27 \times 10^{-24}$ Am^2

$\vec{\tau} = \vec{m} \times \vec{B}$

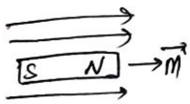
$\boxed{\vec{\tau} = mB\sin\theta}$

$\theta \rightarrow$ between $\vec{m}$ & $\vec{B}$

$\boxed{U_m = -mB\cos\theta}$

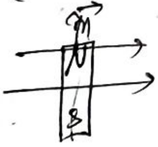
Cases

1) $\theta = 0^\circ$



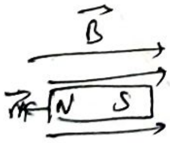
$\boxed{U_m = -mB}$ (most stable)

2) $\theta = \pi/2$



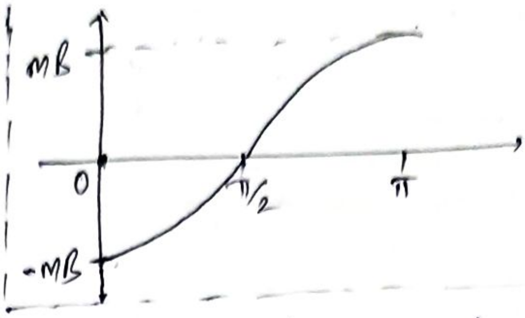
$\boxed{U_m = 0}$

3) $\theta = \pi$



$\boxed{U_m = mB}$

(most unstable)



Time period : angular oscill of Bar M.

$\boxed{T = 2\pi\sqrt{\frac{I}{mB}}}$

$I \rightarrow$ moment of inertia

$m \rightarrow$ Dipole moment

$B \rightarrow$ magnetic field

$\boxed{\omega = \sqrt{\frac{mB}{I}}}$

Magnetization vector $\vec{M} / \vec{I}$

$\boxed{\vec{I} = \frac{\vec{M}_{net}}{V}}$ $\rightarrow$ net magnetic moment / $\rightarrow$ volume

unit : $\frac{Amp\ m^2}{m^3}$ = $Amp\ m^{-1}$

Magnetic Intensity ($\vec{H}$)

$B_{net} = B_{internal} + B_{external}$

$B_{net} \propto (I + H)$

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

$\mu_0 \rightarrow$ permeability of free space

($\mu_0 = 4\pi \times 10^{-7}$)

$\rightarrow \boxed{\vec{H} = \frac{B}{\mu_0} - \vec{I}}$

$I \propto H$

$\boxed{I = \chi H}$

$\chi \rightarrow$ magnetic suspectibility

$\hookrightarrow$ constant (depends upon material & T)

$\rightarrow \boxed{B_m = \mu_m H}$, $\mu_m \rightarrow$ permeability of material

$\rightarrow \boxed{\mu_m = \mu_0 (1 + \chi)}$

In vaccum

$\boxed{B_0 = \mu_0 H}$

→ Permanent magnet → should have
1) High Retentivity
2) High Coercivity
3) Large Area of Hysteresis loop.

→ On heating magnet → it looses magnetism.

→ for superconductor : $\chi = -1$

	dia	para	ferro
χ	$-1 < \chi < 0$	$\chi > 0$	$\chi >> 0$
μ_r	$\mu_r > 0$	$\mu_r > 1$	$\mu_r >> 1$

$$\boxed{\chi_d < \chi_p < \chi_{ferro}}$$

→ Temperature above which a ferromagnetic substances becomes paramagnetic is known as <u>Curie temperature</u>.

Diamagnetism	Paramagnetism	Ferro magnetism
Copper (Cu), gold metal (Au) Bismuth, lead, Silicon, glass, water, wood, Plastic etc.	Aluminium, magnesium lithium, molybdenum, tantalum, & salts Such as $MnSO_4$, H_2O & oxygen gas.	Soft iron

→ Magnetism of a magnet is due to the spin motion of electrons.