Magnetism And Material -5

Bar Magnet ⇒ A bar magnet is a dipole having south and north pole of same strength.

Terms Related to Bar Magnet

(i) **Magnetic pole** ⇒ The preferred regions of attraction near the two ends of magnet where magnetic force due to bar magnet is maximum.

(ii) **Magnetic length** ⇒ The distance b/w the two poles of a magnet is called magnetic length

(iii) **Geometric length** ⇒ It is the actual physical length of bar magnet.

{ Due to attraction b/w the two poles of a bar magnet the distance b/w the two poles that is magnetic length is always less than geometric length. }

Coulomb's law in Magnetism.

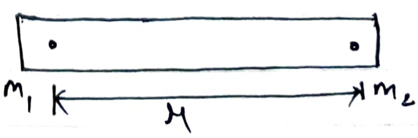
Suppose that two magnetic poles of strength m_1 and m_2 are placed at a distance r. Then the force of attraction or repulsion b/w the poles is found to be

(1) It is directly proportional to product of two pole strength

$F \propto m_1 m_2$ —— ①

(2) It is inversely proportional to the distance b/w them

$F \propto \frac{1}{r^2}$ —— ②



Combining ① and ②

$$F \propto \frac{m_1 m_2}{r^2} \Rightarrow F = K\frac{m_1 m_2}{r^2}$$

$$K = \frac{\mu_0}{4\pi}$$

$$\boxed{F = \frac{\mu_0}{4\pi}\frac{m_1 m_2}{r^2}}$$

Unit of Magnetic pole strength

$m_1 = m_2 = m \quad r = 1m, F = 10^{-7} N$

$$10^{-7} = \frac{10^{-7} \times m \times m}{(1)^2} \Rightarrow m^2 = 1$$

$$\boxed{m = \pm 1} \quad \boxed{m = \pm 1 \, Am}$$

The strength of a magnetic pole is said to be one Ampere meter, if it repels an equal and simillar pole with a force of 10^{-7} N, when placed in vacuum at a distance of one metre from it

Properties of Bar Magnet

(i) Attractive property
(ii) Directive property
(iii) Inductive property
(iv) Unlike poles attract and like poles repel
(v) Magnetic poles always exist in pair.
(vi) Repulsion is the surest test for distinguish b/w a magnet and a piece of iron.

Magnetic Dipole ⇒ An arrangment of two magnetic pole of equal and opposite strength separated by a finite distance is called magnetic dipole.

Magnetic dipole moment ⇒ The product of the strength of either pole and the magnetic length of the magnet is called magnetic dipole moment.

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

* It is a vector quantity. Its direction is always from South to North.

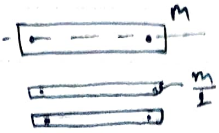
Q. What is the impact on magnetic dipole moment when a bar magnet is cut (i) Along the axial line (ii) Along equitorial line

Sol
$M = m \times (2l)$

Case I When cut along axial line

$M' = m'(2l)$

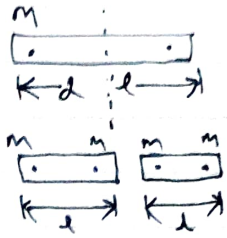
$m' = \frac{m}{2}$



$M' = \frac{m}{2}(2l)$

$$M' = \frac{M}{2}$$

Case-II When cut along equitorial line



$M' = m\left(\frac{2l}{2}\right)$

$M' = \frac{1}{2}\left[m(2l)\right]$

$$M' = \frac{M}{2}$$

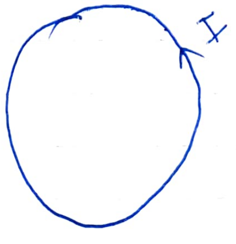
Current loop as a Magnetic Dipole

Consider a circular coil carrying current I. Suppose that the current flows in anticlockwise direction when seen from above.

The magnetic field lines due to each elementary portion of the circular coil will be of the shape of circular loops near that portion and almost straight at the centre of the circular coil.

From Right hand thumb rule it follows that magnetic field lines seem to enter at the lower face of the coil and leave at its upper face.

Thus lower face of the coil behave as South pole and upper face behave as North pole.



Magnetic dipole Moment of the current loop

(i) It is directly proportional to the strength of the current

$M \propto I$ — (1)

(ii) It is directly proportional to the area of the current loop.

$M \propto A$ — (2)

Combining (1) and (2)

$M \propto IA$

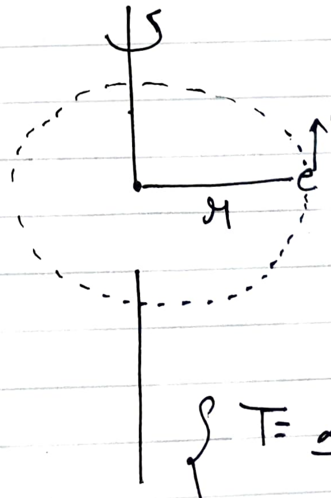
$M = KIA$ if $K = 1$

$M = IA$

Magnetic Dipole moment of a revolving electron:

Let us consider an electron revolving around its nucleus in a circular path of radius r with a velocity v.

Now the magnetic moment



$M = IA$ — (1)

$A = \pi r^2$ — (2)

$I = \frac{Q}{T} = \frac{e}{\frac{2\pi r}{v}}$ { $T = \frac{2\pi r}{v}$

$I = \frac{ev}{2\pi r}$ — (3)

Putting the value of (2) and (3) in equation (1)

$M = \frac{ev}{2\pi r} \times (\pi r^2) = \frac{1}{2} evr$

~~Multiply~~ $L = m_e v r$

$$vr = \frac{L}{m_e}$$

$$M = \frac{1}{2}\frac{eL}{m_e}$$

$$L = \frac{nh}{2\pi}$$

$$M = \frac{1}{2}\frac{nh}{(2\pi)} \times \frac{e}{m_e}$$

$$M = \left(\frac{1}{4\pi} \times \frac{e \times h}{m_e}\right) n$$

$$\boxed{M = \mu_B n}$$

μ_B = Bohr's Magneton

$\mu_B = 9.27 \times 10^{-24}\ A\ m^2$

$$\boxed{\mu_B = \frac{1}{4\pi}\frac{eh}{m_e}}$$

Gauss' law in Magnetism ⇒

According to Gauss' law in electrostatic, the surface integral of electric field $\vec{E}$ over a closed surface S is equal to $\frac{1}{\varepsilon_0}$ times the total charge q enclosed by the surface.

$$\oint_S \vec{E}\cdot\vec{dS} = \frac{q}{\varepsilon_0}$$

But in magnetism isolated magnetic pole is not possible. So if a surface is enclosing a magnet that means it is enclosing a magnetic dipole. So net pole strength enclosed by surface will be zero

$$\boxed{\oint_S \vec{B}\cdot\vec{ds} = 0}$$

Consequences of Gauss' law

(i) The number of magnetic field line entering closed surface must be equal to the number of magnetic field lines leaving the surface.

(ii) Isolated magnetic pole do not exist.

EARTH'S MAGNETISM [10^{-5}T]

Magnetic Elements of the Earth

The earth magnetic field at a place can be completely described by three factors or parameters which are called elements of earth magnetic field.

1 **Magnetic Declination (θ)** ⇒ The angle b/w the geographical meridian and magnetic meridia at a place is called magnetic Declination.

(2) **Magnetic De Inclination or Dip** ⇒ (δ) ⇒ The angle made by Earth's total magnetic field with the horizontal direction is called angle of dip or magnetic declination.

(3) **Horizontal Component of Earth Magnetic field (B_H)** ⇒ It is the component of the earth's total magnetic field $\vec{B}$ in the horizontal direction in the magnetic meridian.

$$\boxed{B_H = B\cos\delta}$$

$$B_V = B\sin\delta$$

$$\boxed{\frac{B_V}{B_H} = \tan\delta}$$

$$B_H^2 + B_V^2 = B^2(\sin^2\delta + \cos^2\delta)$$

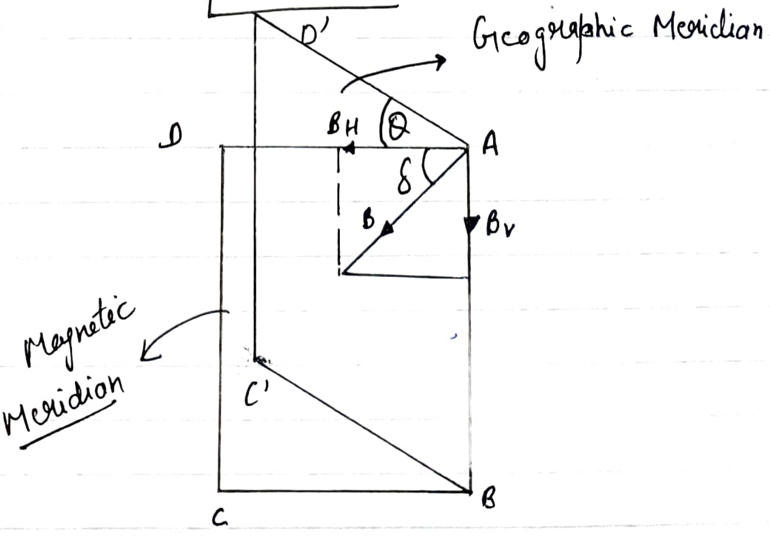
$$\boxed{B = \sqrt{B_H^2 + B_V^2}}$$

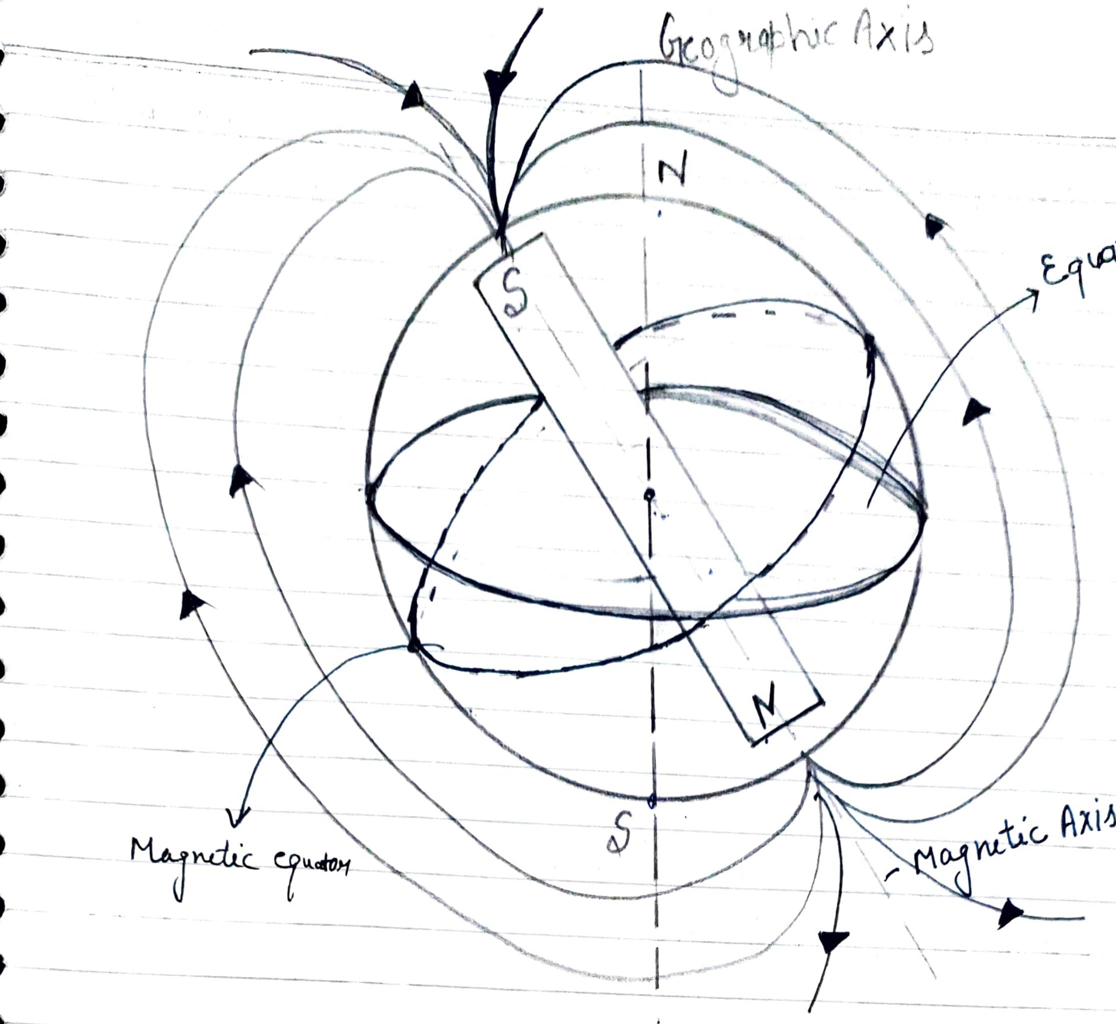
☆☆☆☆ At equator

$$\boxed{\delta = 0^\circ \quad B_H = B}$$

At pole

$$\boxed{\delta = 90^\circ \quad B_H = 0}$$





Important Terms in Magnetism

Magnetisation → The degree or extent to which a substance is magnetised when placed in the magnetising field is called intensity of magnetisation.

OR

The magnetic dipole moment developed per unit volume of the substance is known as intensity of magnetisation.

$$M = \frac{m_{net}}{V} = \frac{IA}{V} = \frac{Am^2}{m^3} = Am^{-1}$$

SI unit = Am^{-1}

It is a vector quantity.

Magnetic Intensity OR **Magnetising force** ⇒ The degree or extent to which the magnetising field can magnetise a substance is known as intensity of magnetising field

$$H = \frac{B_0}{\mu_0} = \frac{\text{Magnetising field}}{\text{Permittivity of free space}}$$

$$\boxed{B_0 = \mu_0 H}$$

Magnetic permitivity ⇒ The degree or extent to which magnetic lines of force can enter a substance is known as magnetic permeability

OR

It is defined as the ratio of magnitude of magnetic induction (B) to intensity of magnetisation (H)

$$\boxed{\mu = \frac{B}{H}}$$

Relative permitivity ⇒ $\mu_r = \frac{B}{B_0} = \frac{\mu H}{\mu_0 H} = \frac{\mu}{\mu_0}$

$$\boxed{\mu = \mu_0 \mu_r}$$

{ B = Magnetic field Induction in medium
B_0 = " " " in vacuum

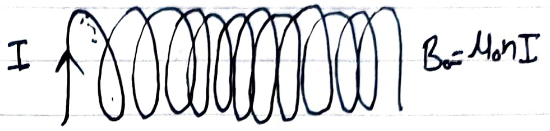
Magnetic Susceptibility ⇒ It is the property of a substance which shows how easily the substance can be magnetised when placed in the magnetising field.

$$\boxed{\chi_m = \frac{M}{H}}$$

Relation between Magnetic permeability and Magnetic susceptibility:

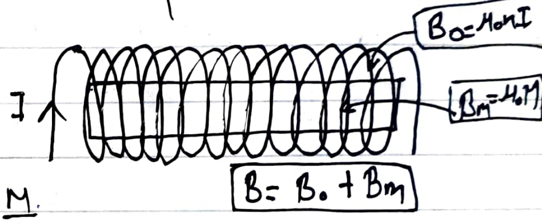
Let us consider a solenoid having n turns in which I current is flowing through it.

When vacuum is inside the solenoid then magnetic field in the solenoid will be



$$B_0 = \mu_0 H = \mu_0 n I$$

Now when a ~~magneti~~ substance is placed inside the core of a solenoid then magnetic field inside solenoid will be



$$B = B_0 + B_m$$
$$B = \mu_0 H + \mu_0 M$$
$$B = \mu_0 H \left(1 + \frac{M}{H}\right) \qquad \left\{ \chi = \frac{M}{H} \right.$$
$$B = B_0 (1 + \chi)$$
$$\frac{B}{B_0} = (1 + \chi) \qquad \left\{ \frac{B}{B_0} = \mu_r \right\}$$

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

Magnetic Materials

1. **Diamagnetism ⇒** The materials which are weakly magnetised in a direction opp to the direction of applied magnetic field are known as ~~diag~~ diamagnetic materials.

Electron theory of diamagnetism ⇒ In diamagnetic materials electrons are

Considered to exist in pairs having orbital motion in opposite direction.

The net magnetic moment in this case is zero when no ~~electric~~ (B) field is applied.

* Diamagnetism is independent of the temprature.

* Meissner Effect ⇒ The perfect diamagnetic super conductors is called Meissner effect.

<u>Paramagnetic Material</u> ⇒ The materials which are weakly magnetised in the direction of external applied magnetic field are known as paramagnetic material.

Electron Theory of Paramagnetism ⇒ The individual atoms of a paramagnetic substance have permanent magnetic dipole moment.

* But the dipole moment of these atoms are cancelled by each other due to their random motion hence the net dipole moment of the substance is zero.

* But when an external magnetic field is applied. They ~~alti~~ align themselves in a particular direction. Now they have net dipole moment.

Example ⇒ Na, Al, Ca

Curie's law ⇒ According to this law magnetisation of a paramagnetic material is inversely proportional to absolute temprature T.