Chp-5: Magnetism and Matter.

* Magnet:

- Attracting force.
- Directional.

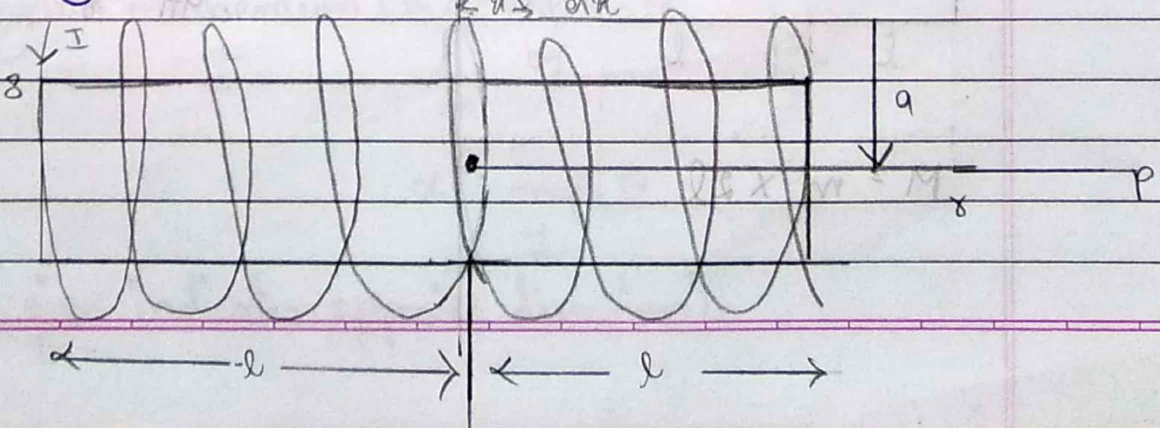
* Important facts:

- Earth behaves like magnet.
- Bar magnet poles is decided when it is hanged over earth's surface. The end of magnet pointing north of earth is north pole and vice-versa.
- Similar poles repel and opposite poles attract.
- North and south poles can be separated.
- Magnet can be made or destroyed.

* Magnetic field lines:

- These lines are continuous close loop.
- Tangent at any point, gives direction at that point.
- Concentration of line gives strength of field.
- Lines do not intersect.

* Bar magnet as a equivalent to C.C solenoid:



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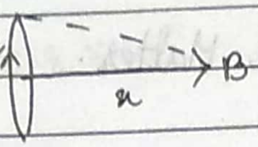


$$B = \frac{\mu_0 N I A}{4\pi (a^2 + x^2)^{3/2}}$$

At P magnetic field dB due to current carrying coil of width dx is $dB = \frac{\mu_0 \cdot n \cdot dx \cdot I a^2}{2\{(r-x)^2 + a^2\}^{3/2}}$

$$B = \frac{\mu_0 n I a^2}{2} \int_{-l}^{+l} \frac{dx}{\{(r-x)^2 + a^2\}^{3/2}}$$

By assuming that $r >>>>> a$.

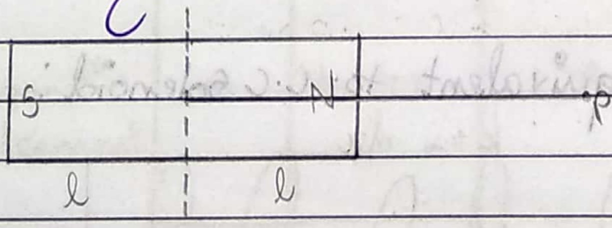
$$\frac{\mu_0 n I a^2}{2r^3} \int_{-l}^{+l} dx = \frac{\mu_0 n I a^2 \times 2l}{2r^3}$$

We know $N = 2ln$. where, n - total no. of turns

$$\therefore B = \frac{\mu_0 n I a^2 2l}{2r^3} = \frac{2\mu_0 n I a^2 2l \cancel{\pi}}{4\pi r^3}$$

$$= \frac{\mu_0 2 N I A}{4\pi r^3} = \frac{\mu_0}{4\pi} \frac{2M}{r^3}$$. Where, m - magnetic dipole movement.

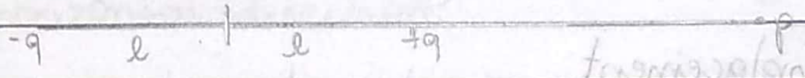
* Bar magnet :



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

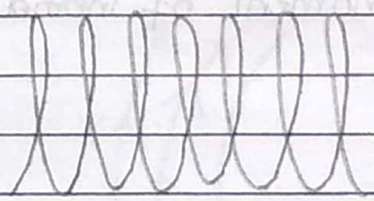
$M = m \times 2l$

* Electric dipole:



$$E = \frac{1}{4\pi\epsilon_0} \frac{2q}{r^3}$$

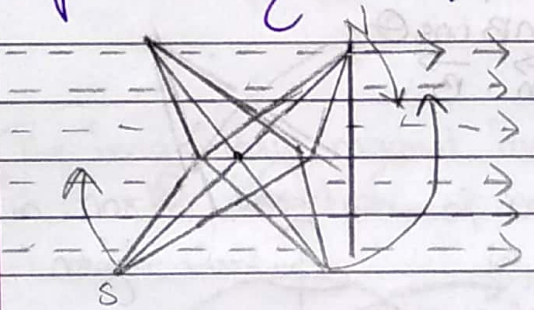
* Solenoid:



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

$M = NIA$.

* Dipole in magnetic field:



$\tau = m \times B$

where, m - magnetic dipole movement.

. Dipole magnetic field will oscillate due to ① Restoring torque & ② Inertia.

$$I\alpha = \vec{m} \times B \quad \text{or} \quad I\alpha = mB\sin\theta$$

$\cancel{\alpha =}$

. Angular momentum $(\alpha) = \frac{mB\sin\theta}{I}$

$$\alpha = \frac{-mB\theta}{I}$$

(-ve sign indicates opposite direction).

∴ It is a simple harmonic motion (S·H·M).

In S·H·M

$$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}$$

$$\therefore T = 2\pi\sqrt{\frac{\theta}{\alpha}} = 2\pi\sqrt{\frac{I}{m\beta}}$$ (I - moment of inertia)

$$\beta = \frac{4\pi^2 I}{mT^2}$$

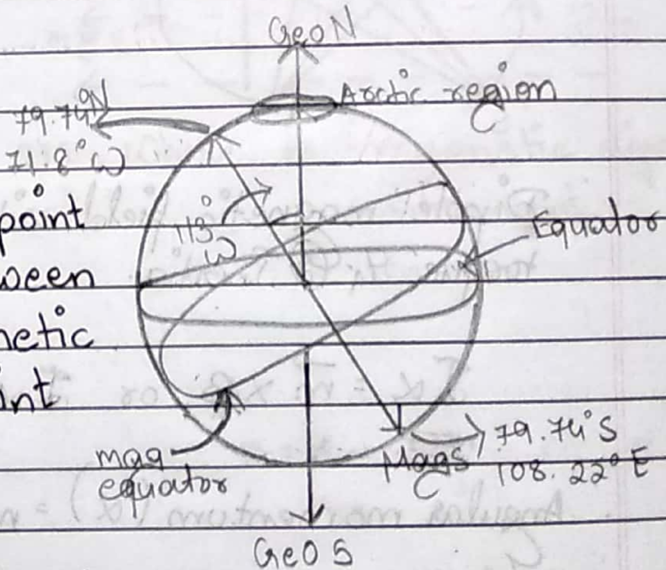
⇒ Potential energy (U) $= \int . \, d\theta$

$$= \int m\beta \sin\theta . \, d\theta$$

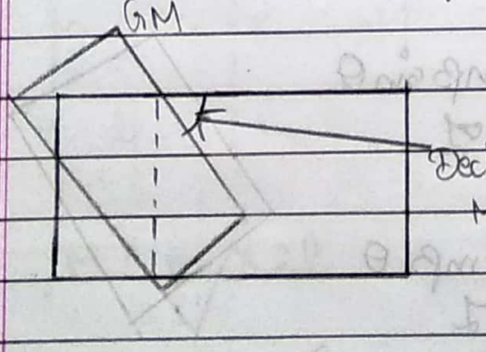
$$= m\beta\cos\theta$$

$$= \vec{m} \cdot \vec{B}$$

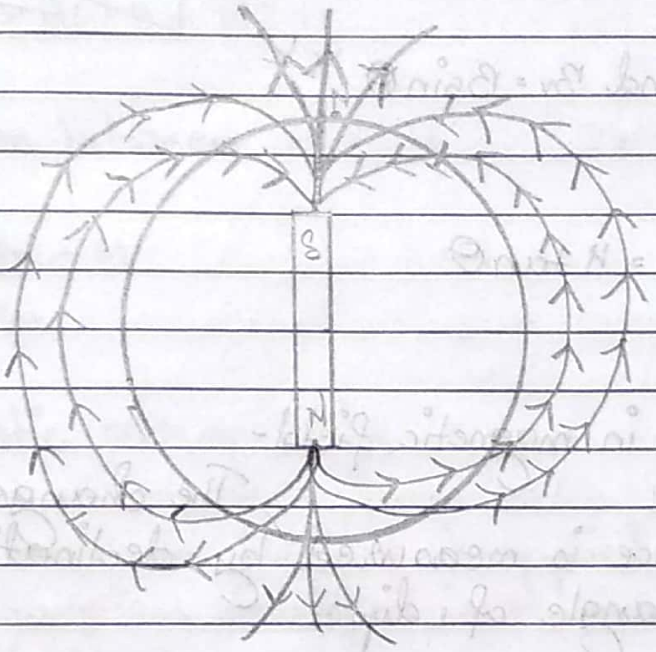
* Earth's magnetism :



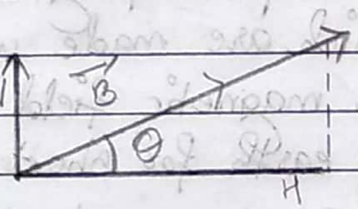
- Declination:
Declination at any point on earth is angle between geographic and magnetic meridian at that point



- **Angle of Dip-** The angle between magnetic field lines and horizontal direction.



The imaginary magnet inside the earth has its south pole in north direction of earth.



θ - angle of dip.

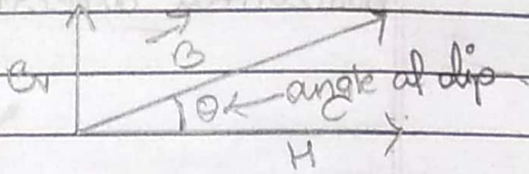
Horizontal component of earth's magnetic field is,
$|\vec{H}| = B\cos\theta$.

$B_V = B\sin\theta$

- H -

Horizontal component of earth's magnetic field.

⇒ w.r.t. T, $H = B\cos\theta$.



$$\therefore B = \frac{H}{\cos\theta} \quad \text{and} \quad B_v = B\sin\theta$$

$$\therefore B_v = \frac{H\sin\theta}{\cos\theta} = H\tan\theta$$

⇒ The changes in magnetic field -

The change from place to place is measured by declination angle as well as angle of dip.

- Time variation:

① Short time variation -

N pole keeps shifting towards west due to solar winds which are made up moving ion of sun and they create magnetic field which affects magnetic field of earth for short time.

② Long time variation.

* Magnetism:

- Magnetisation 'M' = magnetic dipole movement of sample per unit volve. $\therefore \left\{ M = \frac{mne}{V} \right\}$

- Magnetising field 'H' = magnetic field due to current

$H = ni$, $B_0 = \mu ni$ $\therefore B_0 = \mu H$.

Now, if a ($B_{no} = \mu_0 M$) Magnetic field developed by a material magnetization.
If a material is put in solenoid the magnetic field B is $B = B_0 + B_m$.
$\therefore B = \mu_0 (H + M)$.

* Relation between H & M :

$$H = \frac{B}{\mu_0} - M$$

* Magnetic susceptibility :

When magnetic field 'H' is applied on a material and the magnetism developed is M, then $M \propto H$ or $M = \chi H$. or $\frac{M}{H} = \chi_0$ (Chi).

Now, $B = \mu_0 (H + M) = \mu_0 (H + \chi H)$
$= \mu_0 H (1 + \chi) = (H + \chi_0)\, \mu_0 n i$.

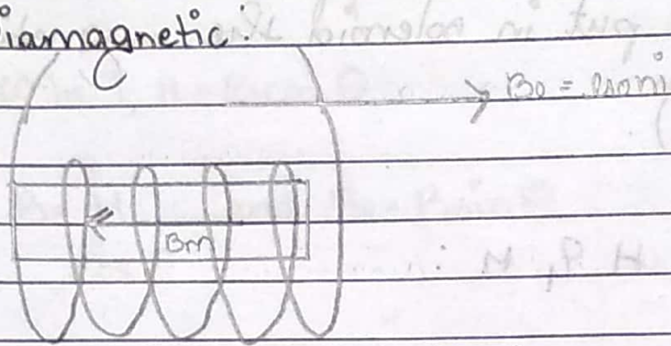
$B = \mu_r \mu_0 n i$ (We know where μ_0 = relative permeability)
$B_m = \mu_m = ni$.

$\therefore (1 + \chi_0 = \mu_r)$ $\left[\frac{\mu_m}{\mu_0} = \mu_r \therefore \mu_m = \mu_r \mu_0\right]$

$\chi_0 = \mu_r - 1$
If $\mu_r > 1$, 0, or < 1
χ = +ve, 0, −ve.

* Diamaggnetic & Paramaggnetic:

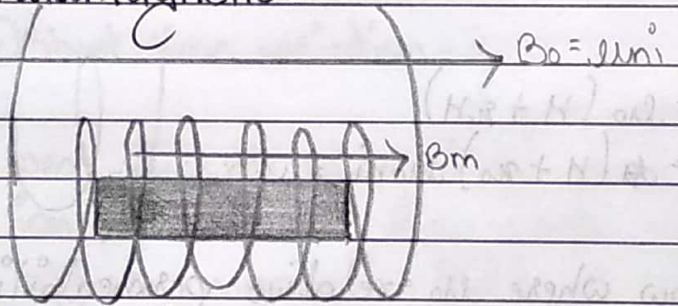
- Diamaggnetic:



①Diamaggnetic is a natural magnetic character of a material. The net magnetic dipole moment of material is zero (Balanced)

②When external magnetic field ($\mu_0 n i$) is applied then as a law of nature material wish to oppose this change. Hence electron making Bm in opposite direction start moving faster. Hence Bm in opposite direction increases. Hence effect is negative.

- Paramaggnetic:



①Material has its own net magnetic dipole movement.

②In presence of external field it aligns itself with applied field and increase its valve.

	Dia	Para	Ferro
①Susceptibility	$-1 \le x < 0$	$0 < x > 1$	$x >>>>> 1$
②Relative permeability	$0 \le \mu_r < 1$	$1 < \mu_r < 1 + x$	$\mu_r >> 1$
③Absolute permeability	$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$

Note:

Diamagnetic don't have magnetic field and vice-versa.

- In Paramagnetic, magnetism $\propto \frac{1}{\text{temperature}}$.

$M = C\frac{B_0}{T}$ (where C is Curies constant).

This can be derived as, $x = C\frac{\mu_0}{T}$ and this is Curies law.

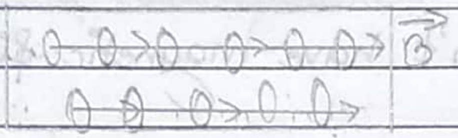
*Curies law:

- When temperature of a paramagnetic material its magnetisation increases towards B_0 according to relation $M = C\frac{B_0}{T}$.
- Limitation -

When temperature of a paramagnetic material is decreased gradually, initially magnetisation increases but after a certain decrease it stops increasing, because magnetisation has reached saturation. This is the limit of Curies law.

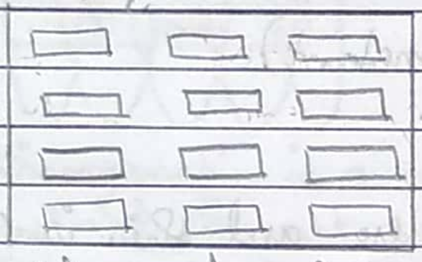
*Domain theory:

- Domain is a group of atoms (nearly 10^{11}) which have come together and aligned their magnetic dipole moment in one direction.



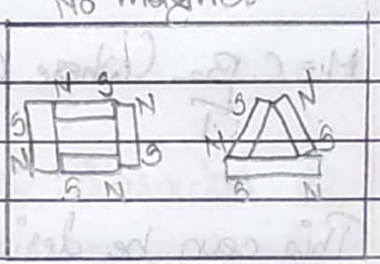
Domain

Magnet



Set of domain aligned

No magnet



closed loop of domain

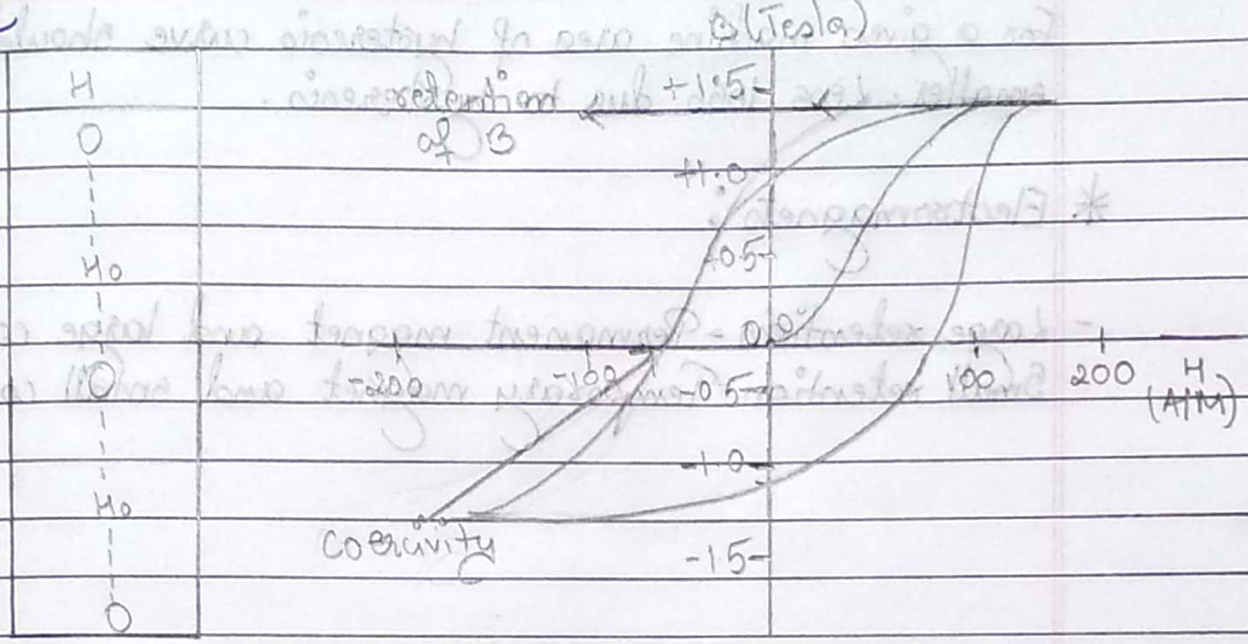
- **Magnetic induction-** When a ferromagnetic material is brought within a magnetic field, the domain align themself to create a magnetic field within them. Now it is capable to exert force of attraction.

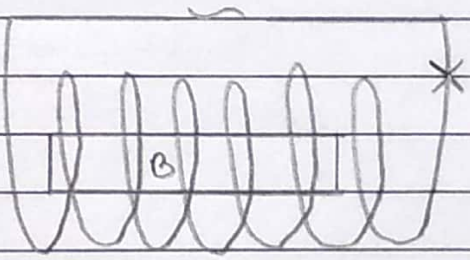
* Curies Temperature:

$$\chi_e = \frac{C}{T - T_c}$$

where,
T - present temperature
T_c - Curries temperature.
C - constant

* Hysteresis:





- **Retentivity** - Retentivity of a material is that value of 'B' which is retained in material when magnetic field H becomes zero.
- **Coercivity** - Coercivity is that -ve value of magnetising field 'H' which compels the retained magnetic field 'B' to become zero.
- Area of hysteresis curve indicates work done during one cycle of magnetisation and demagnetisation. This work done by source of H, current which is loss of energy.

Note:

For a given machine area of hysteresis curve should be smaller. Less loss due to hysteresis.

* Electromagnets:

- Large retention = Permanent magnet and large coercivity.
- Small retention = Temporary magnet and small coercivity.