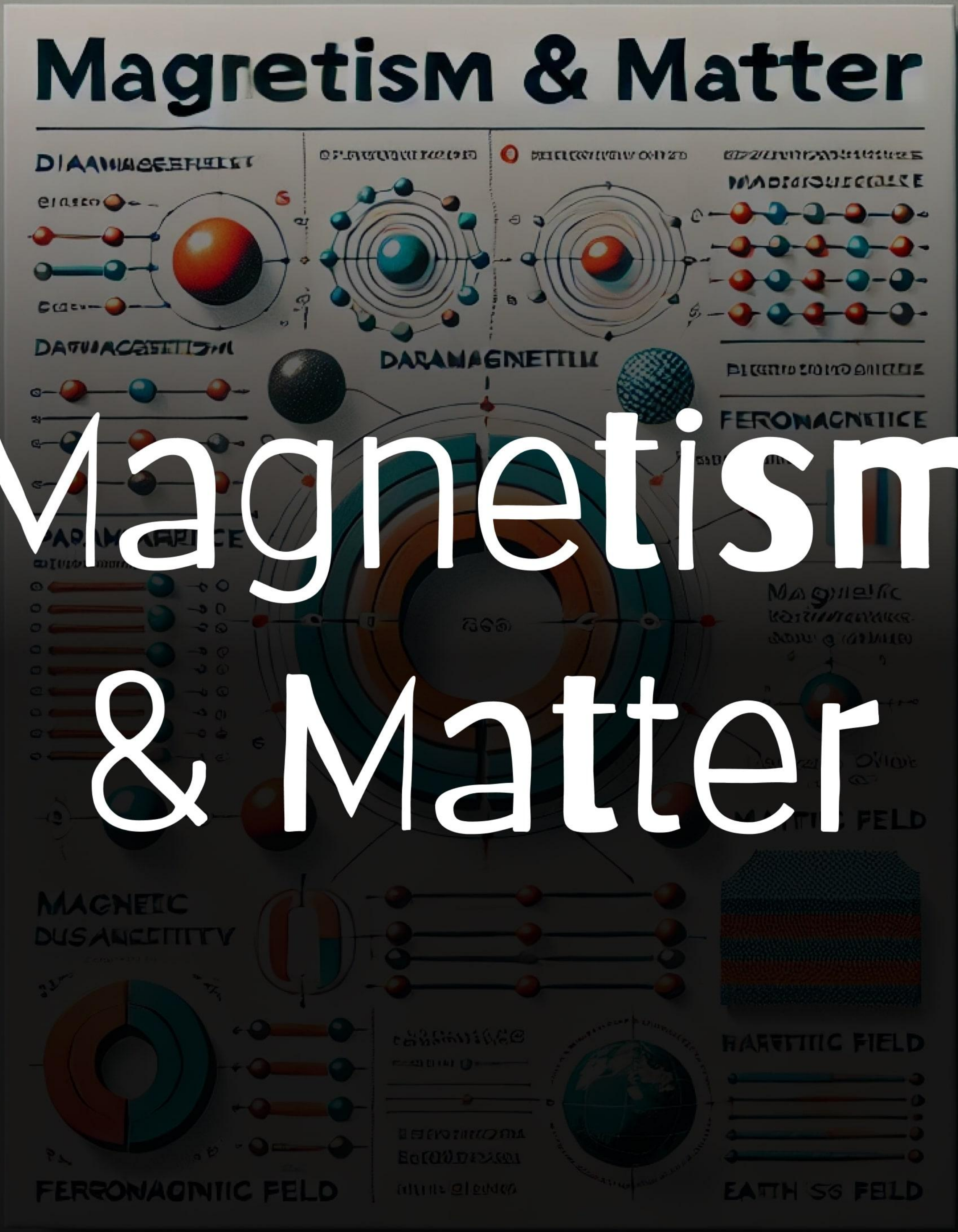
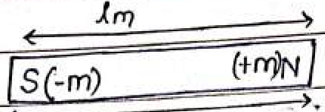
Magnetism & Matter



MAGNETISM AND MATTER.

Electrostatics	Magnetism.
Charge $\begin{cases} \to +Q \\ \to -Q \end{cases}$	two type of pole $\begin{cases} \to \text{North} \\ \to \text{South} \end{cases}$
Same nature → Repel Opposite nature → Attract	Pole strength → North (+m) Pole strength → South (-m)
$F = \frac{Q_1Q_2}{4\pi\epsilon_0 r^2}$ $E = \frac{KQ}{r^2} = \frac{Q}{4\pi\epsilon_0 r^2}$	$B = \frac{\mu_0}{4\pi}\frac{m_1}{r^2}$ $F = \frac{\mu_0}{4\pi}\frac{m_1m_2}{r^2}$
$-q \xleftrightarrow{2a} +q$ $\vec{p} = 2aq$	$\overset{2a}{\longleftrightarrow}$ $-m$ $+m$ $\vec{M} = m(2a)$ ↓ vector direction from South to north.
$E_{axi} = \frac{2K\vec{P}}{r^3} = \frac{4kqar}{(a^2-r^2)^2}$	$\vec{B}_{axial} = \frac{2K\vec{M}}{r^3}$ $\left[K = \frac{\mu_0}{4\pi}\right]$
$E_{equatorial} = \frac{K\vec{P}}{r^3} = \frac{-2kqa}{(r^2+a^2)^{3/2}}$	$\vec{B}_{equatorial} = \frac{-K\vec{M}}{r^3}$
Electric dipole kept in electric field $\tau = \vec{P} \times \vec{E} = PE\sin\theta$ $U = -\vec{P}\cdot\vec{E} = -PE\cos\theta$	$\vec{\tau} = \vec{M} \times \vec{B} = MB\sin\theta$ $U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$



l_G = Geometric length

$$\frac{l_{magnetic}}{l_{Geometric}} = 0.84$$

Magnetic dipole moment

$\vec{M} = IA$
↳ for current carrying loop
↳ Unit → Amp-m^2

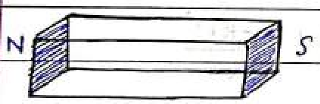
$\vec{M} = ml$ [for bar magnet]
→ Unit ⇒ Amp-m^2
→ Vector
→ direction from south to north.

Unit of pole strength = ?

$\text{Amp}\,(\text{metre})^{\cancel{2}} = m\,(\cancel{\text{metre}})$

$m \Rightarrow$ Amp-m

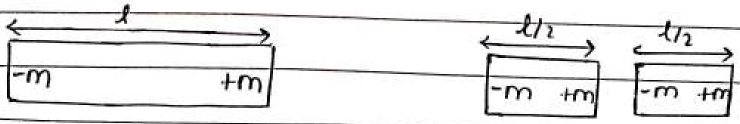
POLE STRENGTH OF MAGNETIC CHARGE



magnetic pole strength ∝ Area

Magnetic dipole moment = ml ∝ Volume

Magnet is cut perpendicular to length of magnet.

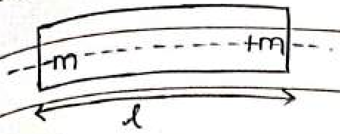


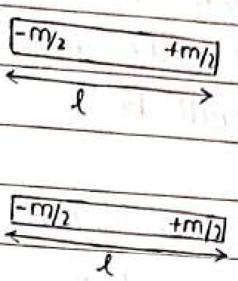
Magnetic dipole moment
$M = ml$

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

$M \propto$ volume $\Rightarrow M' = \frac{M}{2}$

Magnet is cut along the length of magnet.





$M = ml$
↓ → pole strength (charge)

magnetic dipole moment (Electric dipole moment)

$M' = \frac{ml}{2} = \frac{M}{2}$
↓
directly proportional to volume.

BAR MAGNET

When iron fillings are sprinkled on a sheet of glass placed over a short bar magnet, a particular pattern is formed and following conclusions are drawn.

a) A bar magnet has poles similar to the positive and negative charge of an electric dipole.

b) One pole is designated as north pole and other as south pole.

c) When suspended freely, these poles point approximately towards the geographic north and south pole

d) Like poles repel each other and unlike poles attract each other.

e) The poles of a magnet cannot be separated
↓
monopole does not exist.

Q A long magnetic needle of length 2L, magnetic moment M and pole strength m unit is broken into two at the mid point. The magnetic moment and pole strength of each piece will be.

a) $M/2$, $m/2$ (b) M, $m/2$

[✓ c)] $M/2$, m (d) M, m

Q A bar magnet of magnetic moment M is cut into two equal parts along its length. The magnetic moment of either part is.

a) $2m$ (b) M

[✓ c)] $m/2$ (d) Zero

Q Two identical thin bar magnets each of length l and pole strength m are placed at right angle to each other with north pole of one touching the south pole of the other. Magnetic moment of the system is.

a) $2ml$ (b) ml

[✓ c)] $\sqrt{2}ml$ (d) $\frac{ml}{2}$

Q A bar magnet of magnetic moment M is cut into two parts of equal length. The magnetic moment of each part will be.

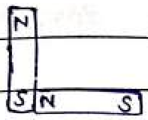
a) M (b) $2M$

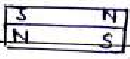
c) Zero [✓ d)] $0.5M$

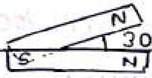
Q Following figures show the arrangement of bar magnets in different configurations. Each magnet has magnetic dipole moment $\vec{M}$. Which configuration has highest magnetic dipole moment?

a) 1 (b) 2

[✓ c) 3] (d) 4

1)


2)


3)


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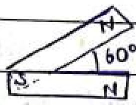
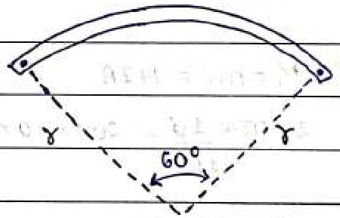


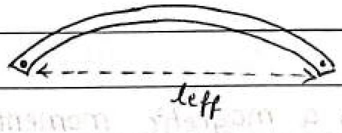
Q A bar magnet of length 'l' and magnetic dipole moment 'M' is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be.

a) $\frac{2}{\pi}M$ (b) $\frac{M}{2}$

c) M [✓ (d) $\frac{3}{\pi}M$]



Ans



$l_{eff} = 2R\sin\frac{\theta}{2}$

$M' = m\,l_{eff} = 2mR\sin\frac{\theta}{2}$

$M' = 2m\frac{l}{\theta}\sin\frac{\theta}{2}$

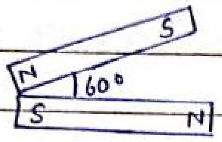
$M' = ml\frac{\sin\theta/2}{\theta/2}$

MIT $\boxed{M' = ml\frac{\sin\theta/2}{\theta/2}}$

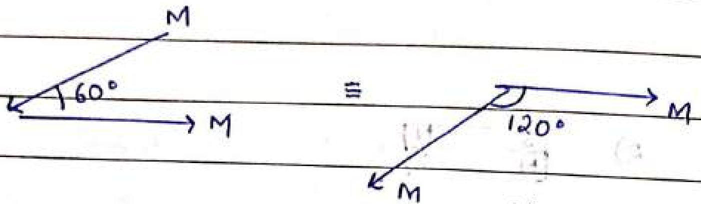
$M' = ml\frac{\sin\frac{60}{2}}{60/2} = ml\frac{1}{\cancel{2}}\frac{\cancel{6}3}{\pi} = \frac{ml3}{\pi}$

$= \frac{3M}{\pi}$

Q Find net magnetic dipole moment if each have magnetic dipole moment M.



⇒



$M_{net} = M$ **Ans**

Q A solenoid of length 10 cm and radius 1 cm contains 200 turns and carries a current of 10 A. The value of pole strength of each pole is.

a) 2 Am ~~(b)~~ 2π Am
c) 4π Am (d) 10π Am

⇒ $M = ml = NIA$

$\Rightarrow m \times \frac{1\cancel{0}}{1\cancel{00}} = 200 \times 10 \times \pi \; 1 \times 10^{-4} \times 1$

$m = 2\pi$ **Ans**

Q A steel wire of length l has a magnetic moment M. It is then bent into a semi-circular arc. The new magnetic moment is.

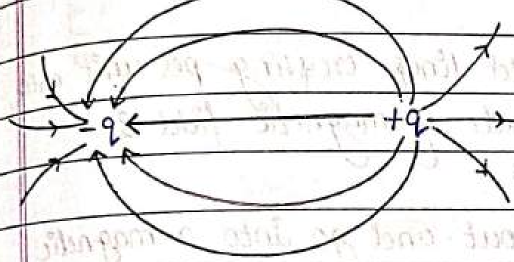
a) M ~~(b)~~ $\frac{2M}{\pi}$

c) $\frac{M}{\pi}$ (d) $2M\pi$

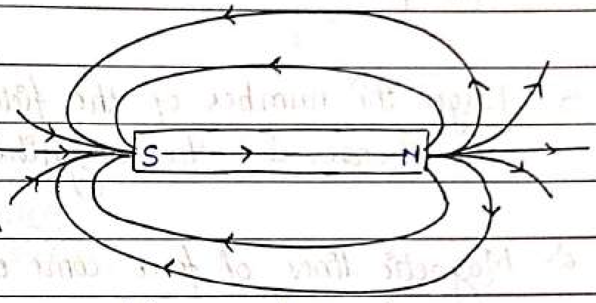
ANS $M' = ml \dfrac{\sin \theta/2}{\theta/2}$

$M' = M \dfrac{\sin 180/2}{\pi/2} = \dfrac{2M}{\pi}$ ANS

- Electric field lines is also called electrostatic force line → True
- Magnetic field lines ins also called magnetic force line → False
  ↳ $\vec{F} \perp \vec{B}$
- Magnetic field lines always from north to south pole → false



Electric field lines
donot form close
loops



Magnetic field line
form close loop

Outside magnet (field from N → S)
Inside magnet (field from S → N)

MAGNETIC FIELD LINES.

1) Magnetic field ~~is a~~ line is an imaginary curve the tangent to which at any pt. gives directly direction of magnetic field B at that point not a direction of force.

2) The magnetic field lines of a magnetic (or of a solenoid carrying current) form close continuous loops.

form close continuous loops.

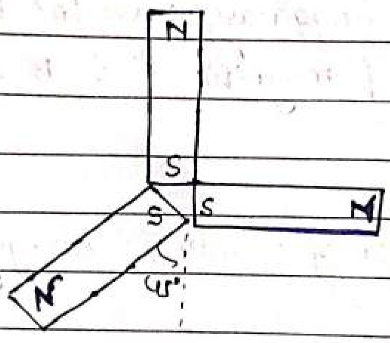
3) Outside the body of magnet, the direction of magnetic field lines are from north pole to south pole.

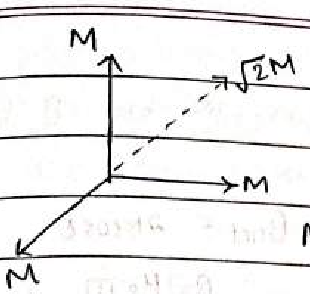
4) No two magnetic field lines can never intersect each other. This is because at the point of intersection, we cannot draw two tangents. This would mean that there are two directions of magnetic field at the same point, which is not possible.

5) Larger the number of the field lines crossing per unit area, the stronger is the magnitude of magnetic field B.

6) Magnetic lines of force come out and go into a magnetic material at any angle.

Q Magnetic moment of each magnet is M then net magnetic dipole moment is.



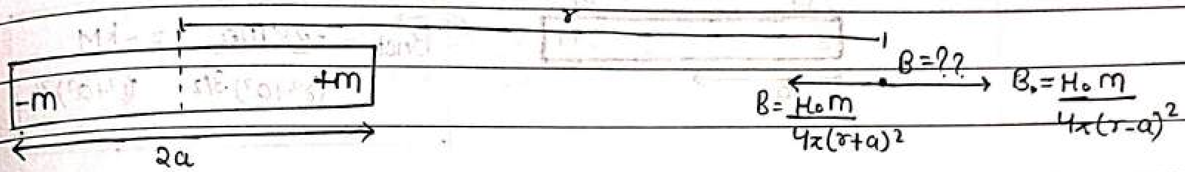


$M_{net} = \sqrt{2}M - M$

$= M(\sqrt{2}-1)$ Ans

MAGNETIC FIELD DUE TO BAR MAGNET

1) ON AXIAL LINE



$$B_{net} = \frac{\mu_0 m}{4\pi(r-a)^2} - \frac{\mu_0 m}{4\pi(r+a)^2}$$

$$\Rightarrow \frac{\mu_0 m}{4\pi}\left[\frac{(r+a)^2 - (r-a)^2}{((r+a)(r-a))^2}\right]$$

$$\Rightarrow \frac{\mu_0 m}{4\pi}\left[\frac{\cancel{r^2}+\cancel{a^2}+2ar-\cancel{r^2}-\cancel{a^2}+2ar}{(r^2-a^2)^2}\right]$$

$$\frac{\mu_0 m 4ar}{4\pi(r^2-a^2)^2} = \frac{4\overset{\mu_0}{\cancel{\pi}} m a r}{4\pi(r^2-a^2)^2} = \frac{2kMr}{(r^2-a^2)^2}$$

MIT

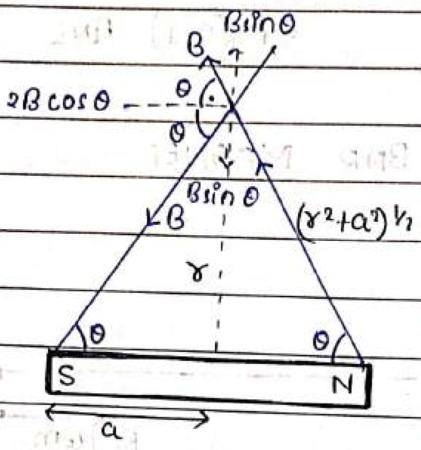
$$\boxed{B_{net} = \frac{4\mu_0 m a r}{4\pi(r^2 a^2)^2} = \frac{2kMr}{(r^2-a^2)^2}}$$

For small dipole

$a <<< r$

$$\vec{B} = \frac{2kMr}{r^4} = \frac{2KM}{r^3}$$

2) On EQUATORIAL LINE



$B_{net} = 2B\cos\theta$

$B = \frac{\mu_0 m}{4\pi(r^2+a^2)} = \frac{km}{(r^2+a^2)}$

$B_{net} = \frac{2km}{(r^2+a^2)}\cos\theta = \frac{2km\,a}{(r^2+a^2)(r^2+a^2)^{1/2}}$

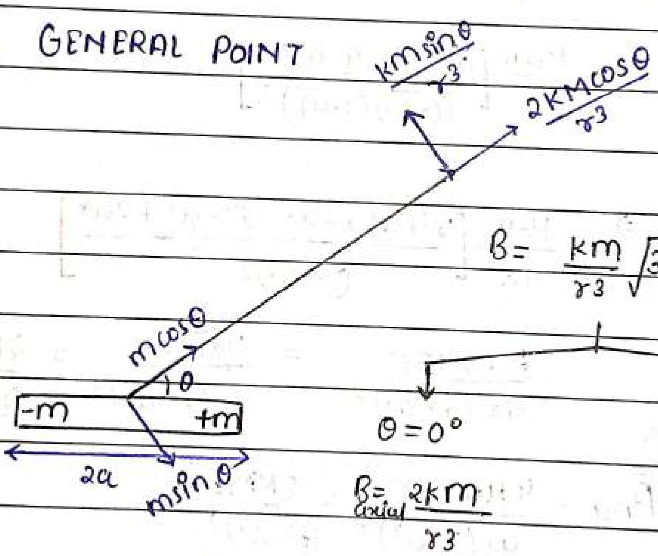
$\Rightarrow \frac{2kma}{(r^2+a^2)^{3/2}}$

$$\boxed{\vec{B}_{net} = \frac{-2kma}{(r^2+a^2)^{3/2}} = \frac{-kM}{(r^2+a^2)^{3/2}}}$$

For $a <<< r$

$\vec{B}_{net} = \frac{-2kma}{r^3} = \frac{-kM}{r^3}$ ANS

3) AT ANY GENERAL POINT



$B = \frac{km}{r^3}\sqrt{3\cos^2\theta+1}$

θ = 0°

$B_{axial} = \frac{2km}{r^3}$

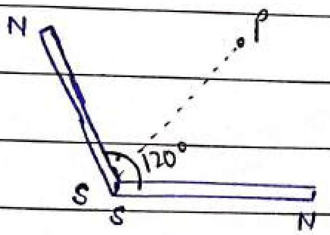
θ = 90°

$B_{equa} = \frac{km}{r^3}$

Q Two identical short bar magnets are placed at 120° as shown in the figure. The magnetic moment of each magnet is M. Then the magnetic field at the point P on the angle bisector is given by.

a) $\frac{\mu M}{4\pi d^3}$ [✓ b) $\frac{\mu_0 2M}{4\pi d^3}$]

c) $\frac{\mu . 2\sqrt{2}M}{4\pi d^3}$ d) zero



Q Point A and B are situated perpendicular to the axis of a small bar magnet at large distance x and 3x from its centre on opposite sides. The ratio of magnetic fields at A and B will be approximately ~~in~~ the ratio equal to.

a) 2:9 (b) 1:9

c) 27:1 (d) 9:1

→ $B = \frac{KM}{r^3}$

$B \propto \frac{1}{r^3}$ → $\frac{B_A}{B_B} = \frac{(r_B)^3}{(r_A)^3} = \frac{(3x)^3}{x^3} = 27:1$

Q Two small bar magnets are placed in a line at certain
★★ distance d apart. If the length of each magnet is negligible
★ compared to d, the force between them will be inversely proportional to.

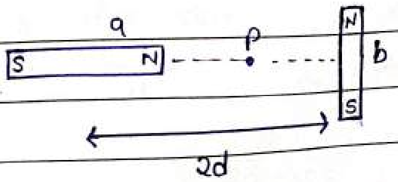
a) d^2 (b) d

c) d^3 (d) d^4

Q Figure shows two small identical magnetic dipole a and b of magnetic moments M each, placed at a separation 2d, with their axes perpendicular to each other. The magnetic field at the point P midway between the dipoles is.

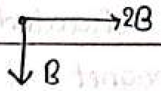
a) $\frac{2\mu_0 M}{4\pi d^3}$ (b) $\frac{\mu_0 M\sqrt{5}}{4\pi d^3}$

c) Zero (d) $\sqrt{5}\,\mu_0 M$



Ans Let magnetic field due to 'a' at P be ~~B~~ 2B

then due to 'b' will be B



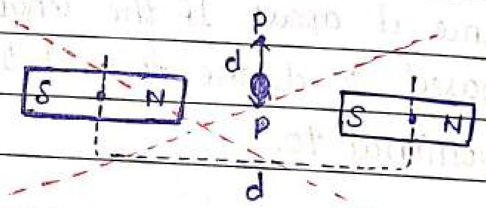
$$B_{net} = (B^2 + 4B^2)^{1/2}$$

$$B_{net} = \sqrt{5}B$$

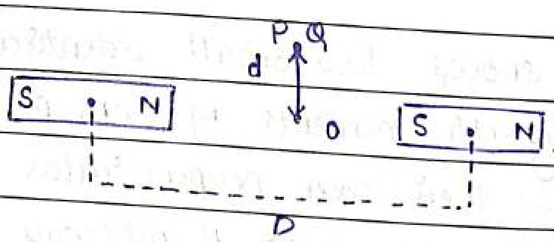
$$B = \frac{\mu_0 M}{4\pi d^3} = \frac{\mu_0 M}{4\pi d^3}$$

$$B_{net} = \frac{\sqrt{5}\mu_0 M}{4\pi d^3} \quad \underline{Ans}$$

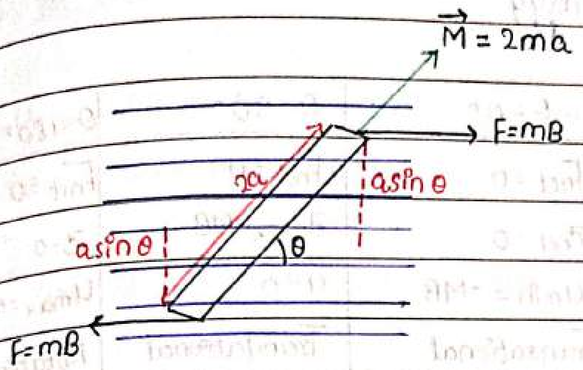
Q Two identical bar magnets are fixed with their centres at distance $\overset{D}{d}$ apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance d from the centre O as shown in the figure. The force on charge Q is.



a) zero
b) directed along OP
c) directed along PO
d) directed perpendicular to the plane of paper.



TORQUE ON MAGNETIC DIPOLE IN UNIFORM MAGNETIC FIELD.



$F_{net} = 0$ ↓ always.

$\tau = mBa\sin\theta + mBa\sin\theta$

$= 2mBa\sin\theta$

$\Rightarrow MB\sin\theta$

$\Rightarrow M \times B$

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

↓

$\vec{\tau}$ is perpendicular to magnet dipole moment and magnetic field

$\theta = 90°$	$\theta = 0°, 180°$
$\tau_{max} = MB$	$\tau = 0$
$F_{net} = 0$	$F = 0$

Q A bar magnet of magnetic moment M is placed at right angle to a magnetic induction B. If a force F is experienced by each pole of the magnet, the length of the magnet will be.

a) MB/F (b) BF/M

c) MF/B (d) F/mB.

Ans : $\tau = mB$

$F \times \frac{l}{2} + F \times \frac{l}{2} = mB$

$Fl = MB \;:\rightarrow\; l = MB/F$ **Ans**

⇒ Stored Potential energy.

$U = -\vec{M}\cdot\vec{B}$	$\theta = 0°$	$\theta = 90°$	$\theta = 180°$
$U = -MB\cos\theta$	$F_{net} = 0$	$F_{net} = 0$	$F_{net} = 0$
	$\tau_{net} = 0$	$\tau_{max} = MB$	$\tau = 0$
	$U_{min} = -MB$	$U = 0$	$U_{max} = MB$
	Translational and Rotational stable equilibrium	Translational eqm but not in stable Rotational eqm	Rotational and translational unstable eqm.

Work done to rotate the magnet by θ

$W_{ext\,F} = \Delta U = U_f - U_i$ $[U = -PE\cos\theta]$ ↳ for electric field

Work done by field

$W = -\Delta U = -[U_f - U_i]$

$= U_i - U_f$

Q A magnetic needle lying parallel to a magnetic field requires ω units of work to turn it through 60°. The torque needed to maintain the needle in this position will be.

a) ω (b) $\sqrt{3}\omega$

c) $\frac{\sqrt{3}\omega}{2}$ (d) 2ω

Ans $W = U_f - U_i$ ⇒ $U_f = -MB\cos 60° = -\frac{MB}{2}$

$U_i = -MB$

$W = U_f - U_i = -\frac{MB}{2} - (-MB) = \frac{MB}{2}$

$2W = MB$ → $\tau = MB\sin 60° = \sqrt{3}\frac{MB}{2}$

$\tau = \sqrt{3}\,W$ Ans

Q Find work done to rotate the magnetic dipole from $\theta = 60°$ to $\theta = 120°$.

Ans $U_f = -MB\cos 120° = -MB \times -\frac{1}{2} = \frac{MB}{2}$

$U_i = -MB\cos 60° = -\frac{MB}{2}$

$W = U_f - U_i = \frac{MB}{2} - \left(-\frac{MB}{2}\right) = MB$

Q Find work done to rotate the magnet from unstable equilibrium to stable equilibrium by magnetic field.

Soln $U_i = -MB\cos 180° = MB$

$U_f = -MB\cos 0° = -MB$

$W = U_i - U_f = MB - (-MB)$

$\Rightarrow 2MB$

Q Magnet is perpendicular to the magnetic field find work done to rotate it by 90° towards field

Ans $U_i = -MB\,\overset{\cos}{\cancel{\sin}}\,90° = 0$

$U_f = -MB\cos 0° = -MB$

$W = U_f - U_i = -MB - 0 = -MB$ Ans

Q The work done in turning a magnet of magnetic moment M by an angle of 90° from the meridian, is n times the corresponding work done to turn it through an angle of 60°. The value of n is given by.

magnetic field

a) $\frac{1}{2}$ (b) $1/4$

~~c)~~ 2 (d) 1

Ans $W_{(initial)} = U_f - U_i = 0-(-MB) = MB$

$W_{(final)} = U_f - U_i = \frac{-MB}{2} - (-MB) = \frac{MB}{2}$

Given $\cancel{MB} = n\frac{\cancel{MB}}{2}$

$n = 2$ **Ans**

SHM in stable equilibrium

$\tau = MB\sin\theta$

$\tau = MB\theta$

$\cancel{MB\theta = \omega^2\theta}$ $\theta MB = I\alpha$

$MB = \frac{4\pi^2}{T^2}$ $\cancel{\theta}\frac{MB}{I} = \omega^2\cancel{\theta}$

$\frac{MB}{I} = \frac{4\pi^2}{T^2}$

MIT

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

A magnetic needle of negligible breadth and thickness compared to its ~~thickness~~ length, oscillates in a horizontal plane with a time period T. What would be the time period of each part of the magnetic needle if the needle is cut into n equal parts perpendicular to its length.

$\frac{I}{n}$ (b) T (c) Tn (d) $\frac{1}{Tn}$

→ $T = 2\pi\sqrt{\frac{I}{MB}}$

$I \propto mL^2$

$I' \propto m'L'^2$

$I' \propto \frac{M}{n}\left(\frac{L}{n}\right)^2$

$I \propto \frac{ML^2}{n^3}$

$I' = \frac{I}{n^3}$

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

$\therefore T' \propto \sqrt{\frac{I'}{M'}} \propto \sqrt{\frac{1}{n^3} \times \frac{n}{1}} = \frac{1}{n}$

$T' = \frac{T}{n}$

Q The time period of freely suspended magnet is 4s. If it is broken in length into two equal parts. and one part is suspended in the same way, then its time period will be.

Ans 2s (b) 4s (c) 0.5s (d) 0.25 ⇒ $T' = T/n$

Q Magnet is break into n part along its length then find timpe period of new period magnet.

Ans $T = 2\pi\sqrt{\frac{I}{MB}}$

$I' = \frac{M'L'^2}{3} = \frac{M \times l^2}{n \times 3} = \frac{ML^2}{3n} = \frac{I}{n}$

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

$\therefore T' = 2\pi\sqrt{\frac{I'}{M'B}} = 2\pi\sqrt{\frac{I\cancel{n}}{\cancel{n}MB}} = 2\pi\sqrt{\frac{I}{MB}}$ Ans

Time period remains same

A 250 turn rectangular coil of length 2.1 cm and width 1.25 cm carries a current of 85 μA and subjected to a magnetic field strength of 0.85 T. Work done for rotating the coil by 180° against the torque is.

4.55 μJ (b) 2.3 μJ

1.15 μJ (d) 9.1 μJ

$M = IAN = 85\mu \times 2.1 \times 1.25 \times 10^{-4} \times 250 =$

Work by external force $= U_f - U_i$

$\Rightarrow MB - (-MB)$

$\Rightarrow 2MB$

$\Rightarrow 2 \times 85\mu \times 2.1 \times 1.25 \times 10^{-4} \times 250 \times 0.85$

$\approx 9.48\ \mu J$ Ans

Q A vibration magnetometer placed in a magnetic meridian has a small bar magnet. The magnet executes oscillations with a time period of 2 sec. in earth's horizontal magnetic field of 24 microtesla. When a horizontal field of 18 microtesla is produced opposite to the earth's field by placing a current carrying wire, the new time period of magnet will be.

a) 1s (b) 2s

c) 3s ~~(d)~~ 4s

ANS $T = 2\pi\sqrt{\frac{I}{MB}}$ $B_i = 24\ \mu T$

$B_f = 24\mu T - 18\mu T = 6\mu T$

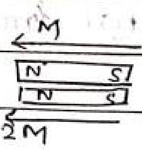
$\frac{B_f}{B_i} = \frac{1}{4}$ $\therefore$ $T' = 2T = 4S$ Ans

Q Two bar magnets having same geometry with magnetic moments M and 2M are firstly placed in such a way that their similar poles are in same side then its time period of oscillation is T. Now the polarity of one of the magnet is reversed then time period of oscillation is T_2, then.

~~a)~~ $T_1 < T_2$ (b) $T_1 = T_2$

c) $T_1 > T_2$ (d) $T_2 = \infty$

ANS $T = 2\pi\sqrt{\frac{I}{BM_{net}}}$ $T_1 = 2\pi\sqrt{\frac{I}{B\times 3M}}$



$T_2 = 2\pi\sqrt{\frac{I}{B\times M}}$

$\therefore$ $T_2 > T_1$

Q A short bar magnet of magnetic moment 0.4 $J T^{-1}$ is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is

a) 0.064 J [✓ (b)] −0.064 J

c) zero (d) −0.082 J

Ans $U = -MB = -0.4 \times 0.16$

$\Rightarrow -0.064 J$

Q A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be.

a) $2\sqrt{3}$ J [✓ (b)] 3 J

c) $\sqrt{3}$ J (d) $\frac{3}{2}$ J

Ans → $W = U_f - U_i$

$U_f = \frac{-MB}{2}$

$U_i = -MB$

$W = \frac{MB}{2} = \sqrt{3} J$

$MB = \cancel{6J}$

$2\sqrt{3}$

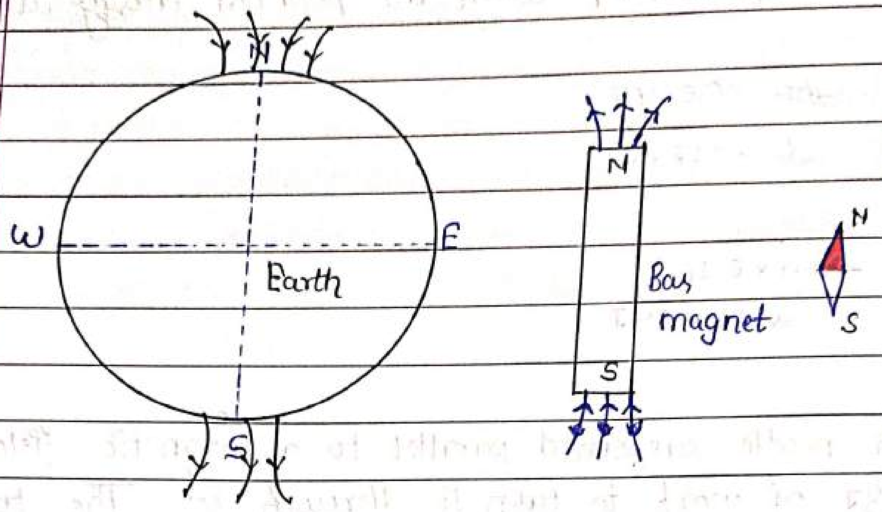
$\tau = MB \sin 60°$

$\Rightarrow \frac{\sqrt{3}}{2} mB$

$\cancel{\frac{\sqrt{3}}{2}} \times \cancel{6\sqrt{3}} = \cancel{3\sqrt{3} J}$

$\frac{\sqrt{3}}{2} 2\sqrt{3} = 3J$ Ans

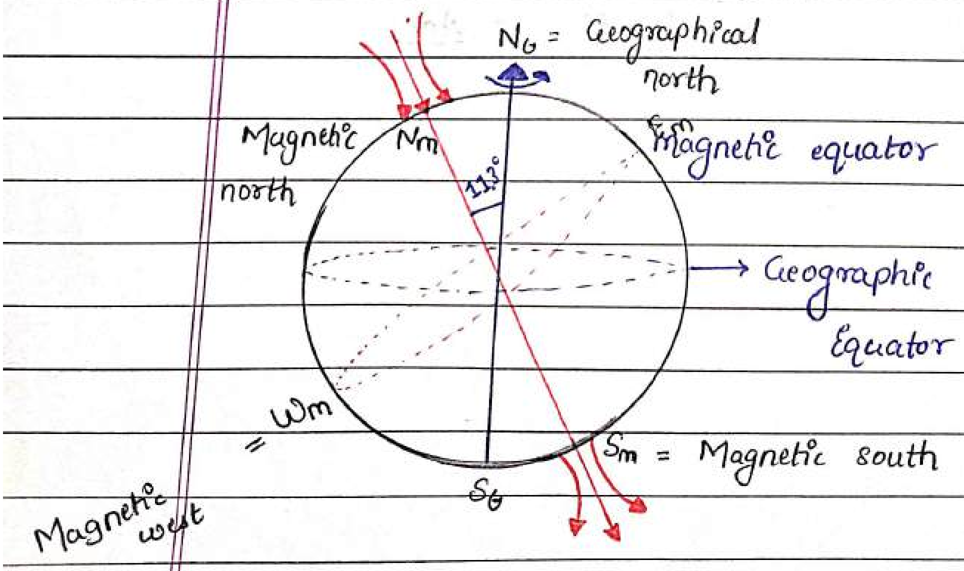
EARTH'S MAGNETISM

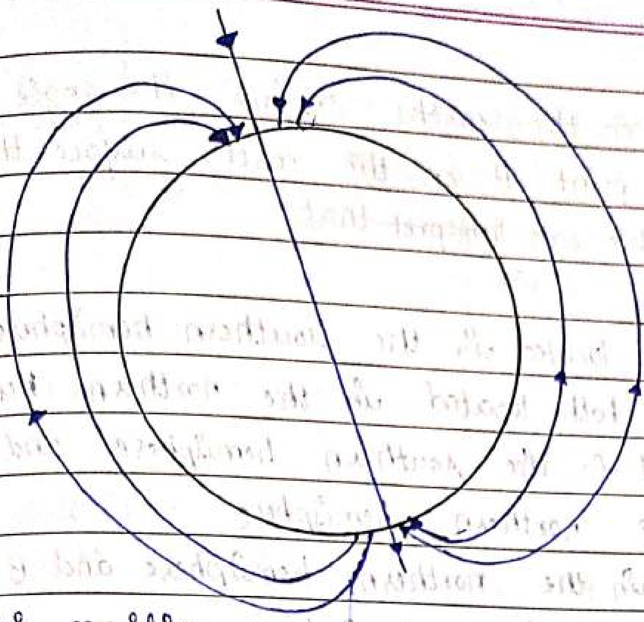


CAUSE OF EARTH MAGNETISM

1) Very large magnet placed deep inside earth (But this is wrong due to high tempr. inside earth)

2) Electric current produce by circular motion of molten [Fe and Ni] fluid in outer core of earth, due to which earth magnetism is created.





Geographic meridian

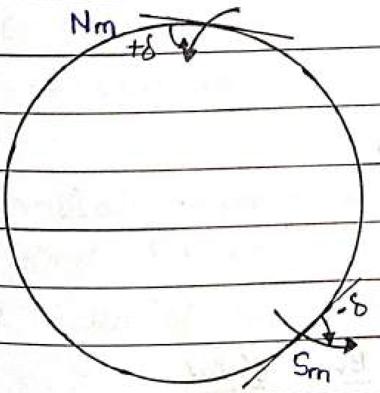
At any point on the earth's surface, vertical plane passing through geographical N-S, pole and at that point.

Magnetic meridian (Vertical plane)

At any point on earth surface, vertical plane passing through magnetic north- south pole and that point.

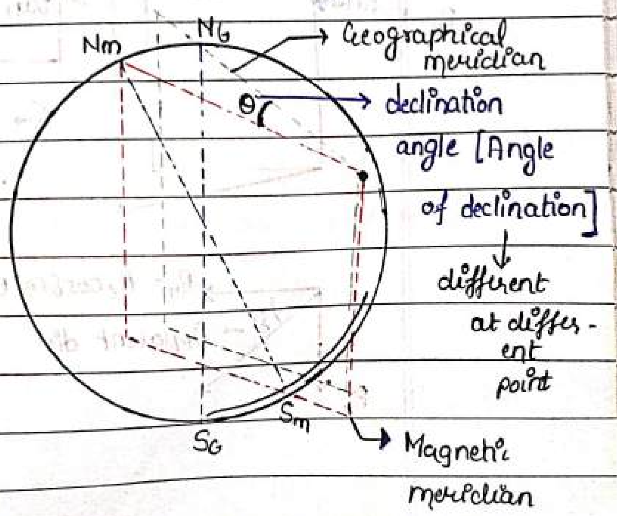
→ with respect to earth surface

- Magnetic field are exactly vertical at north and south pole. $\delta = 90°$ ↳ dip angle
- Magnetic field are exactly parallel at equator, ↳ $\delta = 0°$ ↳ dip angle



Around north pole $\delta = +ve$

Around south pole $\delta = -ve$

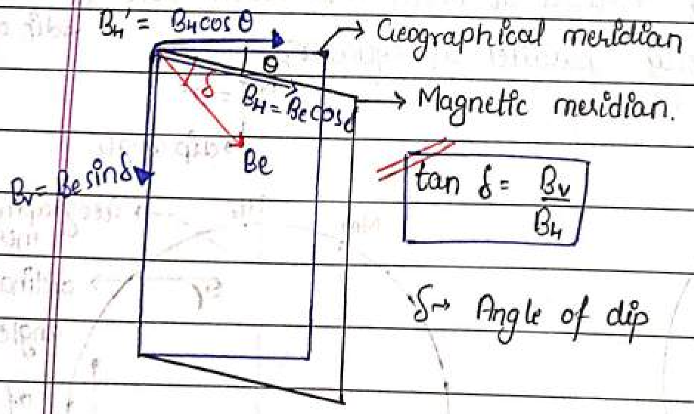


Q At a point A on the earth's surface the angle of dip $\delta = +25^\circ$. At a point B on the earth's surface the angle of dip, $\delta = -25^\circ$. We can interpret that.

1) A and B both located in the southern hemisphere
2) A and B are both located in the northern hemisphere
3) A is located in the southern hemisphere and B is located in the northern hemisphere
4) A is located in the northern hemisphere and B is located in the southern hemisphere.

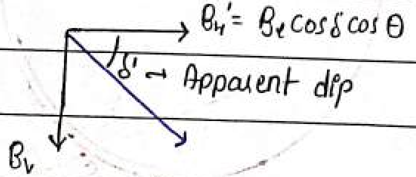
Angle of Dip

The angle ~~of~~ made by net magnetic field of earth from horizontal surface in magnetic meridian



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

δ → Angle of dip



$$\tan\delta' = \frac{B_V}{B_H'} = \frac{\cancel{B_e}\sin\delta}{\cancel{B_e}\cos\delta\cos\theta}$$

$$\tan\delta' = \frac{\tan\delta}{\cos\theta}$$

MIT

$$\boxed{\tan \delta' = \frac{\tan \delta}{\cos \theta}}$$

δ' → Apparent dip at given place along ~~any~~ any Geographic meridian

θ → can be Angle of declinⁿ or any angle.

δ → Real dip at given plance in magnetic meridian.

If $\theta = 0°$ $\tan \delta' = \tan \delta$

MAGNETIC NEEDLE / DIP NEEDLE → Small bar magnet

→ Free to rotate in magnetic meridian

→ Net magnetic field in the plane of magnetic meridian.

Pattern and value of earth magnetic field.

Varies with time and position → because of solar wind → stream of charge particle emitted from sun moves towards earth.

$B_e = 10^{-5} T = 0.1$ Gauss.

Q Calculate Earth's magnetic field at a place where angle of dip δ is 60° and horizontal component of earth's magnetic field is 0.3 G.

Given $B_H = 0.3\,G$, $\delta = 60°$.

Ans $B_H = B_e \cos \delta$

$0.3\,G = B_e \cos 60°$

$B_e = 0.6\,G$ Ans

Q The vertical component of earth's magnetic field at a place is $\sqrt{3}$ times the magnitude of horizontal component. What is the value of angle of dip at the place?

Ans $B_V = \sqrt{3}\, B_H$

$\frac{B_V}{B_H} = \tan \delta = \sqrt{3}$ $\delta = 60°$ Ans

Q The true value of dip at a place is 30°. The vertical plane carrying needle is turned about through 30° from magnetic meridian. Calculate apparent value of dip.

Ans $\delta' = ?$

$\theta = 30°$

$\delta = 30°$

$$\tan\delta' = \frac{\tan\delta}{\cos\theta} = \frac{\tan 30°}{\cos 30°}$$

$$\tan\delta' = \frac{1\times 2}{\sqrt{3}\sqrt{3}} = \frac{2}{3}$$

$$\delta' = \tan^{-1}\left(\frac{2}{3}\right)$$

Q At a place dip angle is known to be 45°. The apparent dip when dip circle is placed ~~45°~~ at a angle of 60°, with the magnetic meridian will be

a) $\tan^{-1}(2)$ (b) $\tan^{-1}\left(\frac{1}{2}\right)$

c) $\tan^{-1}(\sqrt{2})$ (d) $\tan^{-1}\left(\frac{1}{\sqrt{2}}\right)$

Ans $\delta' = ?$

$\delta = 45°$

$\theta = 60°$

$$\tan\delta' = \frac{\tan\delta}{\cos\theta} = \frac{\tan 45°}{\cos 60°} = 2$$

$$\delta' = \tan^{-1}(2)$$

Q A dip circle is placed in geographic meridian at a place where dip and declination are known to be respectively 30° and 45°. What dip will be given by dip circle?

a) $\tan^{-1}\left(\frac{1}{\sqrt{6}}\right)$ (b) $\tan^{-1}\left(\frac{\sqrt{2}}{\sqrt{3}}\right)$

c) $\tan^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (d) $\tan^{-1}\left(\frac{1}{2}\right)$

Ans $\delta = 30°$

$\theta = 45°$

$$\tan\delta' = \frac{\tan\delta}{\cos\theta} = \frac{\tan 30°}{\cos 45°} = \frac{1}{\sqrt{3}}\sqrt{2}$$

$$\delta' = \tan^{-1}\left(\frac{\sqrt{2}}{\sqrt{3}}\right)$$

Q If θ_1 and θ_2 be the apparent angle of dip observed in two vertical planes at right angles to each other, then the true angle of dip θ is given by.

a) $\cot^2\theta = \cot^2\theta_1 + \cot^2\theta_2$

b) $\tan^2\theta = \tan^2\theta_1 + \tan^2\theta_2$

c) $\cot^2\theta = \cot^2\theta_1 - \cot^2\theta_2$

d) $\tan^2\theta = \tan^2\theta_1 - \tan^2\theta_2$

Ans $\tan\theta_1 = \frac{\tan\theta}{\cos\alpha}$ —①

$\tan\theta_2 = \frac{\tan\theta}{\cos(90-\alpha)}$ —②

$\frac{1}{①^2} + \frac{1}{②^2}$

$$\Rightarrow \frac{1}{\tan^2\theta_1} + \frac{1}{\tan^2\theta_2} = \frac{\sin^2\alpha + \cos^2\alpha}{\tan^2\theta}$$

$$\Rightarrow \cot^2\theta_1 + \cot^2\theta_2 = \cot^2\theta$$

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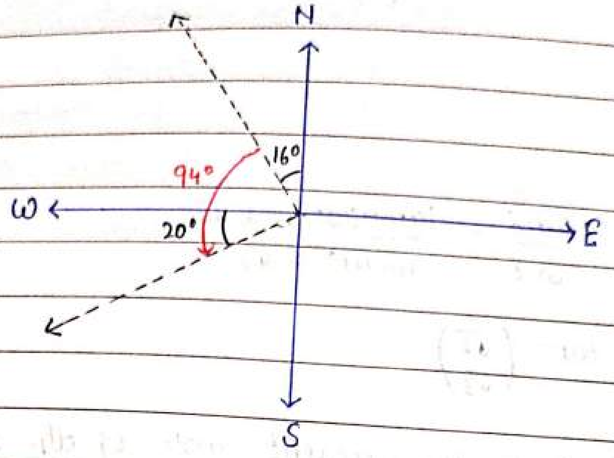
Q If ship is to reach a place 20° south of west. In what direction should it be steered if angle of declination at the place is 16° west?

Ans



The ship should be steered 94°

NEUTRAL POINT

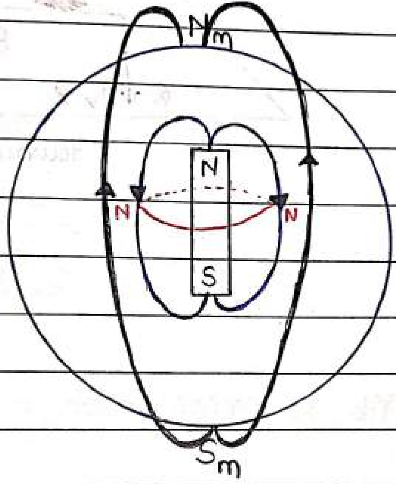
It is a region or space where there is no magnetic field.

a) If the north pole of a magnet points south, the fields of the magnet and the earth will point in opposite directions along its axis of the magnet ; so two neutral points are obtained which are equidistant from the magnet on its axis and the equation used will be $\frac{\mu_0}{4\pi}\frac{2M}{r^3} = B_H$

b) If the north pole of the magnet points north, the fields of the magnet and the earth will point in opposite directions along the equatorial circle of the magnet and there will be infinite neutral points. The equation used will be $\frac{\mu_0}{4\pi}\frac{M}{r^3} = B_H$.

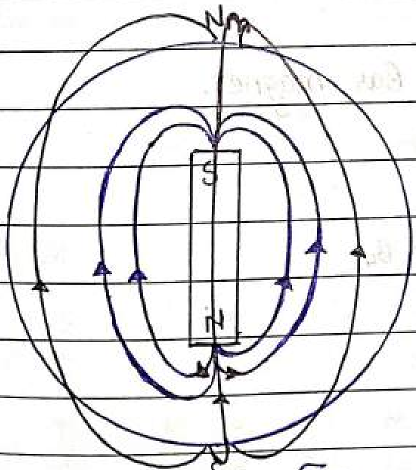
c) There will be only one neutral point on a horizontal plane when a magnet is held vertically on the board.

②



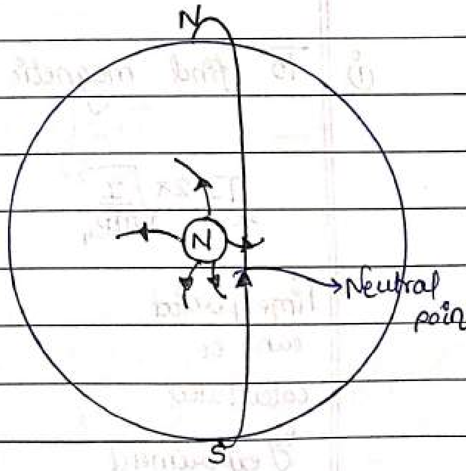
Infinite neutral point.

①



Two neutral point on axis.

③



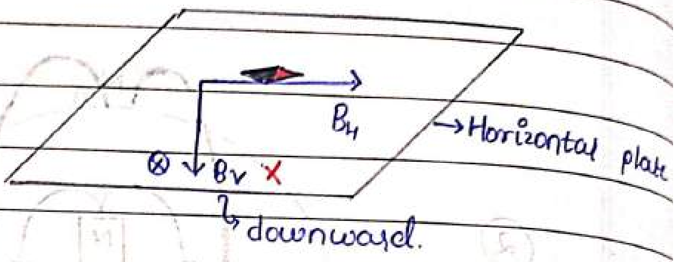
VIBRATIONAL | OSCILATIONAL MAGNETOMETER.

It is an instrument based on torque experienced by Bar magnet in earth magnetic field.

$$\tau = MB_H \sin\theta$$

$$I\alpha = MB_H\theta \quad (\text{for SHM})$$

$$\alpha = \frac{MB_H\theta}{I} = \omega^2\theta$$



$$\omega^2 = \frac{MB_H\cancel{\theta}}{I}$$

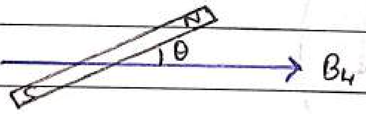
$$\frac{2\pi}{T} = \sqrt{\frac{MB_H\cancel{\theta}}{I}}$$

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

APPLICATION OF MAGNETOMETER.

① To find magnetic moment of a Bar magnet.

$$\underset{\uparrow}{T} = 2\pi\sqrt{\frac{I}{MB_H}}$$



Time period can be calculated by experiment

$$\frac{T}{2\pi} = \sqrt{\frac{I}{MB_H}}$$

$$\frac{T^2}{4\pi^2} = \frac{I}{MB_H}$$

MIT

$$\boxed{M = \frac{4\pi^2 I}{T^2 B_H}}$$

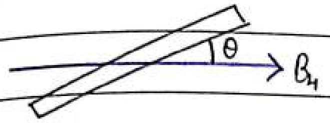
(ii) To compare magnetic moment of two magnet of same size.

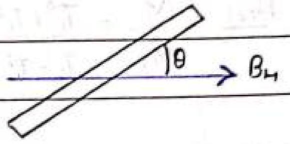
I = MOI of each rod.

M_1 = Magnetic moment of 1st rod. M_2 = Magnetic moment of 2nd rod

$$T_1 = 2\pi\sqrt{\frac{I}{M_1 B_H}} \quad \text{— ①}$$

$$T_2 = 2\pi\sqrt{\frac{I}{M_2 B_H}} \quad \text{— ②}$$

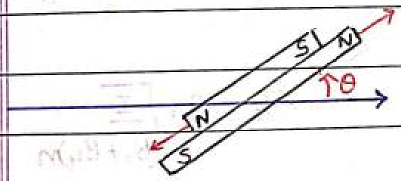


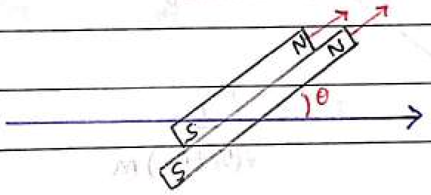


$$\frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$$

$$\boxed{\frac{M_1}{M_2} = \frac{T_2^2}{T_1^2}}$$

(iii) To compare magnetic moment of different size.





$$T_2 = 2\pi\sqrt{\frac{I_1+I_2}{(M_1-M_2)B_H}} \quad \text{—②}$$

$$T_1 = 2\pi\sqrt{\frac{I_1+I_2}{(M_1+M_2)B_H}} \quad \text{—①}$$

① / ②

$$\frac{T_1}{T_2} = \cancel{\sqrt{\frac{(M_1+M_2)}{(M_1-M_2)}}} \qquad \frac{T_1}{T_2} = \sqrt{\frac{M_1-M_2}{M_1+M_2}}$$

$$\frac{T_1^2}{T_2^2} = \cancel{\frac{M_1+M_2}{M_1-M_2}} \qquad \frac{T_1^2}{T_2^2} = \frac{M_1-M_2}{M_1+M_2}$$

$$T_1^2 M_1 + T_1^2 M_2 = T_2^2 M_1 \mp M_2 T_2^2$$

$$M_1(T_2^2 - T_1^2) = M_2(T_1^2 + T_2^2)$$

$$\boxed{\frac{M_1}{M_2} = \frac{T_1^2+T_2^2}{T_2^2-T_1^2}}$$

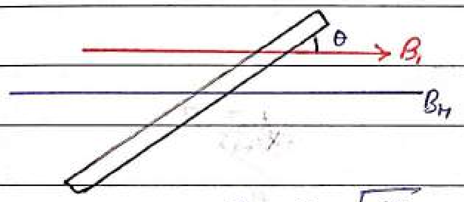
Q The combination of two bar magnets makes 10 oscillations per second in an oscillation magnetometer when like poles are tied together and 2 oscillation per second when unlike poles are tied together. Find the ratio of the magnetic moments of the magnets.

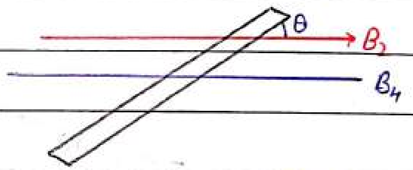
Ans $\frac{M_1}{M_2} = \frac{T_1^2+T_2^2}{T_2^2-T_1^2} = \frac{(0.01)+0.25}{0.25-0.01}$

$\frac{M_1}{M_2} = \frac{0.26}{0.24} = 13/12$ Ans

(iv) To compare two magnetic field.

↳ Take one bar magnet





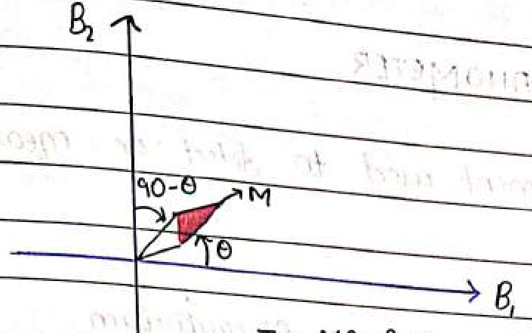
$T_1 = 2\pi\sqrt{\frac{I}{(B_1+B_H)M}}$

$T_2 = 2\pi\sqrt{\frac{I}{(B_2+B_H)M}}$

$$\boxed{\frac{T_1^2}{T_2^2} = \frac{B_H+B_2}{B_H+B_1}}$$

TANGENT LAW

A bar magnet is placed between crossed magnetic field then at balance point net torque on Bar magnet is zero.



$\tau_1 = MB_1 \sin\theta$

$\tau_2 = MB_2 \sin 90-\theta = MB_2 \cos\theta$

At equilibrium

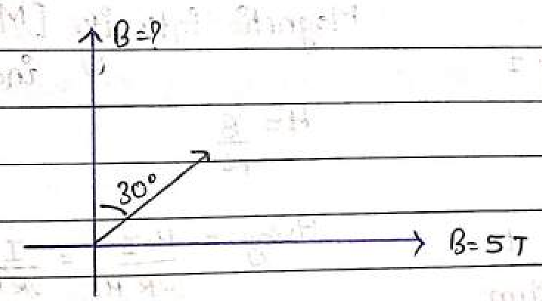
$\tau_1 = \tau_2$

$\cancel{M}B_1 \sin\theta = \cancel{M}B_2 \cos\theta$

$\boxed{B_1 \tan\theta = B_2}$

APPLICATION OF TANGENT LAW

i) To find magnetic field



$\cancel{M}B_1 \sin 30° = \cancel{M}B_1 = \sin 90-\theta$

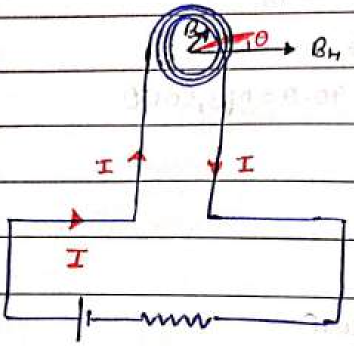
$B\frac{1}{2} = 5\cos 30°$

$\frac{B}{2} = 5\frac{\sqrt{3}}{2}$

$B = 5\sqrt{3}$ Ans

TANGENT GALVANOMETER.

It is an intrument used to detect or measure current ~~at equit~~



At equilibrium

$\cancel{M} B_H \sin\theta = B \cancel{M} \cos\theta$

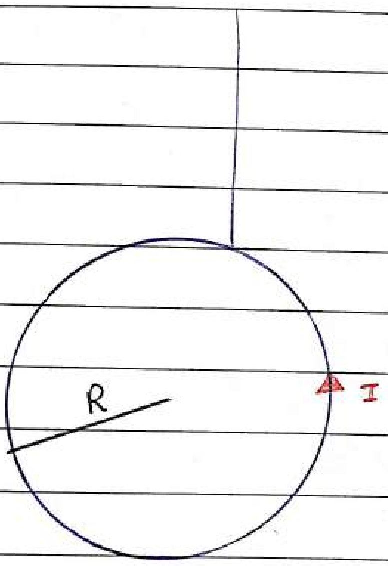
$B_H \tan\theta = \frac{\mu_0 I N}{2R}$

$I = \left(\frac{B_H 2R}{\mu_0 N}\right) \tan\theta$

$I = k \tan\theta$

$I \propto \tan\theta$

k → Reduction constant ↓ constant for instrument.



Magnetic intensity [Magnetic field independent of medium]

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

$H_{ring} = \frac{\mu_0 I}{2R \mu_0} = \frac{I}{2R}$

{ Magnetic field due to circular loop + medium → Magnetic ~~intensity~~ induction (magnetic field)

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

Q Find magnetic intensity of solenoid

ANS B (magnetic field) = $\mu_0 N I$

$H = \frac{B}{\mu_0} = NI$

MAGNETIC INTENSITY [INTENSITY OF MAGNETISING FIELD]

$\vec{H} = \frac{B_0}{\mu_0}$ for any medium = $H = \frac{B}{\mu}$

↓ Vector

MAGNETIC PERMEABILITY (μ)

It is defined as the ratio of the magnitude of total magnetic field (B) inside a material to that of magnitude of magnetic intensity (H)

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

1) It is a scalar quantity. Its unit is $\frac{Wb}{A\text{-}m}$ and dimensions are $[MLT^{-2}A^{-2}]$ $[F/I^2]$

2) The physical significance of magnetic permeability is that, it measures the extent to which a magnetising field can penetrate or permeated a given magnetic ~~field~~material.

$B = \frac{\mu I}{2R}$

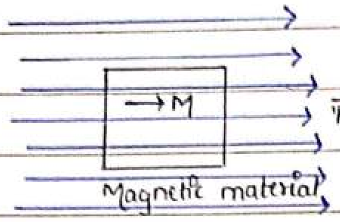
for finding unit $\left\{ \mu_0 = \frac{BR}{I} = \frac{\text{Tesla-metre}}{\text{Amp}} = \frac{\text{Tesla } m^2}{\text{Amp } m} = \frac{Wb}{\text{Amp } m} \right.$ → Unit of magnetic flux.

MAGNETIC SUSCEPTIBILITY

INTENSITY OF MAGNETIC FIELD MAGNETISATION (I)

$\vec{I} = \frac{\vec{M}}{V}$ → Induced magnetic moment per unit volume of magnetic material.

depend on material



→ Vector

Unit → Amp/metre

MAGNETIC SUSCEPTIBILITY (χ_m)

It is defined as the "ratio of magnitude of intensity of magnetisation (I) to that of magnetic intensity ($\vec{H}$)."

1) It is a scalar quantity with no dimension, no unit.
2) The physical significance of magnetic susceptibility is that it is the degree of ease with which a magnetic material can be magnetised. A material with higher value χ_m can easily be magnetised.

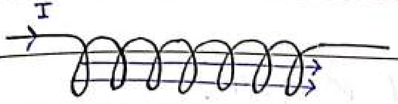
$$\chi_m = \frac{\vec{I}}{\vec{H}}$$

for magnetic material

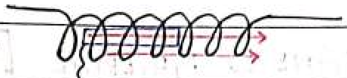
RELATIVE PERMEABILITY [μ_r]

It is the ratio of permeability of a medium to that of permeability of free space ⇒ $\mu_r = \frac{\mu_m}{\mu_0}$

Unit and dimensionless



$B_0 = \mu_0 n I$



$B_{net} = B_{air} + (B_{induced})_{magnetic\ material}$

$\mu_r = 1 + \chi_m$

$\mu_r = 1 + \chi_m$

μ_r → Relative permeability

χ_m → Magnetic susceptibility.

$B_{net} = B\,\mu_0 H_0 + \mu_0 I_0$

$B_{net} = \mu_0 (H_x + I_x)$

$B_{net} = \mu_0 (H_x + \chi_m H_x)$

$B_{net} = \mu_0 H_x (1 + \chi_m)$

$\frac{B_{net}}{\mu_0 H_x} = 1 + \chi_m$

$\frac{\mu}{\mu_0} = \boxed{1 + \chi_m}$

CAUSE OF MAGNETISM

- Orbital motion of electron
- Quantum spin
- Magnetic moment of nucleus

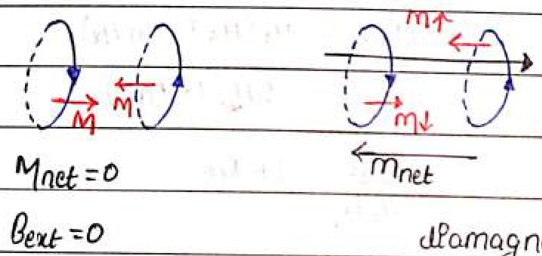
} thousand's times less than magnetic field generated due to orbital motion of electron.

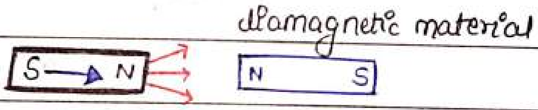
Atom → electrons are in orbital motion about nucleu → Produce current in circular loop → Current loop behave as a magnetic dipole ($\vec{M} = I\vec{A}$)

Paired $e^{\ominus}$ system $[\vec{M}_{atom}] = 0$ → Diamagnetic
Unpaired $e^{\ominus}$ system $[\vec{M}_{atom}] \neq 0$ → Paramagnetic

DIAMAGNETIC MATERIAL [Paired $e^{\ominus}$ system]

When we apply external magnetic field on diamagnetic substance then $e^{\ominus}$ whose magnetic moment opposite to external field speed up and parallel speed down, then atom will develop Mnet opposite to external magnetic field.





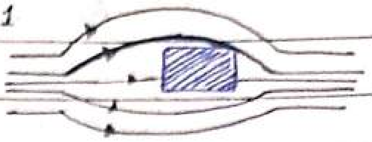
(move away from strong field to weak field)

The substances which have tendency to move from stronger to weaker part of external magnetic field. They develop this tendency because they are feebly magnetised in a direction opposite to that of external magnetic field.

Some of the diamagnetic substances are as follows bismuth, copper, lead, silicon, nitrogen (at STP) water and sodium chlorid

The magnetic field lines are expelled by these substances.

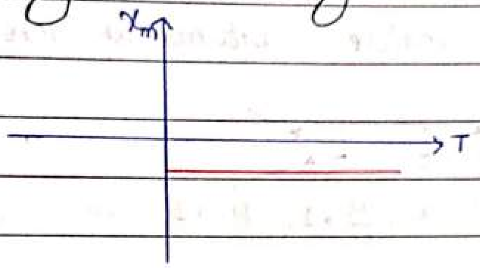
Magnetic field inside diamagnetic substance (B) is less than in free space B_0 therefore $\frac{B}{B_0}<1$, $\frac{\mu}{\mu_0}<1$, $\mu_r<1$



Relative permeability of diamagnetic substance is less than one.

As $\mu_r = 1+\chi_m$ $\mu_r<1$, therefore χ_m is negative for diamagnetic material

Magnetic susceptibility χ_m of diamagnetic substance is independent of temperature.



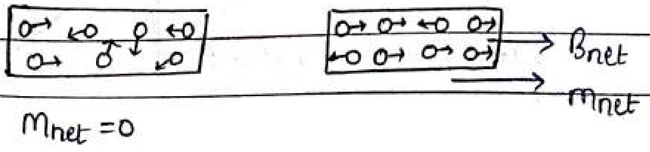
Diamagnetism is a universal property i.e. it is present in all substances. However the effect of is so weak in most cases that it gets shifted by other effects like paramagnetism, ferromagnetism etc.

PARAMAGNETIC MATERIAL

Unpaired electron system

atom have non zero magnetic moment but $M_{net} = 0$ of matter due to random orientation of matter atom

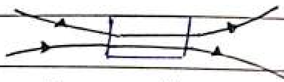
When ext. field is applied then some atom become parallel to field and hence have $M_{net} \neq 0$ for matter.



These are the substances which get feebly magnetised in the direction of applied external magnetic field. Therefore they have tendency to move from region of weak magnetic field to strong magnetic field i.e they get weakly attracted to a magnet.

Some paramagnetic substances are as follows :- aluminium sodium, calcium, oxygen (at STP) and copper chloride.

Magnetic field tend to pass through these substances therefore magnetic field inside substance is more than the outside.



$B > B_0$, $\frac{B}{B_0} > 1$, $\mu > \mu_0$, $\frac{\mu}{\mu_0} > 1$, $\mu_r > 1$

The relative permeability of paramagnetic substances is >1
As $\mu_r = 1 + \chi_m$, χ_m is positive. (χ_m is small and positive)

CURIES LAW

This law states that the magnetisation of a paramagnetic material is inversely proportional to the absolute temperature T.

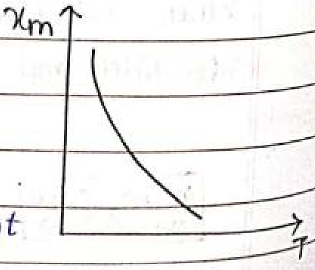
$I \propto \frac{B_0}{T}$ $I = \frac{CB_0}{T}$

OR

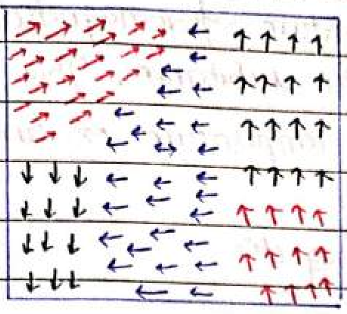
Magnetic susceptibility of a paramagnetic substance is inversely proportional to absolute temperature T.

$\chi_m \propto \frac{\mu_0}{T}$ $\chi_m \propto \frac{1}{T}$

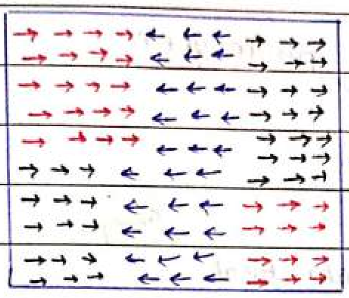
$\chi_m = C\frac{\mu_0}{T}$



The constant C is called curies constant



domain formation due to mutual torque applied on atom.



$\vec{M}_{one\ domain} \neq 0$

$\vec{M}_{matter} = 0$

↓

due to random motion of domain

FERROMAGNETISM

These are the substance which get strongly magnetised when placed in an external magnetic field. So they have strong tendency to move a region of weak magnetic field to strong magnetic field. They get strongly attracted to magnet.

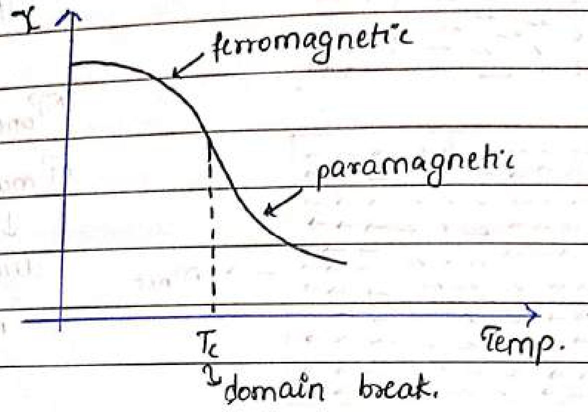
Some of the ferromagnetic substances are as follows :- iron, cobalt, nickel, alloys like alnico etc.

Magnetic field lines tend to crowd into ferromagnetic material

Permeability of ferromagnetic materials is very large, of the order of hundreds and thousands.

Magnetic susceptibility χ_m of ferromagnetic substance is very high, therefore they can be magnetised easily and strongly.

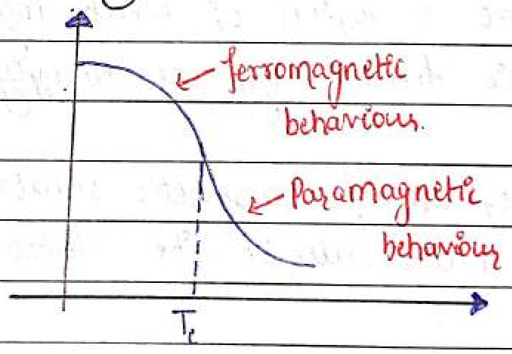
With rise in temp, susceptibility of ferromagnetic materials decreases. At a certain temperature ferromagnetic substance is converted into paramagnetic substance. This transition temperature is called curie temperature or curie point T_c.



Curie-Weiss law :- At temperature above the Curie temperature a ferromagnetic substance becomes an ordinary paramagnetic substance whose substance magnetic susceptibility obeys the curie-Weiss law according to which

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

Law is valid after T_c



Q Domain formation is the necessary feature of

a) Diamagnetism (b) Paramagnetism
[✓ c) ferromagnetism] (d) All of these.

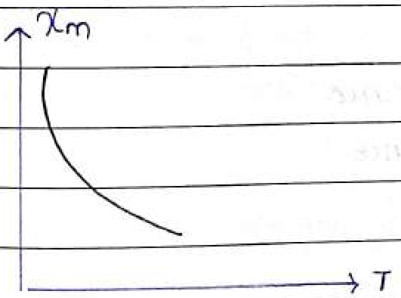
Q Susceptibility of a magnetic substance is found to depend on temperature and the strength of the magnetising field. The material is.

a) Diamagnetic (b) Ferromagnet
c) Paramagnetic (d) Superconductor

Diamagnetic	Paramagnetic	Ferromagnetic
$-1 \leq \chi_m < 0$	$0 < \chi_m < \epsilon$	$\chi_m >> 1$
$0 \leq \mu_r < 1$	$1 < \mu_r < 1+\epsilon$	$\mu_r >> 1$
$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$
	ϵ(small positive no.)	

$\chi_m = 0$ → Non magnetic material
$\chi_m = -1$ → for superconductors.

Q The variation of magnetic susceptibility (χ) with absolute temperature (T) for a ferromagnetic material is.

1)


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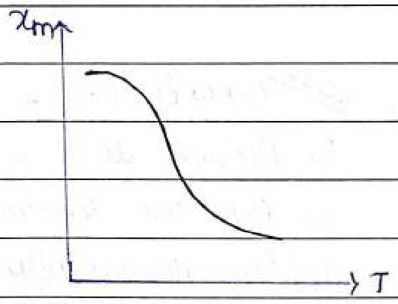

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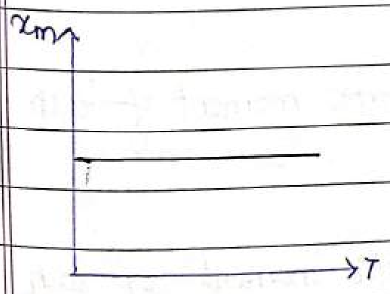

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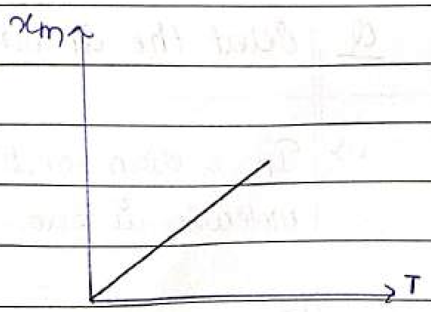
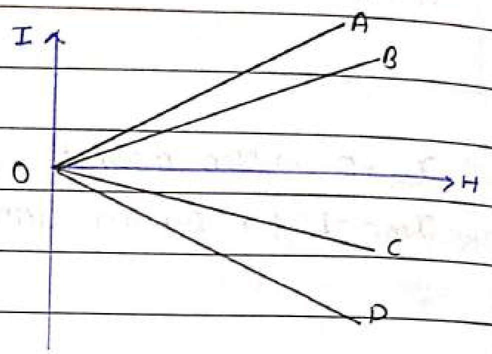


Q The universal property of all substance is.

[✓ a) Diamagnetism] b) Ferromagnetism
c) Paramagnetism d) All of these.

Q The variation of the intensity of magnetisation (I) with respect to the magnetising field (H) in a diamagnetic substance is described by the graph.

[✓ a) OC] b) OD
c) OA d) OB.



→ $\underbrace{\chi}_{\text{-ve (small)}} = \frac{I}{H}$

Q When a ferromagnetic substance is heated to a temperature above its curie temperature, it.

[✓ a) Behaves like a paramagnetic substance]
b) Behaves like a diamagnetic substance
c) Remains ferromagnetic
d) Is permanently magnetised.

Q Select the incorrect statement.

a) In a diamagnetic substance net magnetic moment of each atom/molecule is zero.

b) In a paramagnetic substance net magnetic moment of each atom/ molecule is non zero

c) In a ferromagnetic material net magnetic moment of each domain is zero.

d) In a ferromagnetic material net magnetic moment of each domain is non zero.

Q Relative permeability of superconductor is.

a) 0 (b) 1
c) -1 (d) 0.5

⇒ $\chi_m = -1$
$\mu_r = 1 + \chi_m = 1 - 1 = 0$.

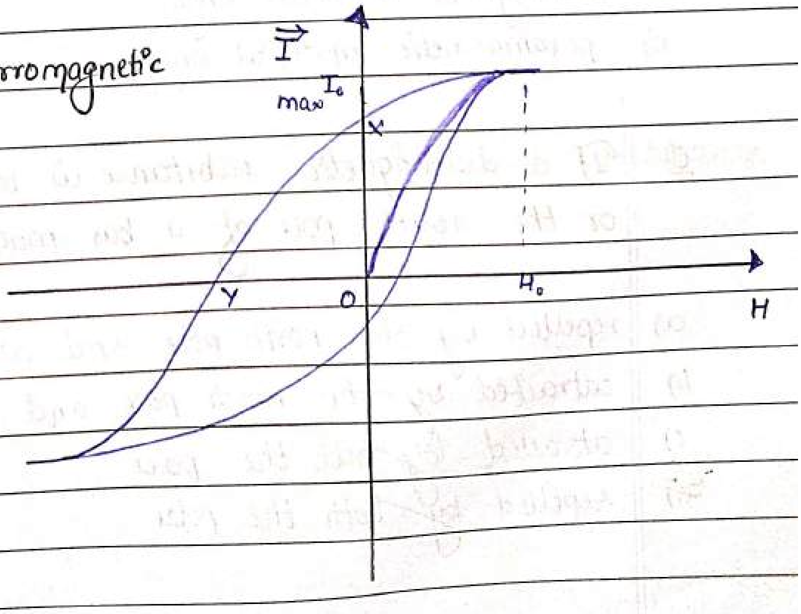
Q The magnetic moment of dimagnetic atom is.

a) much greater than one (b) 1
c) between zero and one (d) equal to zero.

HYSTERESIS. → for ferromagnetic

Retentivity → OX
Coercivity → OY

Area → Energy loss.



Q The hysteresis curve is studied generally for.

a) Paramagnetic particles (b) Diamagnetic materials
[✓ c)] Ferromagnetic materials d) All of these.

Q Soft iron core is used to manufacture electromagnets because their.

[✓ a)] Magnetic permeability is high and retentivity and coercive force are small
b) Retentivity is high
c) Coercive force is high
d) Area of hysteresis is high.

⇒ Permanent magnets → Retentivity very high.

Q The magnetic susceptibility is negative for.

a) ferromagnetic particle only
b) paramagnetic and ferromagnetic materials.
[✓ c)] diamagnetic material only
d) paramagnetic material only.

Q If a diamagnetic substance is brought near the north or the south pole of a bar magnet, it is.

a) repelled by the north pole and attracted by the south pole
b) attracted by the north pole and repelled by the south pole
c) attracted by both the poles
[✓ d)] repelled by both the poles

Q Curie temperature is the temperature above which.

a) paramagnetic material becomes ferromagnetic material
b) ferromagnetic material becomes diamagnetic material
c) parafmagnetic material becomes ~~paramagnetic~~ diamagnetic material
[✓ d)] ferromagnetic material becomes ~~diamagnetic~~ paramagnetic material

Q Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature then it will show.

a) antiferromagnetism
b) no magnetic property
c) diamagnetism
[✓ d)] paramagnetism

Q A diamagnetic material in a magnetic field moves.

[✓ a)] from stronger to weaker parts of the field
b) from weaker to the stronger parts of the field
c) perpendicular to field
d) in none of the above directions.

Q According to Curie's law, the magnetic susceptibility of a substance at an absolute temperature T is proportional to.

[✓ a)] $1/T$ b) T
c) $1/T^2$ (d) T^2

Q Among which the magnetic susceptibility does not depend on the temperature?

[✓ a)] Diamagnetism b) Paramagnetism

c) Ferromagnetism d) Ferrite.