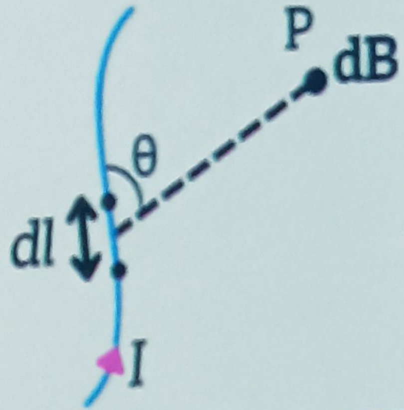
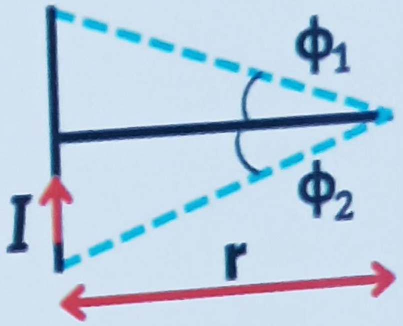
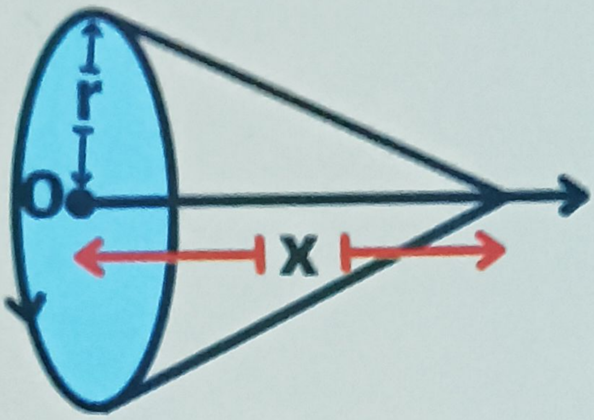
Magnetic Field

Biot Savart's Law dB = Magnetic field Change μ_0 = absolute permeability of free space dl = length of current carrying element θ = angle between length of the current element and line joining the element to P.	$dB = \frac{\mu_0}{4\pi}\frac{I(dl \times r)}{r^3}$ $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$ 
Magnetic Field due to a Straight Current Carrying Conductor $B = \frac{\mu_0}{4\pi}\frac{I}{r}(\sin\phi_1 + \sin\phi_2)$	
For Infinite length conductor, Observation point near to center of conductor	$B = \frac{\mu_0}{4\pi}\frac{2I}{r}$
For Infinite length conductor, Observation point near to center of conductor	$B = \frac{\mu_0}{4\pi}\frac{I}{r}$

Magnetic Field on the Axis of a Current Carrying Circular Coil



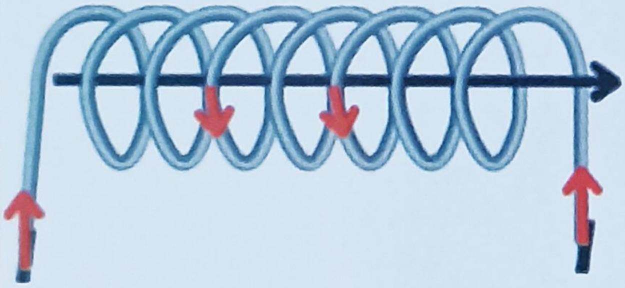
$$B = \frac{\mu_0 n I r^2}{2(r^2 + x^2)^{3/2}}$$

n = number of turns in the coil

At the centre of the coil

$$B = \frac{\mu_0 n I}{2r}$$

Magnetic field in a long solenoid



At a Point inside a long solenoid

$$B = \mu_0 n I$$

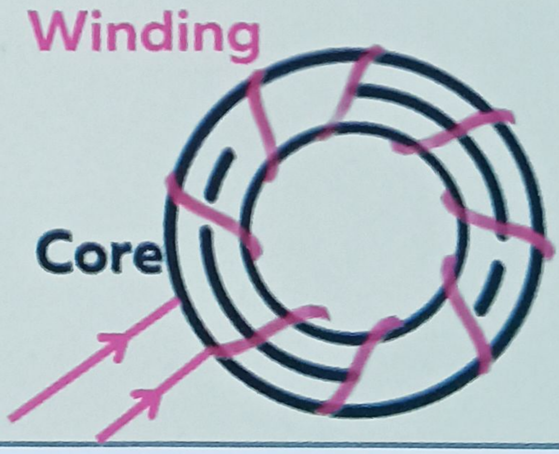
At a point on one end of a long solenoid

$$B = \frac{\mu_0 n I}{2}$$

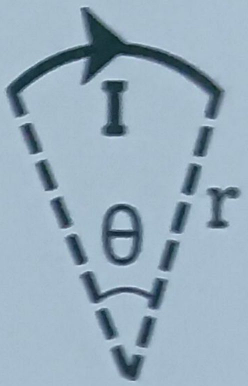
Magnetic Field Inside the Turns of Tordroid

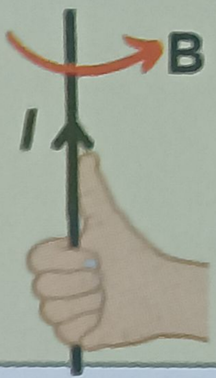
$$B = \mu_0 n I$$

$n =$ *number of turns per unit length*



Magnetic Field at the Centre of a Circular Current Carrying Coil

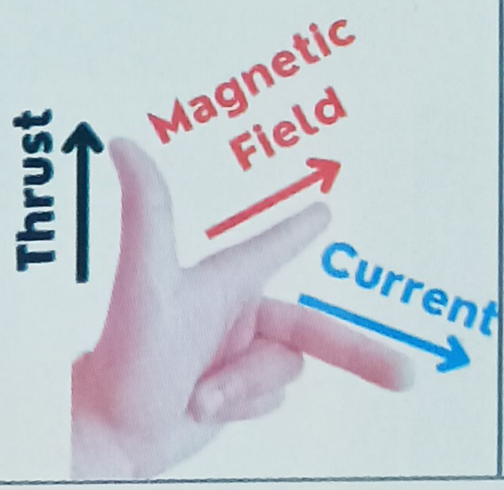
Due to whole circular loop	$B = \frac{\mu_0 I}{2\pi a}$	
Due to an arc	$B = \frac{\mu_0 I}{4\pi r}\theta$	

Right Hand Thumb Rule 	If we hold a current carrying conductor in the grip of the right hand in such a way that thumb points in the direction of current, then curling of fingers represents the direction of magnetic field lines
Ampere's Circuital Law $\oint B.dl = \mu_0 I$	The line integral of magnetic field induction B around any closed path in vacuum is equal to μ_0 times the total current threading the closed path, i.e.

Magnetic Force

Force Acting on a Charge Particle Moving in a Uniform Magnetic Field	$F = q(v \times B)$ $F = Bqv\sin\theta$
Motion of Charged Particle in Combined Electric and Magnetic Field *Lorentz Force*	$F = q(E + v \times B)$ $F = F_E + F_M$

Fleming's Left Hand Rule



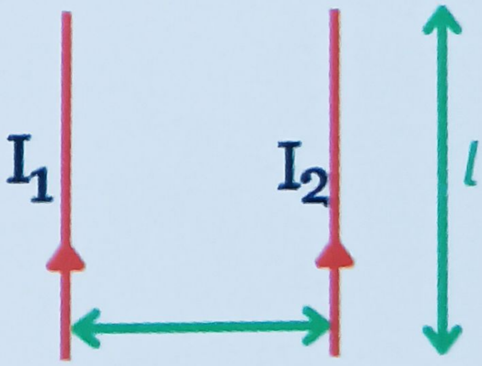
If we stretch the thumb, the forefinger and the central finger of left hand in such a way that all three are perpendicular to each other, then if forefinger represents the direction of magnetic field, central finger represents the direction of current flowing through the conductor, then thumb will represent the direction of magnetic force.

Force on a Current Carrying Conductor in A Magnetic Field

$$F = I(l \times B)$$
$$F = BIl\sin\theta$$

Force between Two Infinitely Long Parallel Current Carrying Conductors

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}l$$



Cyclotron

Principle	**Cyclotron Frquency**	**Maximum Kinetic Energy**
A charged particle moving normal to a magnetic field experiences magnetic lorentz force due to which the particle moves in a circular path.	$v = \dfrac{Bq}{2\pi m}$	$E_{max} = \dfrac{B^2 q^2 r_0^2}{2m}$

Galvanometer

Torque acting on a Current Carrying Coil Placed Inside a Uniform Magnetic Field	$\tau = NBIA \sin\theta$ N = number of turns in the coil A = area of cross-section of the coil
Galvanometer deflecting torque = restoring torque	$NBIA = k\theta$ $I = \dfrac{k}{NBA}\theta$
Current Sensitivity	$I_s = \dfrac{\theta}{I} = \dfrac{NBA}{k}$
Voltage Sensitivity	$V_s = \dfrac{\theta}{V} = \dfrac{NBA}{kr}$
Conversion of a Galvanometer into an Ammeter	$S = \left(\dfrac{I_g}{I - I_g}\right)G$
Conversion of a Galvanometer into a Voltmeter	$R = \dfrac{V}{I_g} - G$

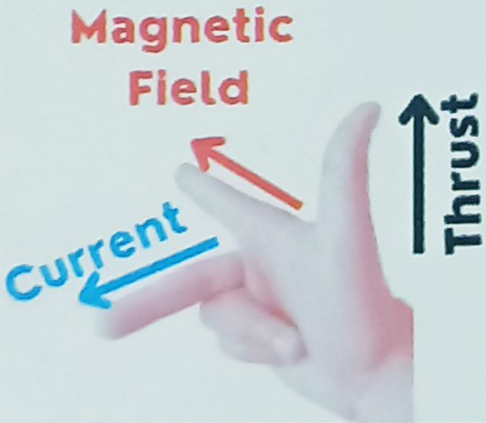
Electromagnetic Induction

Magnetic Flux	$d\phi = \vec{B}.\vec{A} = BA\cos\theta$
Faraday's Law of Electromagnetic Induction (i) Whenever the magnetic flux linked with a circuit changes, an induced emf is produced in it. (ii) The induced emf lasts, so long as the change in magnetic flux continues. N = number of turns in the coil	The magnitude of induced emf is directly proportional to the rate of change in magnetic flux, i.e. $\varepsilon \propto \frac{d\phi}{dt} \Rightarrow \varepsilon = -\frac{d\phi}{dt}$ $\varepsilon = -N\frac{d\phi}{dt}$

Lenz's Law

The direction of the current induced in a conductor by a changing magnetic field (as per Faraday's law of electromagnetic induction) is such that the magnetic field created by the induced current opposes the initial changing magnetic field which produced it. The direction of this current flow is given by Fleming's right hand rule.

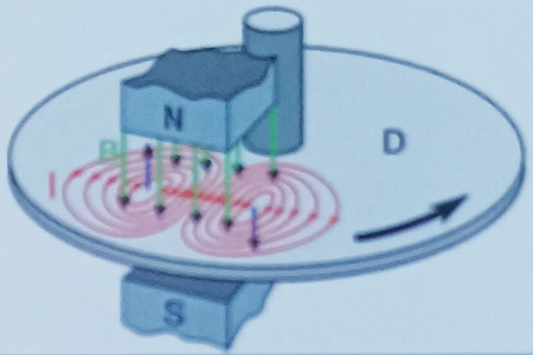
Fleming's Right Hand Rule



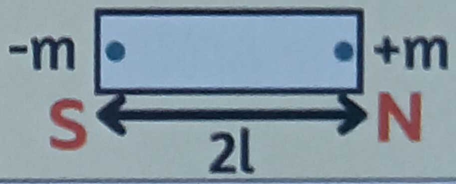
If we stretch the thumb, the forefinger and the central finger of right hand in such a way that all three are perpendicular to each other, then if thumb represent the direction of motion, the forefinger represent the direction of magnetic field, then central finger will represent the direction of induced current.

Eddy Currents

If a piece of metal is placed in a varying magnetic field or rotated with high speed in a magnetic field, then induced currents set up in the piece are like whirlpool of air, called eddy currents.

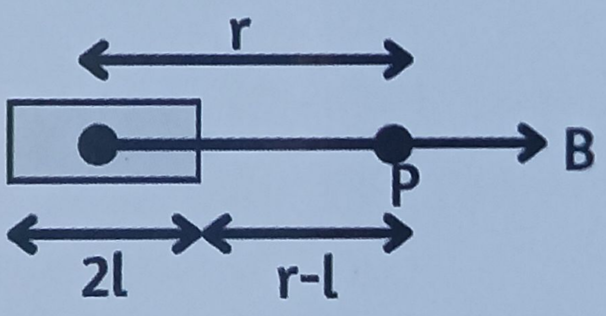
$I = -\frac{\varepsilon}{R} = \frac{d\phi/dt}{R}$	
Self Inductance N = number of turns in solenoid	$L = \frac{\mu_0 N^2 A}{l} = \mu_0 n^2 A l$ n = number of turns in the coil
Mutual Inductance	$M = \sqrt{L_1 L_2}$ $M = \frac{\mu_0 N_1 N_2 A}{l} = \mu_0 n_1 n_2 A l$
Coefficient of Coupling	$K = \sqrt{\frac{M}{L_1 L_2}}$
Energy stored in inductor	$U = \frac{1}{2} L I^2$

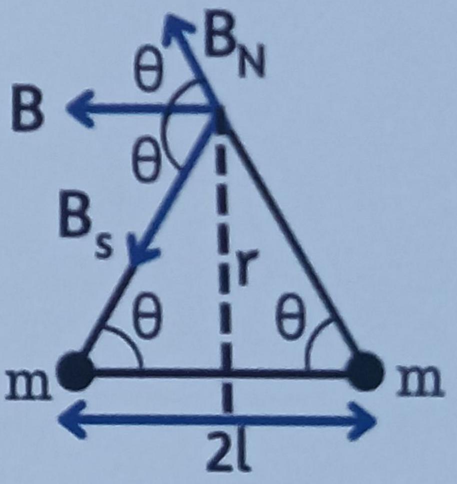
Magnetism and Matter

Magnetic Dipole Moment $M = m(2l)$	

Magnetic Field Due to a Magnetic Dipole

On Axial Line	$B = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}$	if $r \gg l$, $B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$
On Equitorial Line	$B = \frac{\mu_0}{4\pi}\frac{M}{(r^2 + l^2)^{3/2}}$	if $r \gg l$, $B = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

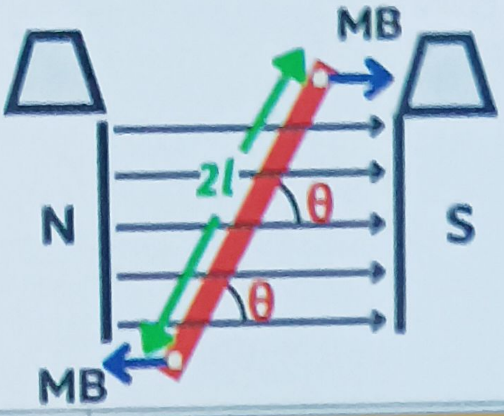




Potential Energy of a Magnetic Dipole in a Uniform Magnetic Field	$U = W = -M.B$ $U = -MB\cos\theta$
Gauss's Law in Magnetism Surface integral of magnetic field over any closed surface is always zero.	$\oint_S B.dS = 0$

Torque Acting on a Magnetic Dipole

$$\tau = M \times B$$
$$\tau = MB \sin\theta$$



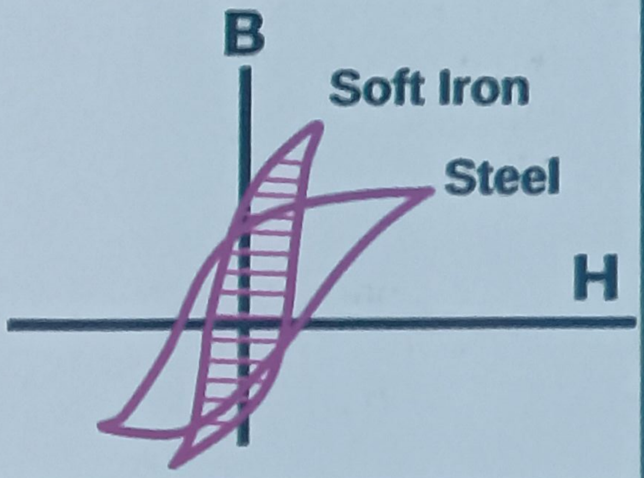
Earth's Magnetism

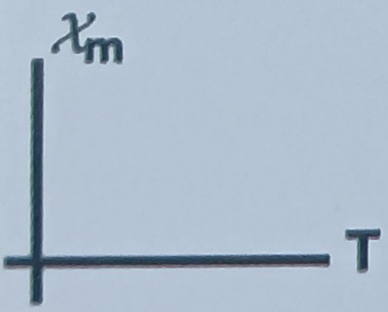
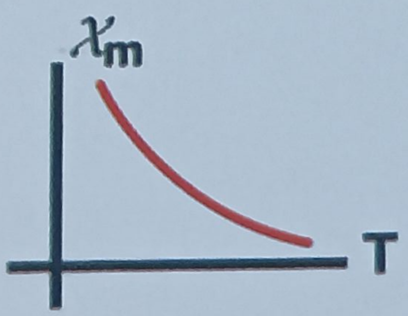
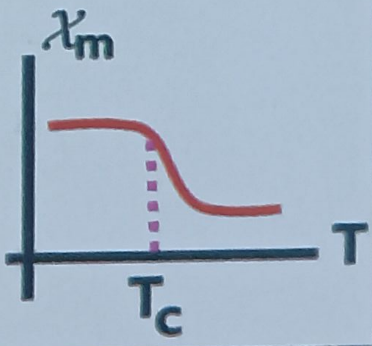
Vertical Component of Earth's Magnetic Field	$V = B \sin\delta$
Horizontal Component of Earth's Magnetic Field	$H = B \cos\delta$
Magnetic Field	$B = \sqrt{H^2 + V^2}$
Magnetic Dip	$\tan\delta = \frac{V}{H}$
Apperent Dip	$\tan\delta' = \frac{\tan\delta}{\cos\theta}$

Tangent Law It states that, if a magnet is placed in two magnetic fields right angle to each other, then it will be acted upon by two couples tending to rotate it in opposite directions. It will be deflected through an angle θ, such that two couples balance each other.	$\tan\theta = \frac{B_1}{B_2}$
Time Period of Vibrations in Vibration Magnetometer	$T = 2\pi\sqrt{\frac{I}{MH}}$
Magnetic Permeability	$\mu = \frac{B}{H}$
Magnetic Intensity	$H = \frac{B}{\mu}$
Intensity of Magnitisation	$I = \frac{M}{V} = \frac{m}{A}$
Magnetic Induction	$B = \mu_0(H + I)$
Magnetic Susceptibility	$\chi_m = \frac{I}{H}$

Hysteresis

The lagging of intensity of magnetisation (I) or magnetic induction (B) behind magnetising field (H), when a specimen of a magnetic substance is taken through a complete cycle of magnetisation is called hysteresis.

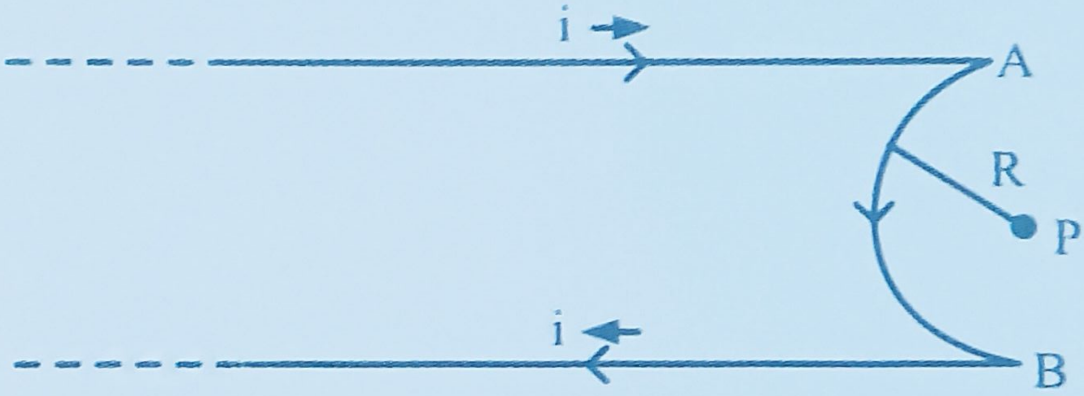


Diamagnetism	Paramagnetism	Feromagnetism
Universal Property $-1 \le \chi_m < 0$ $0 \le \mu_r < 1$ $\mu < \mu_0$	χ_m = small number (ε) $\mu_r = 1 + \varepsilon$ $\mu > \mu_0$	$\chi_m \gg 1$ $\mu_r \gg 1$ $\mu \gg \mu_0$
Paired electron	Unpaired electron	Unpaired electron
$B_{net} < B_{ext}$	$M_{net} = 0$	χ_m = constant at low T.
Move from stronger to weaker	Move from weaker to stronger	Move from weaker to stronger rapidly
Ex- Copper, Lead, Silicon< Bismuth	Ex- Aluminium, Sodium, Calcium	Ex- Iron, Cobalt, Nickel
		

NEET 2023 PYQ'S (Chapter 17 Magnetism)

- A wire carrying a current I along the positive x-axis has length L. It is kept in a magnetic field $B=(2\hat{i}+3\hat{j}-4\check{k})T$. The magnitude of the magnetic force acting on the wire is :
  5IL

- A very long conducting wire is bent in a semi-circular shape from A to B as shown in figure. The magnetic field at point P for steady current configuration is given by :



$\frac{\mu_0 I}{4R}\left[1-\frac{2}{\pi}\right]$ outward i.e. away from page.