20/7/16

Magnetic Field & Its Effect

✡ Physical quantities — Symbol

Physical quantities		Symbol
Pole Strength	–	m
Length	–	l
Magnetic field	–	B (vector)
Magnetic flux	–	ϕ
Energy	–	E
Inductance	–	L
Resistance	–	R
force	–	F (vector)
Current	–	I

✡ Magnetic field in the Sense of Magnet —

- In the sense of magnet the space around a magnet when iron like material comes in field it feels an attractive force.

✡ Magnetic field in the sense of current —

- When the current passing through a conductor a field is develop around it when an another conducting wire is place it feels a magnetic force this field is

known as magnetic field of a conducting wire.
Its unit is Tesla or weber/m^2

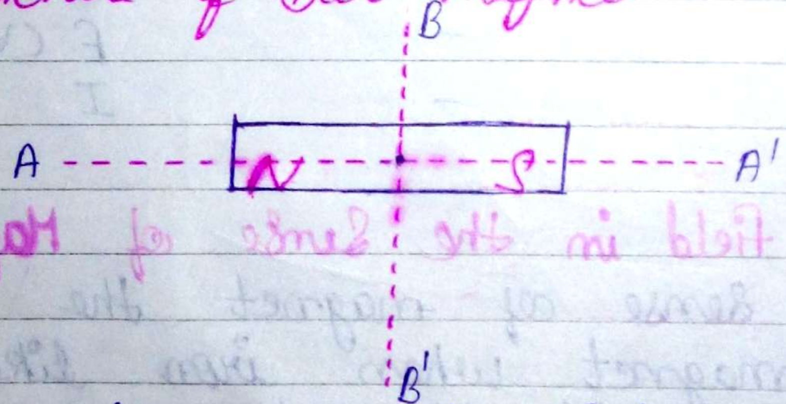
✯ Magnetic lines of force —

- The imaginary closed curve originate from north pole and ending at South pole. Any tangent at that curve shows the direction of magnetic field.
- Properties —

(i) It start from North externaly.
(ii) It Start from South internaly.
(iii) It is a close curve.

✯ Magnetic field due to a bar magnet —

(i) Structure of Bar magnet —



The poles are that point where the max. attraction of force exists.
North pole are generally +ve and South pole are generally -ve.

✯ Magnetic lines of force —

- Properties —

(iv) They never intersect each other.

(v) Place where force field is strong the density of field lines is more while at the place of weak field lines force is not strong.

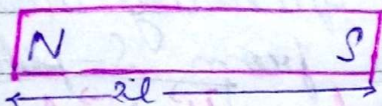
(vi) They can enter in North pole from any angle and can come out from South pole from angle.

(2) Pole strength — The strength of the attraction of the poles of the magnet is called pole strength.

- It is a Scalar quantity.
- Its unit is Ampere Metre.

(3) Geometrical length or Actual length of the magnet —

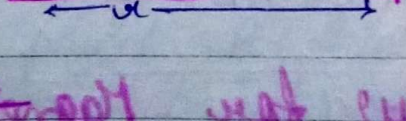
- The distance between the two opposite ends of a magnet is called the magnetic length of the magnet.



(4) Magnetic / effective length →

The distance between the two poles of a magnet is called Magnetic / effective length.

Magnetic length is $\frac{5}{6}$ of Geometrical length

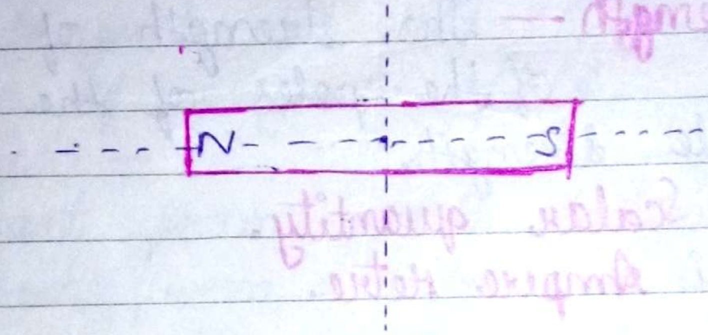


(5) Axial line

The distance between the two poles of a magnet is called

(5) Axial line —

- The line passing through the poles of a magnet is called axial line and we can also say that the line passing through the centre.
- The line perpendicular to the axis and passing through the center.



Magnetic dipole moment —

- The product of the strength of the either pole and effective length is called dipole moment.
- It is a vector quantity and denoted by $\vec{M}$.
- Its direction is from S-pole to N-pole.

formula — $\boxed{\vec{M} = 2\vec{m}l}$

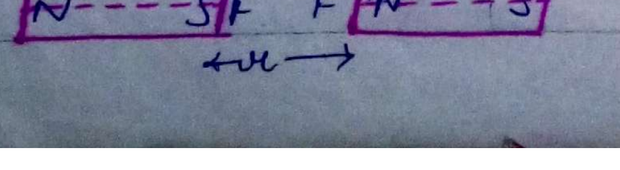
unit → Amperem^2

Dimension → $[L^2 T^0 A^1]$

Relation between Magnetic field and Magnetic force ⟶

$$\boxed{F_m = mB}$$

Coloumb's law for Magnetic field —



According to this law attractive or repulsion force between two magnetic poles is proportional to the square of the distance between them.
If the pole strength are m_1 and m_2 and distance between them is r the force betw. them.

$$f \propto m_1 m_2 \quad \text{---(A)}$$
$$f \propto \frac{1}{r^2} \quad \text{---(B)}$$

Therefore, $f \propto \frac{m_1 m_2}{r^2}$ ---(C) [from (A) & (B)]

$$f = K \frac{m_1 m_2}{r^2}$$
$$f = \frac{\mu_0}{4\pi} \frac{m_1 m_2}{r^2}$$

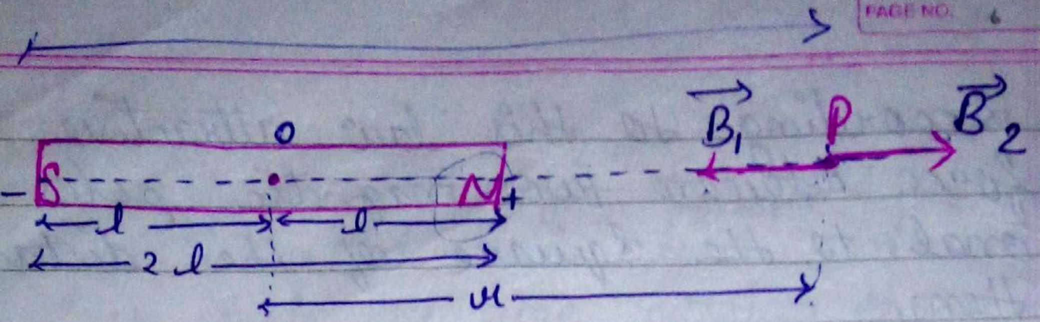
but, $f = mB$

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

assumption $\longrightarrow M = 1$

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

★ Magnetic field due to a bar magnet at an axial point —
If magnetic moment of a bar magnet is M then at a point P which is at r distance from its mid point, magnetic field can be determined as follows →



If magnetic field at point P due to S & N pole are $\vec{B_1}$ and $\vec{B_2}$ respectively.
Then,

$$\vec{B_1} = \frac{\mu_0}{4\pi}\frac{m}{(r+l)^2} \quad \text{—— (A)}$$

$$\vec{B_2} = \frac{\mu_0}{4\pi}\frac{m}{(r-l)^2} \quad \text{—— (B)}$$

Resultant, magnetic field at point P.

$$B = B_2 - B_1 \quad \text{—— (C)}$$

by eq^n (A) (B) & (C)

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

$$B = \frac{\mu_0}{4\pi} m\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]$$

$$B = \frac{\mu_0 m}{4\pi}\left[\frac{r^2 + l^2 + 2rl - (r^2 + l^2 - 2rl)}{(r^2 - l^2)^2}\right]$$

$$B = \frac{\mu_0 m}{4\pi}\left[\frac{4rl}{r^4}\right]$$

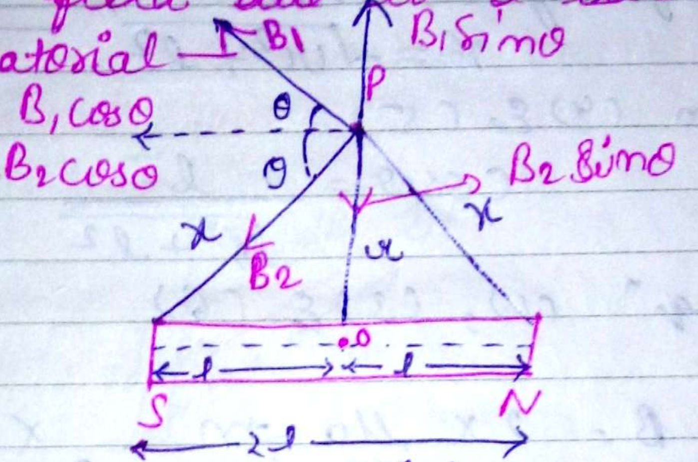
$$= \frac{2\mu_0\, 2ml}{4\pi r^3}$$

$$\boxed{B = \frac{\cancel{2}\,\mu_0\, 2M}{4\pi r^3}} \quad \text{—— (i)}$$

In vector Notation —

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

Magnetic field due to a bar magnet at an equatorial —



(a)

Let us consider a bar magnet NS of length 2l and pole strength m. Suppose the magnetic field is to be determined at point P lying on the equatorial of the magnet NS at a distance r from its centre, as shown in fig (a). Let distance betw. PN & PS is x.

force exert on point P from N pole is B_1

$$B_1 = \frac{\mu_0}{4\pi} \frac{m}{x^2} \quad \text{—— (1)}$$

force exert on point P from S pole is B_2

$$B_2 = \frac{\mu_0}{4\pi} \frac{m}{x^2} \quad \text{—— (2)}$$

As the vertical components get cancelled $B_1 \sin\theta$ and $B_2 \sin\theta$ equal and opposite in direction, whereas horizontal components add up.

$$B = B_1 \cos\theta + B_2 \cos\theta$$

from eq^n (1) & (2) $B_1 = B_2$

$$B = 2 B_1 \cos\theta \quad \text{—— (3)}$$

Now,

$$\cos\theta = \frac{l}{x} \quad \text{—— (4)}$$

from pythagores theorem,

$$x = \sqrt{r^2 + l^2} \quad \text{—— (5)}$$

from (4) & (5)

$$\cos\theta = \frac{l}{\sqrt{r^2 + l^2}} \quad \text{—— (6)}$$

from eq^n (1), (3) & (6)

$$B = 2 \times \frac{\mu_0}{4\pi} \frac{m}{(\sqrt{r^2+l^2})^2} \times \frac{l}{\sqrt{r^2+l^2}}$$

$$B = 2 \frac{\mu_0}{4\pi} \frac{m \quad l}{(r^2+l^2)(r^2+l^2)^{1/2}}$$

$$B = 2 \frac{\mu_0}{4\pi} \frac{ml}{(r^2+l^2)^{3/2}}$$

As per the condition,

$$r >> l$$

So,

$$B = \frac{\mu_0}{4\pi} \frac{2ml}{(r^2)^{3/2}}$$

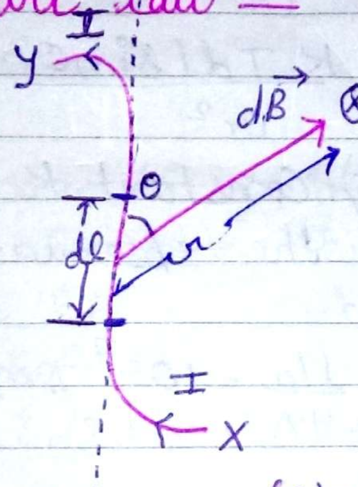
$$B = \frac{\mu_0}{4\pi} \frac{2ml}{r^3}$$

we know that, $2ml = M$

$$\boxed{B = \frac{\mu_0}{4\pi} \frac{M}{r^3}} \quad \text{—— (ii)}$$

→ On comparing (i) & (ii), we note that the magnetic field at a point at a certain distance on the axial line of short magnet is twice of that at the same distance on its equatorial line.

Biot - Savart law —



(a)

As shown in fig (a), consider a current carrying wire xy. A current element $\vec{dl}$ of a conductor xy carrying current I.
Let P be the point where the magnetic field $\vec{dB}$ due to the current element $\vec{dl}$ is to be Calculated.
Let the position vector of point P relative to element $\vec{dl}$ be $\vec{r}$.
Let θ be the angle between $\vec{dl}$ and $\vec{r}$.
Now, Acc. to Biot Savart law, the magnitude of the field $|\vec{dB}|$ is

1. directly proportional to the current I through the conductor. $|dB| \propto I$ — (1)
2. directly proportional to the length dl of the current element, $dB \propto dl$ — (2)
3. directly proportional to angle $\sin\theta$.
$dB \propto \sin\theta$ — (3)

4. Inversly proportional to the Square of the distance 'r' of the point 'P' from the current element. $dB \propto \frac{1}{r^2}$ —— (4)

Then, from eq^n (1),(2),(3) & (4)

$$dB \propto \frac{I\,dl\,\sin\theta}{r^2}$$

or

$$dB = \frac{K\,I\,dl\,\sin\theta}{r^2}$$

The proportionality Constant K depends on the medium between the observation point P and the current element.

Here, $K = \frac{\mu_0}{4\pi} = 10^{-7}\ T.m.A^{-1}$ (or $wbm^{-1}A^{-1}$)

In vector form →

As we know that $\hat{r} = \frac{r}{|r|}$

So, $$dB = \frac{\mu_0}{4\pi}\frac{I\,r\,dl\,\sin\theta}{r^3}\hat{r}.$$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,r\,dl\,\sin\theta}{r^3}$$

$$\vec{dB} = \frac{\mu_0 I}{4\pi}\frac{\vec{dl}\times\vec{r}}{r^3}$$

There are Some special cases →

(i) when, $\theta = 90°$

So, $$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin 90}{r^2}$$ [$\sin 90° = 1$]

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

In this case dB is max.

It means the magnetic field due to a current element is maximum in a plane passing through the element and perpendicular to its axis.

(2). When, $\theta = 0^\circ$

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \sin 0}{r^2}$$

$$\sin 0 = 0$$

$$dB = 0$$

i.e., the magnetic field is 0 at points on the axis of the current element.

(3) when, $\theta = 180^\circ$

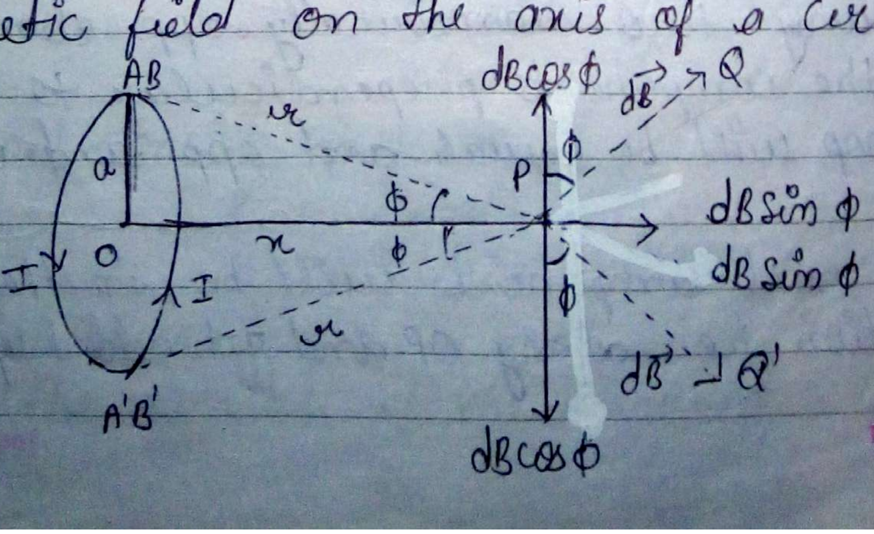
$$\sin 180^\circ = -1$$

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl \sin 180}{r^2} \rightarrow dB = \frac{\mu_0}{4\pi} \frac{I\, dl (-1)}{r^2}$$

$$\rightarrow d\vec{B} = -\frac{\mu_0}{4\pi} \frac{I\, dl}{r^2}$$

It means dB is minimum, It means the magnetic field due to a current element is minimum in a plane passing through the element and perpendicular to its axis.

Magnetic field on the axis of a circular loop -



Consider a circular loop of wire of radius a and carrying current I, as shown in digram. Let the plane of the loop be perpendicular to the plane of the paper.
We wish to find field $\vec{B}$ at an axial point P at a x distance from the centre O.
Consider a current element $d\vec{l}$ at the top of the loop. It has an outward coming current.
If $\vec{r}$ be the position vector of point P relative to the element $d\vec{l}$, then from Biot-Savart law, the field at point P due to the current element is

$$dB = kI \frac{dl \sin\theta}{r^2}$$

Since $d\vec{l} \perp \vec{r}$, i.e., $\theta = 90°$, therefore

$$dB = \frac{\mu_0}{4\pi} \frac{I\, dl}{r^2}$$

The field $d\vec{B}$ lies in the plane of paper and is perpendicular $\vec{r}$, ... angle between OP and CP. Then dB can be resolved into two rectangular components—

1. $dB \sin\phi$ along the axis
2. $dB \cos\phi$ ... to the axis.

For any two diametrically opp. elements of the loop, the components perpendicular to the axis of the loop will be equal and opp. and will cancel out.
Their axial components will be in the same direction, i.e., along OP and get added up.

∴ Total magnetic field at the point P in the dir^n OP is,

$$B = \int dB \sin\phi$$

But $\sin\phi = \frac{a}{r}$ and $dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{r^2}$

Since $\frac{\mu_0}{4\pi}$ and I are constant, and r and a are same for all points on the circular loop, we have

$$B = \int \frac{\mu_0}{4\pi} \frac{I\,dl\,a}{r^3}$$

$$B = \frac{\mu_0}{4\pi} \frac{I a}{r^3} \int dl$$

$$B = \frac{\mu_0 \times I a}{\cancel{4\pi}_{2}\, r^3} \times \cancel{2\pi} a \quad [\because dl = \text{circumference} = 2\pi a]$$

$$B = \frac{\mu_0 I a^2}{2 r^3}$$

By pythagores theorem —

$$r = (a^2 + x^2)^{1/2}$$

$$B = \frac{\mu_0 I a^2}{2\,[a^2 + x^2]^{3/2}}$$

As the dir^n of the field is along +ve x-dir^n, so we can write,

$$\vec{B} = \frac{\mu_0 I a^2}{2(x^2 + a^2)^{3/2}} \hat{i}$$

If coil consists of N no. of turns,

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

→ Special Cases —

(i) At the centre of the current loop,

$r=0$, therefore,

$$B = \frac{\mu_0 N I a^2}{2a^3} = \frac{\mu_0 N I}{2a}$$

2. At the axial points lying far away from the coil, $r >> a$, so that

$$B = \frac{\mu_0 N I a^2}{2r^3}$$

3. At an axial point at a distance equal to the radius of the coil i.e., $r = a$, we have

$$B = \frac{\mu_0 N I a^2}{2(a^2+a^2)^{3/2}} = \frac{\mu_0 N I}{2^{5/2} a}$$

✱ Ampere's circuital law –

Ampere's circuital law states that the line integral of the magnetic field $\vec{B}$ around any closed circuit is equal to μ_0 (permeability constant) times the total current I threading or passing through this closed circuit.

Mathematically,

$$\oint B \cdot dl = \mu_0 I$$

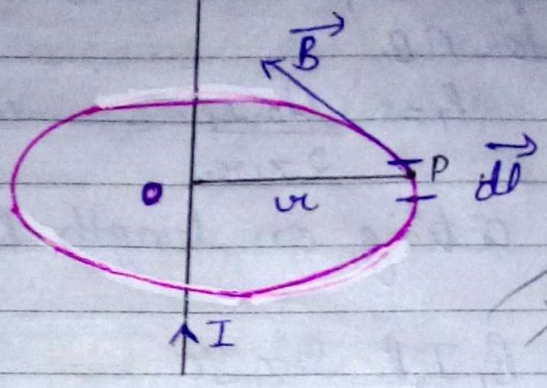
✱ Application of Ampere's law to a straight conductor →

circular loop of a radius r around an infinitely long straight wire carrying current. Draw a perpendicular on straight wire OP. Consider a circular path of radius r.

~~Ac~~.

Teacher's Signature

$r = 10 \times 10^{-2}$
$T = 3 \times 10^{-3}$
$n = 100$



$$\frac{\cancel{4\pi} \times 10^{-7} \times 100 \times 3 \times 10^{-3}}{2 \times \cancel{\pi} \times 10 \times 10^{-2}}$$

$10^{2} \times 10^{-7} \times 10^{2} \times 10^{-3} \times 3$

$10^{-3} \times 10 \times 3$

3

According to Ampere's law.

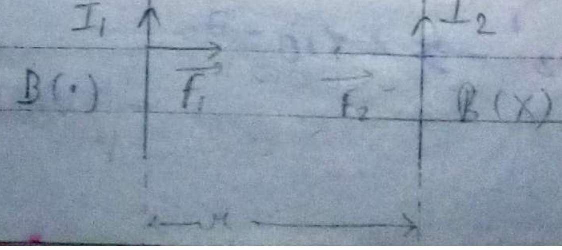
$$\oint B \cdot dl = \mu_0 I$$
$$\oint B\,dl \boxed{\cos 0^\circ} = \mu_0 I$$
$$\oint B\,dl = \mu_0 I$$
$$B \oint dl = \mu_0 I$$
$$B\,2\pi r = \mu_0 I$$
$$B = \frac{\mu_0 I}{2\pi r}$$

Both $\vec{B}$ and $\vec{dl}$ are tangential to the circle so the angle b/w them is zero.

- As the field lines are circular, the field $\vec{B}$ at any point of loop is directed along the tangent to the circle at the point.

Forces: between two parallel current carrying conductor —

- As shown in fig. consider two long parallel wires AB and CD carrying currents I_1 and I_2. Let r be the seperation between them,



Magnetic field produce on conductor CD due to conductor AB.

$$B_1 = \frac{\mu_0 I_1}{2\pi r} \longleftarrow (1)$$

The force acting on length l of the wire CD will be,

$$F_2 = B_1 I_2 l \sin 90$$

$$F_2 = B_1 I_2 l \text{ ——— (ii)}$$

from eq^n (i) & (ii)

$$F_2 = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$

Force applied on per unit length of Conductor CD.

$$F_2' = \frac{F_2}{l} = \frac{\mu_0 I_1 I_2 \cancel{l}}{\cancel{l}\, 2\pi r} = \frac{\mu_0 I_1 I_2}{2\pi r} \text{ —(iii)}$$

Similarly, force applied on per unit length of conductor AB.

$$F_1' = \frac{F_1}{l} = \frac{\mu_0 I_1 I_2}{2\pi r} \text{ —(iv)}$$

from eq^n (iii) & (iv)

$$F_1' = F_2' = \frac{\mu_0 I_1 I_2}{2\pi r}$$

If, $I_1 = I_2 = 1$ Amp and $r = 1m$

Then,

$$F_1' = F_2' = \frac{\mu_0}{2\pi}$$

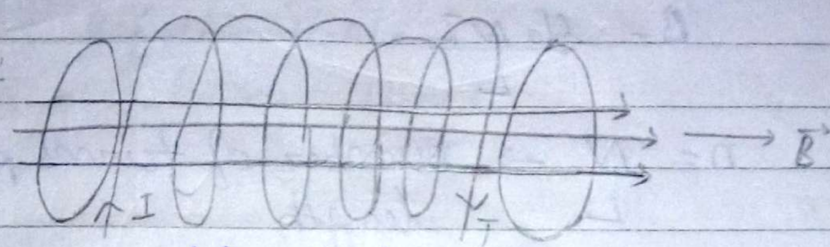
$$F_1' = F_2' = \frac{{}^{2}\cancel{4}\pi \times 10^{-7}}{\cancel{2}\pi}$$

$$F_1' = F_2' \rightarrow 2 \times 10^{-7}$$

Teacher's Signature

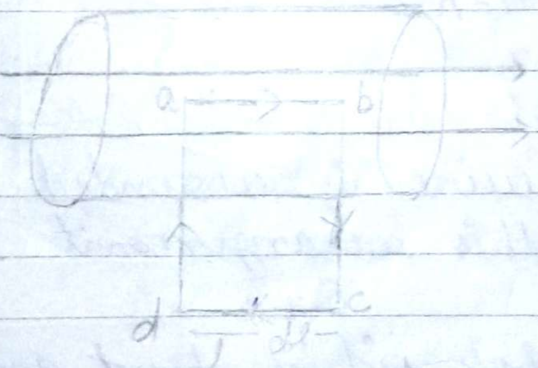
Magnetic field in a Solenoid

A solenoid means an insulated copper wire wound closely in the form of a helix.



The magnetic field inside a closely wound long Solenoid is uniform everywhere and zero outside it.

To determine the magnetic field $\vec{B}$ at any inside point, consider a rectangular closed path abcd as the Amperean loop.



Ampere loop for closed loop abcd

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \Sigma I$$

$$\oint_{ab} \vec{B} \cdot \vec{dl} + \oint_{bc} \vec{B} \cdot \vec{dl} + \oint_{cd} \vec{B} \cdot \vec{dl} + \oint_{da} \vec{B} \cdot \vec{dl} = \mu_0 N I$$

N → Number of turns

outside the solenoid

$$\oint_{ab} B\,dl \cos 0^\circ + \oint_{bc} B\,dl \cos 90^\circ + 0 + \oint_{da} B\,dl \cos 90^\circ$$

$$= \mu_0 N I$$

Teacher's Signature

$$\oint_{ab} B\,dl + 0 + 0 + 0 = \mu_0 N I$$

$$B \int dl = \mu_0 N I$$

$$B L = \mu_0 N I$$

$$B = \frac{\mu_0 N I}{L}$$

$n = \frac{N}{L} \rightarrow$ number of turns per unit length

$$B = \mu_0 n I$$

So, Magnetic field for a solenoid is $B = \mu_0 n I$

If magnetising field is H,

$$B = \mu_0 H$$

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

$$H = n I$$

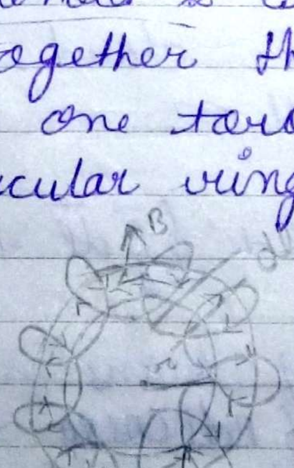
* Magnetic field in a toroid —

• If copper wire is wounded over a circular ring then this arrangement is called toroid.

Or

If a long solenoid is bend and its both ends made joint together then it is called toroid.

In the figure one toroid is shown which is made by a circular ring of radius r.



According to Ampere's law →

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \Sigma I$$

$$\oint B\,dl \cos 0^\circ = \mu_0 N I$$

N is number of turns

$$B \oint dl = \mu_0 N I$$

$$B\, 2\pi r = \mu_0 N I$$

$$B = \frac{\mu_0 N I}{2\pi r}$$

$\frac{N}{2\pi r} = n$ → no. of turns per unit length

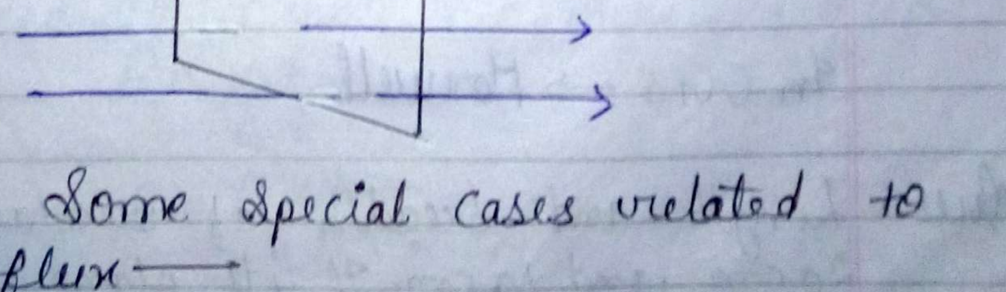
$$B = \mu_0 n I$$

Magnetic flux →

- Number of magnetic field lines passing through a surface area placed normal to the magnetic field is known as magnetic flux
- Denoted by ϕ.
- It can also be defined as the Scalar product of magnetic field $\vec{B}$ and area vector $\vec{A}$.

$$\phi = \vec{B} \cdot \vec{A}$$

$$\phi = BA \cos\theta$$



* There are some special cases related to magnetic flux →

(1.) Case I →

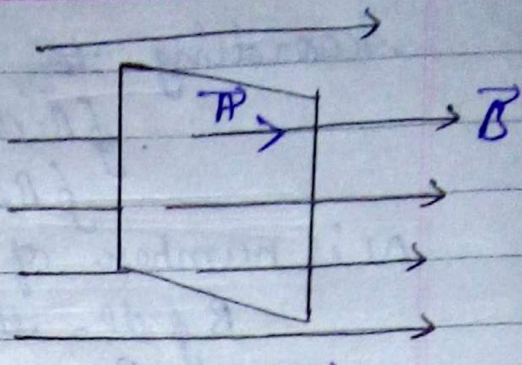
If $\theta = 0°$

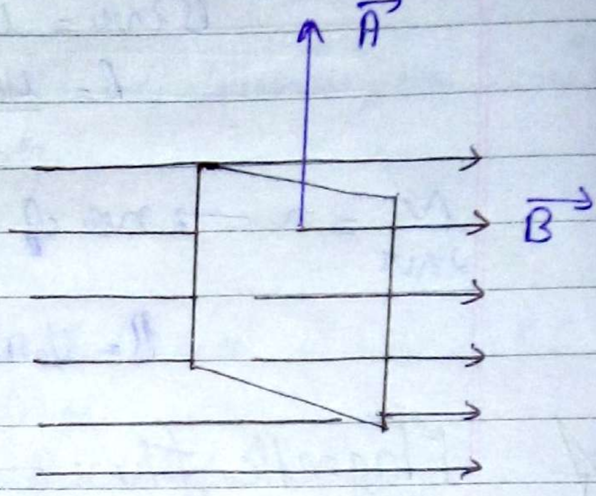
Then from eq^n (A)

$$\phi = BA\cos\theta$$

$$\phi = BA\cos 0°$$

$$\phi = BA_{max}$$





If, $\theta = 90°$

Then, from eq^n (A)

$$\phi = BA\cos\theta$$

$$\phi = BA\cos 90°$$

$$\phi = 0_{min}$$

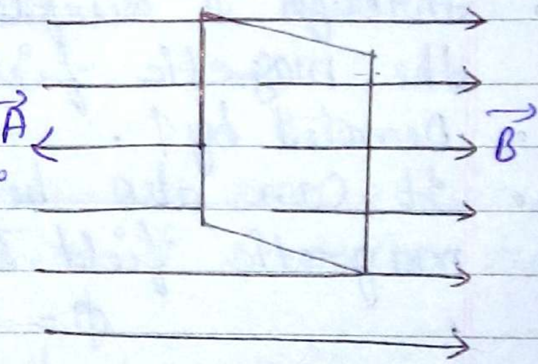
If $\theta = 180°$

Then, from eq^n (A)

$$\phi = BA\cos\theta$$

$$\phi = BA\cos 180°$$

$$\phi = -BA$$



Unit of magnetic flux —

In MKS → $\phi = B.A$

$$\phi = \frac{\text{Weber}}{\cancel{m^2}} \times \cancel{m^2} = \text{Weber}$$

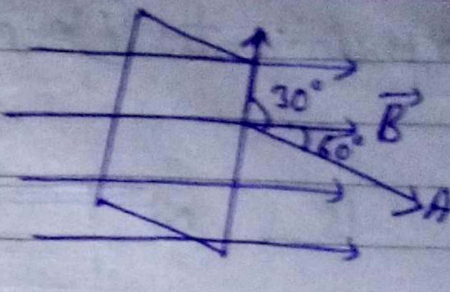
In CGS → Maxwell

Ques → Length and breadth of rectangular coil are 20 cm and 10 cm. If its plane makes an angle of 30° to the dir^n of magnetic field 0.3 T. Calculate the magnetic flux.

Teacher's Signature

Sol^n → Acc. to Question →

$\theta = 60^\circ$



$\phi = BA\cos\theta$

$\phi = 3\times10^{-1} \times 2\times10^{-2} \times \frac{1}{2}$

$\phi = 3\times10^{-3}$ wb Ans

Faraday's Law:—

(1) first law of faraday →

- According to this law " when there is change in magnetic flux linked with any coil EMF and current are induced in the coil." The EMF is induced upto the direction the flux is changes.

" Or "

- The magnetic flux changes with time in a circuit it produced an electromotive force (EMF).

(2) Second law of Faraday —

"According to this rule the induced EMF in the coil is proportional to the rate of change in flux." If change in magnetic flux in Δt time is $\Delta\phi$ then induced EMF $\propto$ rate of change in flux.

$$E \propto \frac{\Delta\phi}{\Delta t}$$

$$E = K\frac{\Delta\phi}{\Delta t}$$

" Or "

The induced EMF is equal to the rate of change of magnetic flux. $E = \frac{d\phi}{dt}$ or $-\frac{d\phi}{dt}$

✱ Faraday's Experiments —

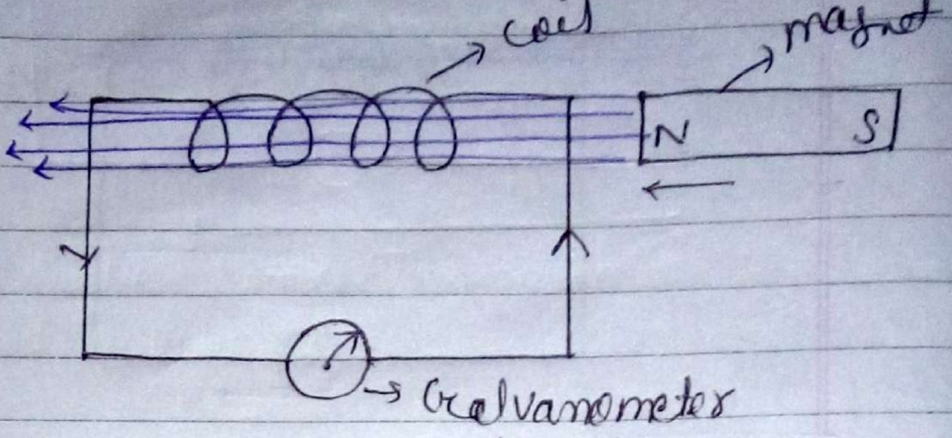


fig → Magnet is moving towards coil

(i) When the North pole of a strong bar magnet is moved towards the coil, then the deflection in galvanometer is towards right side.

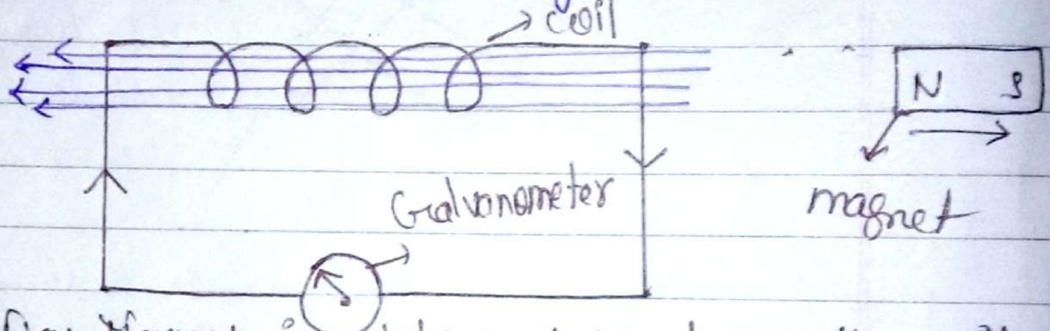


fig: Magnet is taken away from the coil

(ii) When the N-pole of the bar magnet in moved away from the coil, then the deflection in galvanometer is in opposite direction.

(iii) If the above experiments are repeated by bring-ing the S-pole of the magnet towards or away from the coil, then the direction of current in the coil is opposite to that obtained in the case of N-pole.

(iv) When the magnet is held stationary anywhere near or outside the coil, the galvanometer does not show any deflection.

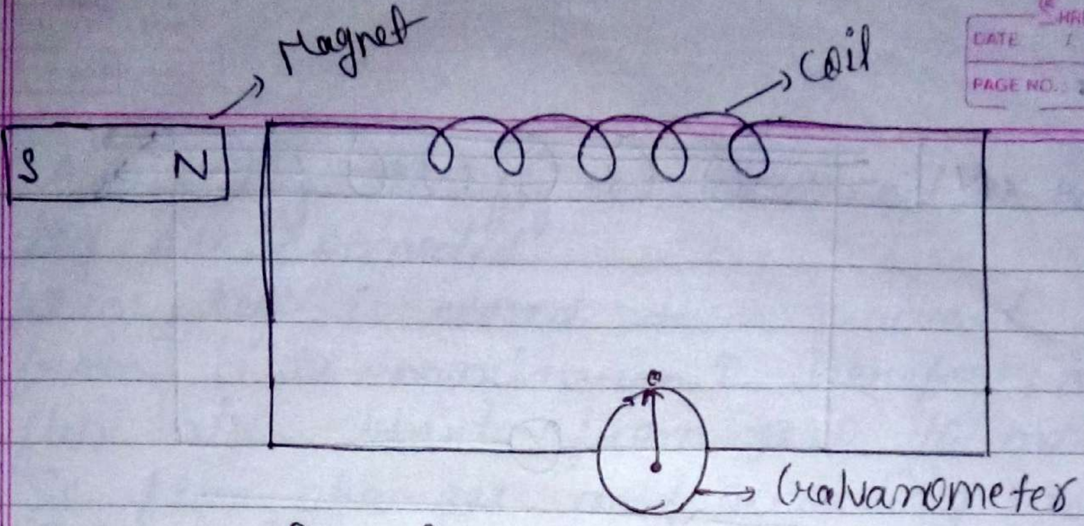


fig → Stationary position of magnet

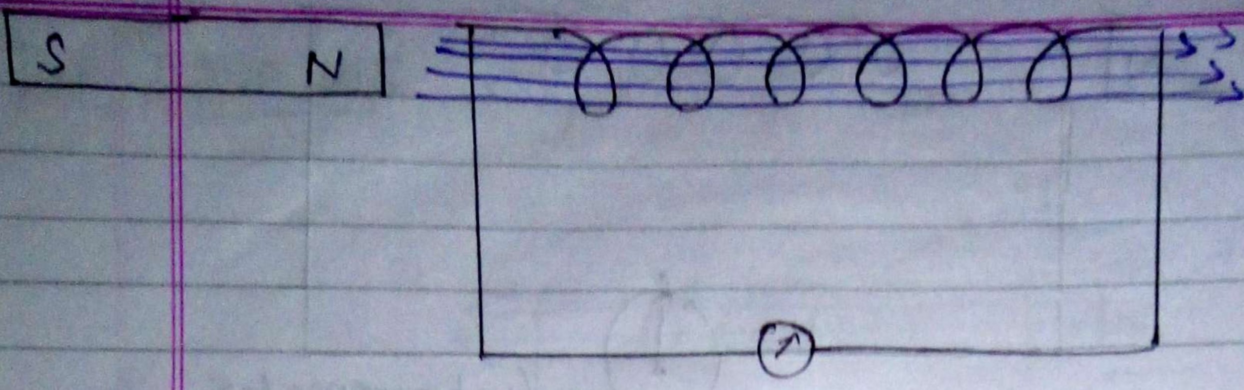
Explanation → When a bar magnet is placed near a coil, a number of lines of force pass through it.

- As the magnet is move closer to the coil, the magnetic flux (the total number of line of force) linked with coil increases, then the induced current is set up in the coil in one direction.
- As the magnet is move away from the coil, the magnetic flux linked with the coil decreases, an induced EMF & an induced current is set up in the coil in opposite direction.
- When the relative motion in coil and magnet is stop, the magnetic flux linked with the coil stops therefore the induced current through the coil is 0.

(b) Induced EMF with the stationary magnet and moving coil →

- Now, in this condition, when the relative motion between the coil and magnet is fast, the deflection in the galvanometer is large and when the relative motion is slow, the galvanometer deflection is small.

Teacher's Signature



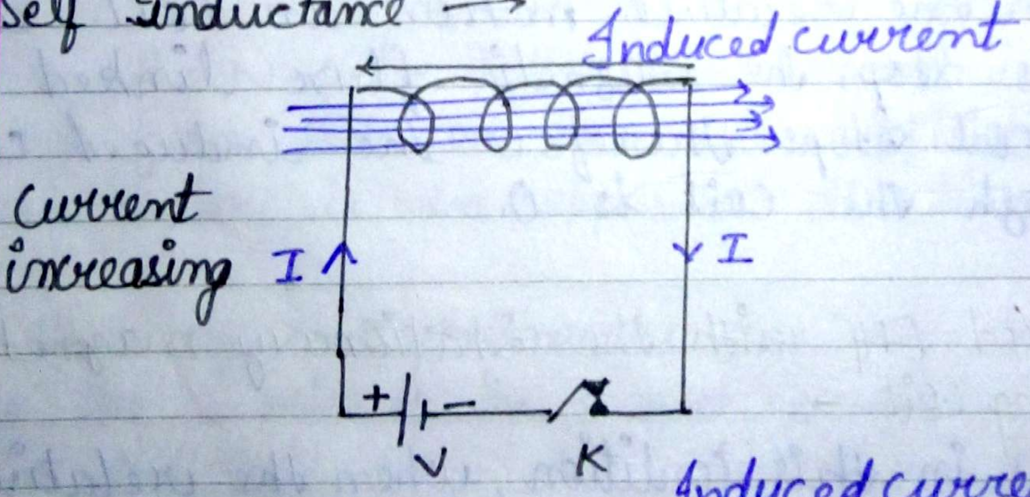
Electromagnetic induction with a stationary magnet and moving coil

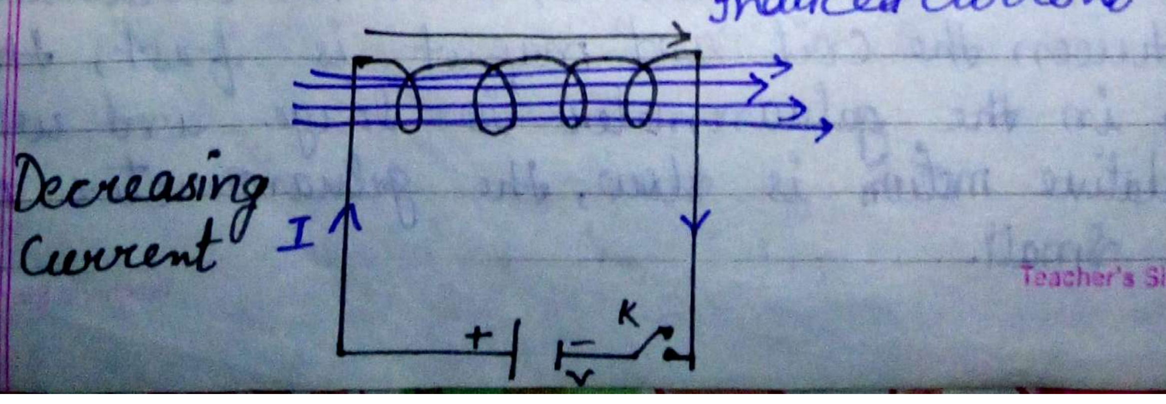
✱ Lenz's Law →

Acc. to this rule → In each case of electromagnetic induction, the direction of induced EMF and induced current as such that they always oppose the reasons behind their origin.

$$E = -\frac{d\phi}{dt}$$

✱ Self Inductance →





- According to fig (a), in a coil a battery and key are connected.
- When key is closed then current starts from 0 to maximum ↑. Therefore, magnetic flux also starts from zero to maximum.
- So, flux changes and according to Faraday's law EMF is induced in the coil.
- When key is opened then current and hence flux changes from maximum to 0 and once again EMF is induced but in opp. dir?
- Self inductance →
- Phenomenon of arising induced EMF or induced current in the same coil in which flux changes (increase or decrease) is called Self inductance.

Coefficient of Self induction L.
Magnetic flux in the coil is directly to induced EMF.

$$\phi \propto I$$

$$\phi = LI \quad \text{---(1)}$$

from eq^n (1),

$$\boxed{L = \frac{\phi}{I}} \quad \text{---(2)}$$

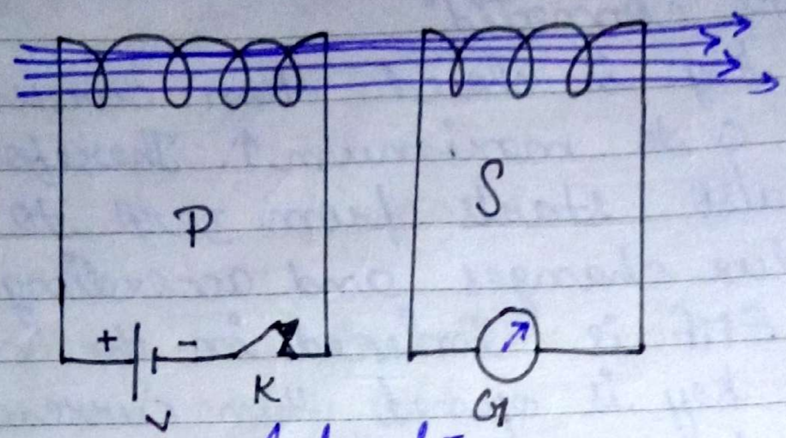
If, in eq^n (2) I = 1 Ampere, then we will find that

$$\boxed{\phi = L}$$

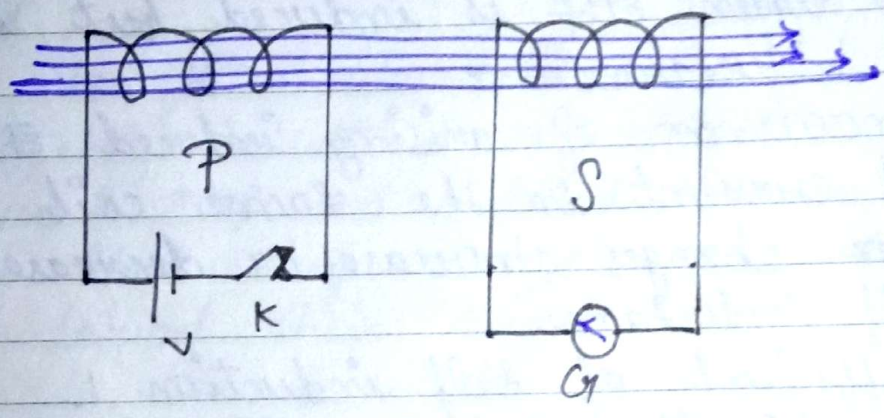
is such that
they always
oppose
the

Teacher's Signature

Mutual Induction →



Induced I →



- As shown in fig. there are two coils.
- A cell and key is connected between the ends of the primary coil and a galvanometer is connected between the ends of the secondary coil.
- When key K is closed then magnitude of current get increased from 0 to maximum
- Then flux associated with primary and secondary coil is ~~produced~~ changed & induced current EMF developed in the secondary coil.
- When key is open then magnitude of current get decreases from maximum to 0.

- Induced current flow in secondary coil but in opposite direction from.

Mutual Induction The phenomenon of arising induced current in a coil due to change in current in a ~~m~~ nearby coil is called Mutual induction.

- flux associated with secondary coil ϕ_2 is directly $\propto$ to current P coil I_1.

$$\phi_2 \propto I_1$$

$$\boxed{\phi_2 = MI_1} \text{ — (A)}$$

- Here M is a constant and known as mutual constant.

from eq^n (A) $\rightarrow$ $M = \dfrac{\phi_2}{I_1}$

Let, $I_1 = 1$ Ampere, so, $M = \phi_2$

Types of Magnetic property of Material $\rightarrow$

There are three types of Magnetic property of Materials

- Diamagnetic Substances
- Paramagnetic Substances
- ferromagnetic Substances

S.No.	Property	Diamagnetic Substances	Paramagnetic Substances	Ferromagnetic Sub.
1.	Effects of magnets →	They are feebly repelled by magnets.	They are feebly attracted by magnets.	They are strongly attraced by magnets.
2.	In External magnetic field →	Acquire feeble magnetisation in opposite direction of the magnetising field.	Acquire feeble magnetisation in the direction of the magnetising field.	Acquire strong magnetisation in the direction of the magnetising field.
3.	In a non-uniform magnetic field →	Tend to move slowly from stronger to weaker parts of the field.	Tend to move slowly from weaker to stronger parts of the field.	Tend to move quickly from weaker to stronger parts of the field.
4.	In a uniform magnetic field →	A freely suspended diamagnetic rod aligns itself perpendicular to the field	A freely suspended paramagnetic rod aligns itself parallel to the field.	A freely suspended ferromagnetic rod aligns itself parallel to the field.
5.	Susceptibility (χ_m)	Susceptibility is small and negative $-1 \le \chi_m < 0$	Susceptibility is small and +ve, $0 < \chi_m < \varepsilon$, where ε is small number	Susceptibility is very large and positive. $\chi_m > 1000$
6.	Permeability value (μ) →	$\mu < \mu_0$	$\mu > \mu_0$	$\mu >> \mu_0$
7.	Relative Permeability value (μ_r)	slightly less than 1. $0 \le \mu_r < 1$	Slightly greater than 1 $1 < \mu_r < 1 + \varepsilon$	of the order of thousands $\mu_r > 1000$
8.	Effect of temperature	Susceptibility is independent of temperature.	Susceptibility varies inversely as temperature : $\chi_m \propto \frac{1}{T}$.	Susceptibility decreases with temperature in a complex manner. $\chi_m \propto \frac{1}{T - T_C}$ $(T > T_C)$
9.	Removal of magnetising field →	Magnetisation lasts as long as the magnetising field is applied.	As soon as the magnetising ~~is lost~~ field is removed magnetisation is lost.	Magnetisation is retained even after the magnetisation field is removed.
10.	Variation of M with H. →	M changes linearly with H.	M changes linearly with H and attains saturation at low temperature and in very strong fields.	M changes with H non linearly and ultimately attains saturation.
11.	Hysteresis effect →	B-vector shows no hysteresis.	B-vector shows hysteresis	B-vector shows hysteresis.
12.	Physical state of material	Solid, liquid or gas.	Solid liquid or gas.	Normally solids only.
13.	Examples	Bi, Cu, Pb, Si, N_2 (at STP), H_2O, NaCl	Al, Na, Ca, O_2 (At STP), $CuCl_2$	Fe, Ni, Co, Gd, Fe_2O_3, Alnico.

Scanned by CamScanner

Ques → Diff. betw. magnetic field and magnetising field? L.R. Circuit?

DATE / /
PAGE NO. 30

Intensity of Magnetisation →

- When a magnetic material is placed in a magnetising field, it gets magnetised. The magnetic moment developed per unit volume of a material when placed in a magnetising field is called intensity of magnetisation or simply magnetisation.

$$I = \frac{M}{V}$$ → magnetic moment

Magnetising field →

If B_0 is magnetic induction in vaccum and μ_0 is magnetic permeability of vaccum then the ratio of B_0 to μ_0 is known as magnetising field.

magnetising field ← $\boxed{\vec{H} = \frac{\vec{B_0}}{\mu_0}}$

Magnetic Susceptibility →

- Magnetic susceptibility measures the ability of a substance to take up magnetisation
- when placed in magnetic field.

"It is define as the ratio intensity of magnetisation M to the magnetising field intensity H. It is denoted by . Thus,

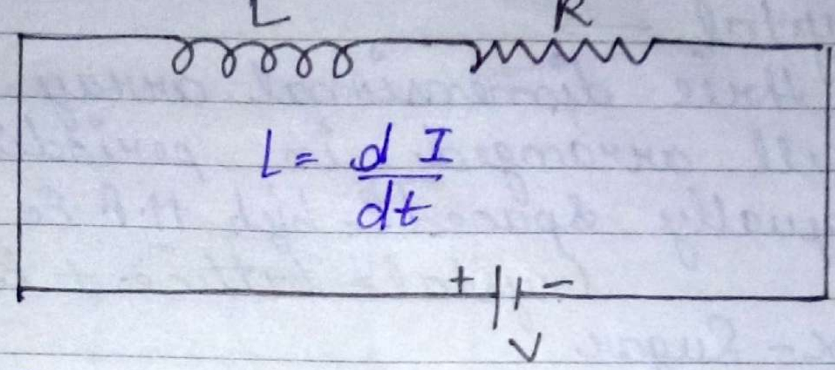
$$\boxed{\chi_m = \frac{M}{H}}$$ → intensity of magnetisation

χ_m → magnetic susceptibility

H → magnetising field intensity

Teacher's Signature

✱ LR-Circuit →



growth of current →
when K is closed –

$$E = L\frac{dI}{dt} + IR \quad —(1)$$

when $\frac{dI}{dt} = 0$, $I = I_0$

$$E = I_0 R \quad —(2)$$

$$(I_0 - I)R = L\frac{dI}{dt} \quad \Rightarrow \frac{R}{L}\int dt = \int \frac{dI}{(I_0 - I)}$$

$$\int \frac{dI}{(I_0 - I)} = \frac{R}{L}\int dt$$

$$\log_e (I_0 - I) = \frac{R}{L}t + c$$

At, $t = 0$ $\quad I = 0$

$$c = -\log_e I_0$$

$$I = I_0(1 - e^{R/Lt})$$

when $\frac{dI}{dt} = 0$, $I = I_0$

$$E = I_0 R \quad —(3)$$

$$(I_0 - I)R = L\frac{dI}{dt}$$