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CHAPTER = 6

Electolomagnetic Induction.

Magnetic flux - The number of magnetic lines of force passing normally throw any area In a mg. field is called magnetic flux. linked with that area. It is denoted by ϕ_B

$\phi_B = BA$ → (area)
(mg. field)

But they are inclined by an angle θ.

$\phi_B = BA\cos\theta$

In vector form. $\phi_B = \vec{B}.\vec{A}$

Cases (I)
If ~~theta~~ θ = 0°
$\phi_B = BA\cos 0$
$\phi_B = BA$ (maximum)

case (II)
If θ = 90°
$\phi_B = BA\cos 90°$
$\phi_B = 0$. (minum)

• **Unit of magnetic flux** - The S.I unit of magnetic flux weber
D.f = $(ML^2T^{-2}A^{-1})$

Faraday's law first law -
• when ever magnetic flux linked with a circuit changes induce EMF is Produce.
• The induce EMF lasts as long as the change in the magnetic flux change.
E.M.F (Electoro motive force)

Explination -
when a magnetic is brought near a coil then the flux linked with coil increase. ~~near~~ on the other hand when the magnetic is moved away from the coil then the flux of coil decrease. In both condition flux of coil changes due to it induced EMF Is setup and current flows throw the coil show the galvenometer ~~shows~~ shows deflection.

Faraday's second law - The magnitude of Induced EMF is directly proportional to the rate of change of magnetic flux linked with the circuit.

Explination - Let the flux linked with a coil change from ϕ_1 to ϕ_2 in t second.

rate of change of flux = $\frac{\phi_2 - \phi_1}{t}$

by Faraday's second law

$$e \propto \frac{\phi_2 - \phi_1}{t} = \frac{d\phi_B}{dt}$$

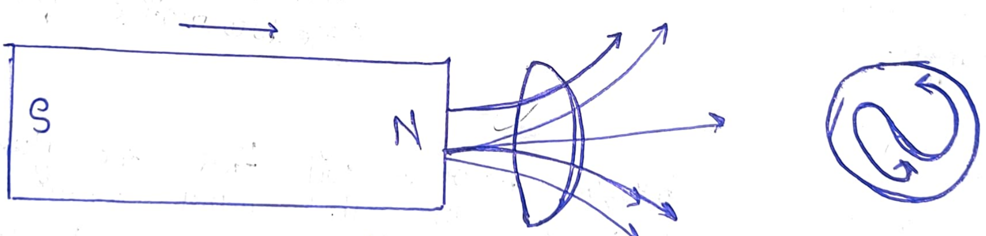
when the magnetic moves faster flux linked with coil changes rapidly in short interval of time. hence more induce EMF is created and hence more induce current so galvanometer gives ~~more~~ more deflection

• ~~Lenz's law~~ - The direction induced current is such that is opposes the change or the cause which produced it

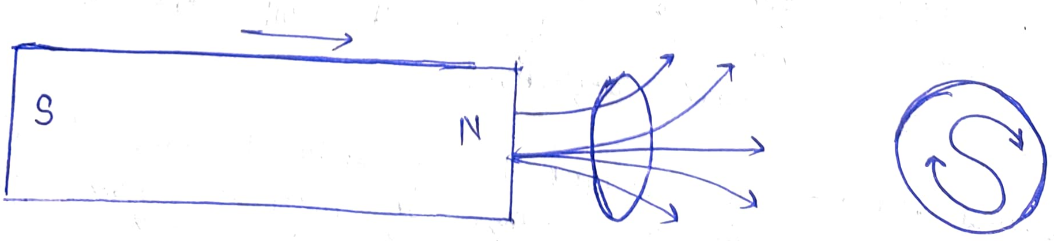
Explination -

when the North pole of a magnetic is moved towards the coil an Induced current is produced in the coil. ~~then the~~ then the direction of induce current will be such that it opposes the motion of N pole hence N pole is formed at the face of the coil thus the direction of current current will be anti clock wise

when the ~~on~~ N - pole moved away from the coil induce current is produce in the coil it opposes the cause there fore the face of the coil ~~S~~ S - pole is formed the direction of current will be clock wise.



(a)



(b)

Lenz's law is in accordance with law of conservation of Energy !

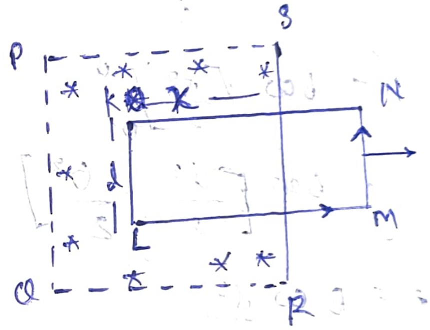
When N-Pole of a magnetic is moved towards the coil then magnetic become N-pole and force of repplsion acts between them so to bring the magnetic near to the coil more work has to done. against the repplison this mecinal energy changed into Electric energy show the galvanometer shows deflection.

When the N-pole is moved away from the coil. The coil becomes becomes S-Pole this will try to attract the magnetic the work is done against the force of attraction and the mecinal energy change into Electrical energy. There fore lenz's law is similar to law of conservation of energy.

• Motional Electro motive force - When a straight conducting rod is moved in a magnetic field then the magnetic flux of rod changes and some EMF will be induce a cross its and non as motional Electro motive force.

• Producting Induce emf due to linear motion.

Suppose a uniform mg. field $\vec{B}$ let rectingular loop of wire KLMN let KL = l let x is the portion of the loop in the field. at any strength where the loop moved with velocity v Induced EMF is setup in the wire this is shown by galvanometer.



Suppose in a small time dt the loop is moved by small distance ds

Initial area in the field $= lx$

final area in the field

$= l(x - dx)$

$= lx - ldx$

change in area

$= lx - ldx - lx$

$= lx - ldx - lx$

$= -ldx$

∴ Decreases in magnetic

$d\phi_B = B(-ldx)$

B is inducted emf

$e = \frac{d\phi_B}{dt}$

$e = \frac{-(-Bldx)}{dt}$

$= Bl\frac{dx}{dt}$

$\frac{dx}{dt} = v$

$e = Blv$

Induced current

$I = \frac{e}{R}$

$= \frac{Blv}{R}$

$F = IBl$

$= \frac{Blv \times lB}{R}$

$= \frac{B^2l^2v}{R}$

$P = Fv$

$P = \frac{B^2l^2v^2}{R}$

Electro motive force induced across the bar rotating in a Uniform magnetic field.

Suppose a rod op of length l is rotating in uniform magnetic field B angular velocity ω let us consider element of rod of length dr at distance r from o and rotating with speed v

the motional emf across the end of this Element.

$de = B dr v$

The induce emf across end of rod op

$$\int de = \int_0^l B v \, dr$$

$$e = \int_0^l B \omega r \, dr$$

$$= B\omega \int_0^l \frac{r \, dr}{l}$$

$$= B\omega \left[\frac{r^2}{2}\right]_0^l$$

$$= B\omega \left[\frac{l^2}{2} - \frac{0^2}{2}\right]$$

$$e = B\omega \frac{l^2}{2}$$

Induced current

$$I = \frac{e}{R}$$

$$I = \frac{B\omega \cdot l^2}{2R}$$

- Self indectant or ~~coficent~~ coefficient of self Induction -

(1) When current flows throw a coil than a magnetic field is produce is around it if the current increases then the magnetic field & intensity also increases thus the flux linked with the coil also increase.

Thus, the flux linked with a coil is proptional to the current flowing throw it.

$$= \phi_B \propto I$$

$$\phi_B = LI$$

Where, L is known as self induction or coefficient of self induction.

$$\phi = L$$

(2) If the magnitude flux changes the by law of the Electro magnetic Induction.

$$\mathcal{E} = -\frac{d(\phi_B)}{dt}$$

$\left[\frac{dI}{dt} \text{ chang in current}\right]$

$$\mathcal{E} = -\frac{d(LI)}{dt}$$

$$\mathcal{E} = -L\frac{dI}{dt}$$

If $\frac{dI}{dt} = 1$

S.I unit - Henry

D.F = $[ML^2 T^{-2} A^{-2}]$

$$\mathcal{E} = -L$$

• Self inductance of a long current carrying coil -

Consider a so solenoid of length l and cross sectional area A throw which current I is flowing let, n be the number of turns on unit length solenoid

The magnetic field inside the solenoide

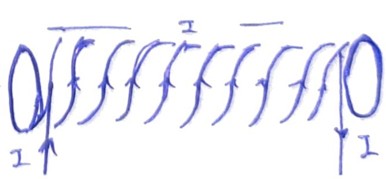
$$B = \mu_0 nI$$

$n = \frac{N}{l}$

$$\phi_B = NBA$$

$$\phi_B = nl\mu_0 nIA$$

$$\phi_B = LI$$



$$L = \frac{\phi_B}{I}$$

$$= \mu_0 n^2 l A \times \frac{l}{l}$$

$$= \frac{\mu_0 n^2 l^2 A}{l} = \frac{\mu_0 N^2 A}{l}$$

If the permeability of medium μ_r

$$L = \frac{\mu_0 \mu_r N^2 A}{l} \text{ Henry}$$

Factor affecting self inductance of solenoid -

- Cross sectional area of solenoid - self inductance of solenoid increases with area of cross section.
- Numbers of turns - Self inductance of a solenoid increases with no. of turns
- Length of a solenoid - self inductance of solenoid decreases on increasing the length of the solenoid.
- Relative permeability of the core - The self inductance of a solenoid increases on placing a core of higher permeability.

Self inductance of plane current carrying circular coil -

The mg. field at the center of current carrying circular coil of radius r, having N turns and carrying I, current is given by

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

$$\therefore \phi_B = B \cdot A$$

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

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

$$L = \frac{N \phi_B}{I}$$

$$= \frac{N}{I} \left(\frac{\mu_0 \pi N r}{2} I \right)$$

$$= \frac{\mu_0 \pi N^2 r}{2}$$

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

If Core of permeability μ.

$$L = \frac{\mu_0 \mu_r \pi N^2 r}{2}$$

$$= \frac{\mu \pi N^2 r}{2} \quad \text{Henry}$$

Energy Stored in a Inductant coil - Consider a circuit consulting of coil of self inductant L with a battery and key when but initialy circuit is closed a current setup in the coil the growth of the the self inductant of the coil appose the growth in increasing the current. thus some work has to be done in increasing the current from 0 to 2 its maximum value I_0 against the apposing induced emf. This work is done by the current It is stored in the form of magnetic field associated with coil.

if $= \frac{dI}{dt}$ be the broth of current according to faraday

$$\varepsilon = -L \frac{dI}{dt}$$

The amount of work done on it per unit time.

$$P = \frac{dw}{dt} \quad -(1)$$

$$P = \varepsilon I = -LI \frac{dI}{dt} \quad -(11)$$

$$\frac{dw}{dt} = \frac{-LI\, dI}{dt}$$

$$dw = -LI\, dI$$

Total work done on increasing the current from 0 to I_0 will be

$$W = \int dw$$

$$= \int_0^{I_0} LI\,dI$$

$$= L\int_I^{I_0} LI\,dI$$

$$= L\left[\frac{I^2}{2}\right]_0^{I_0}$$

$$= \frac{L I_0^2}{2}$$

★ Mutual Inductance or Cofficent of mutual Induction -

- first def - let I_p be the current flowing throw primary coil causes magnetic flux ϕ_s linked with secondary coil then $\phi_s \propto I_p$

$$\phi_s = M I_p$$

$$I_p = 1$$

then $\phi_s = M$

- Second def - when current flowing throw primary coil is change then induce emf is setup across the secondary coil. then by faraday law

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

$$e = -\frac{d(MI_p)}{dt}$$

$$= -M\frac{dI_p}{dt}$$

$$\frac{dI_p}{dt} = 1$$

$$e = +M$$

S.I unit - henry

D.F → $[ML^2T^{-2}A^{-2}]$

- **Mutual Inductance betw the two long solenoids -**

let S_1 and S_2 be to long solenoids S_1 is completely surronded by S_2 the length of both the solenoids are l and n_1 and n_2 are the no. of turns per unit length respectively

Case (I) If S_1 is taken s primary and S_2 as secondary solenoids.

magnetic field intensity inside the solenoids S_1

$$B_1 = \mu_0 n_1 I_1$$

Magnetic flux linked with S_2

$$= B_1 A$$

Magnetic flux linked with all turns of S_2

$$\phi_{21} = B_1 A n_2 l$$

$$\phi_{21} = \mu_0 n_1 I_1 A n_2 l$$

$$= \mu_0 n_1 n_2 I_1 A l$$

$$\phi_{21} = M_{21} I_1 \qquad \left[M_{21} = \frac{\phi_{21}}{I_1}\right]$$

$$M_{21} = \mu_0 n_1 n_2 A l$$

Case II - S_2 - Primary
S_1 → Secondry

$$B_2 = \mu_0 n_2 I_2$$

Flux linked with S_1

$$\phi_{12} = B_2 A$$

Flux linked with all turns of S_1

$$\phi_{12} = B_2 A n_1 l$$

$$= \mu_0 n_2 I_2 A n_1 l$$

$$\phi_{12} = M_{12} I_2$$

$$M_{12} = \frac{\phi_{12}}{I_{12}}$$

$$M_{12} = \mu_0 n_1 n_2 A l$$

$$M_{12} = M_{21}$$

For long solenoids

$$M = \mu_0 n_1 n_2 A l \qquad n_1 = \frac{N_1}{l}$$

$$= \mu_0 \frac{N_1}{l} \times \frac{N_2}{l} A l \qquad n_2 = \frac{N_2}{l}$$

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

If an iron core relative permiability μ_r

$$M = \frac{\mu_0 \mu_r N_1 N_2 A}{l}$$

$$M = \frac{\mu N_1 N_2 A}{l} \quad \text{Henry}$$

- mutual Inductance betw two plain circular coil.

Let P and S are two plain circular coils which are kept near each other the no. of turns in coil P are N_1 and its radious is r_1 the no. of turns in the coil S are N_2 and its radious is r_2

suppose. I current is flowing throw the primary coil P then the mg. field at it center

N = no. of turns

$$B = \frac{\mu_0 N_1 I}{2r_1}$$

magnetic flux with secondry coil S will be

$$\phi_B = N_2 B A_2$$

$$= \frac{N_2 \mu_0 N_1 I}{2 r_1} \times \pi r_2^2$$

$$M = \frac{\phi_B}{I_1}$$

$$M = \frac{\mu_0}{2} \frac{N_1 N_2}{r_1} \pi r_2^2$$

If permeability of coil is μ

$$M = \frac{\mu}{2} \frac{N_1 N_2}{r_1} \pi r_2^2$$

$$M = \frac{\mu_r \mu_0}{2} \frac{N_1 N_2}{r_1} \pi r_2^2 \quad \left[\mu_r = \frac{\mu}{\mu_0} \right]$$

Henry

• ~~factor~~ factor affecting the mutual inductance

(1) Permeability of material core μ = If a core is introduce whose permeability is high then the mutual inductance of coil increases..

(2) Number of turns in primary coil - If the no. of turns in the primary coil is increase then the mutual inductance of coils increases.

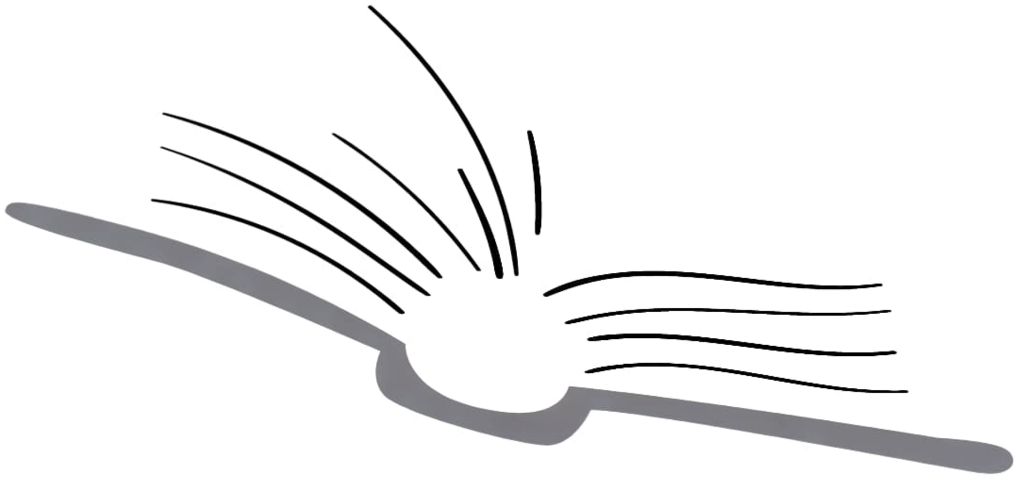
(5) No. of turns In secondary coil - If the no. of turns In the secondary coil is increase then mutual inductance of coil increases.

(4) Radious of primary coil - If the radious primary coil is small then the mutual inductance will be increase

(5) Radious of secoundary coil - with increase in the radious of secoundary coil the mutual inductance increases.

* Write difference betw self induction and mutual induction -

Self · induction	mutual induction.
when the current flowing throw a coil changes induce current is setup in the same coil.	when the current flowing throw a coil changes an induce current is setup in another coil.
one coil is required.	Two coil are required.
Induce current affect the main current.	Induce current does not affect the main current.
It is denoted by L	It is denoted by M



THANKYOU

FOR

READING