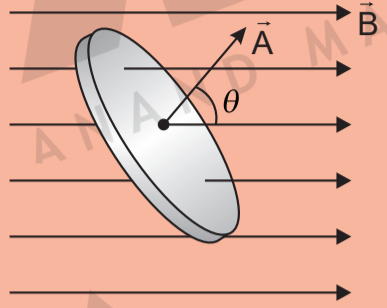# ELECTROMAGNETIC INDUCTION

MAGNETIC FLUX

It is defined as the number of magnetic field lines passing through a surface normally.

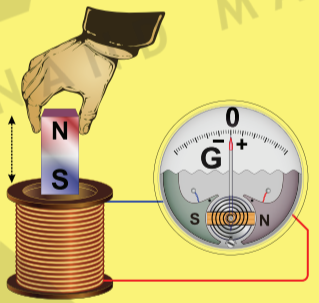$$\phi_B = \vec{B} \cdot \vec{A} = BA_{\cos\theta}$$

ELECTROMAGNETIC INDUCTION

It is phenomena of inducing an electric field or emf in a conductor by varying the magnetic field.
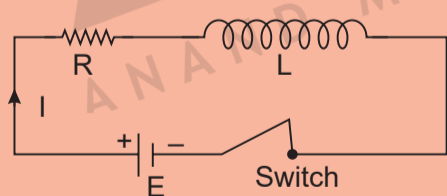
FARADAY'S LAW

This law states that magnitude of the induced emf in a circuit is equal to the rate of change in magnetic flux through a circuit.

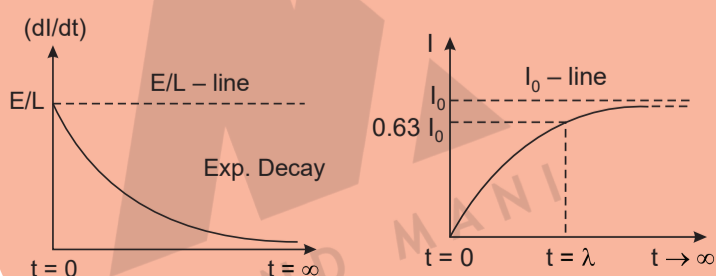$$\varepsilon = \frac{d\phi_b}{dt} = -\frac{d(BA_{\cos\theta})}{dt}$$

LENZ'S LAW

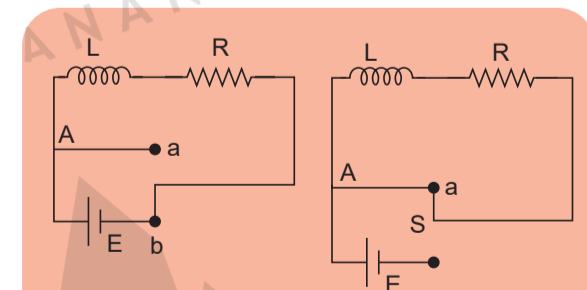This law states that polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.
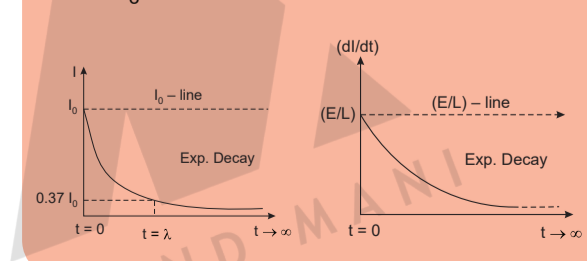

rest

rest
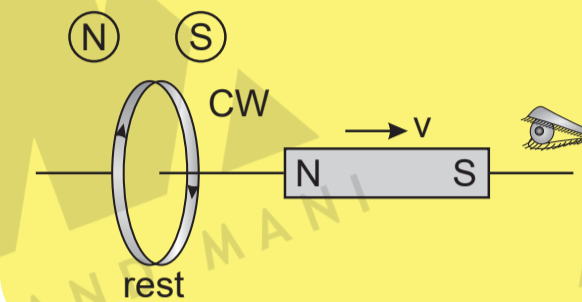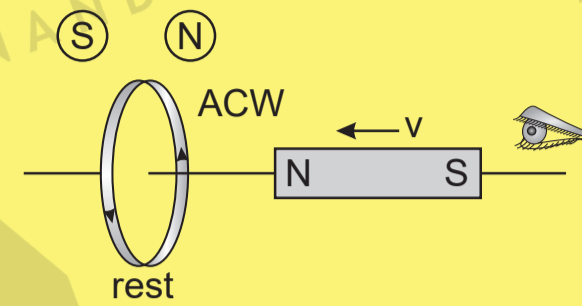
METHODS TO CHANGE IN MAGNETIC FLUX

- Magnetic flux can be increased by increasing the strength of magnetic field and vice – versa.

- The magnetic flux can be increased by increasing the area of coil and vice – versa.

- The magnetic flux can vary from maximum to minimum value for variation in θ.

- The magnetic flux can be increased by increasing the number of coils.

R – L DC CIRCUIT

CURRENT GROWTH

- $I = I_o (1 - e^{-1/z})$

- Decay constant $t = \dfrac{L}{R}$

CURRENT DECAY

- $I = I_o e^{-1/z}$

ENERGY STORED IN AN INDUCTOR COIL

- $U = \dfrac{1}{2} L I^2$

Induced current:

$$i = \frac{1}{R}\left(\frac{-d\phi_B}{dt}\right)$$

Induce charge:

$$q = \left(\frac{\Delta\phi_B}{R}\right)$$

MOTIONAL EMF

- When a conductor moves in a magnetic field it will experience a force and emf is induced in the coil. This emf is know as motional emf.

$$\varepsilon = \int_D^\alpha (\vec{dl} \times \vec{v}) \cdot \vec{B}$$

STRAIGHT CONDUCTOR IN $\vec{B}$

Induced emf, $\varepsilon = Bwl^2$

STRAIGHT CONDUCTOR ROTATING IN MAGNETIC FIELD

Induced emf, $\varepsilon = \dfrac{1}{2} Bwl^2$

COMBINATIONS OF INDUCTORS

- $L_s = L_1 + L_2$
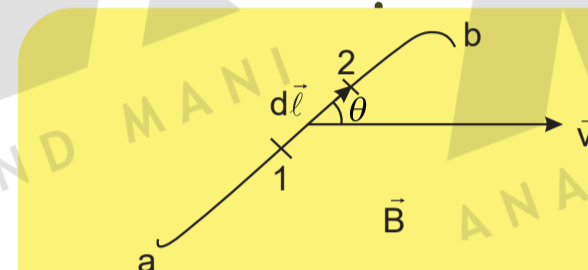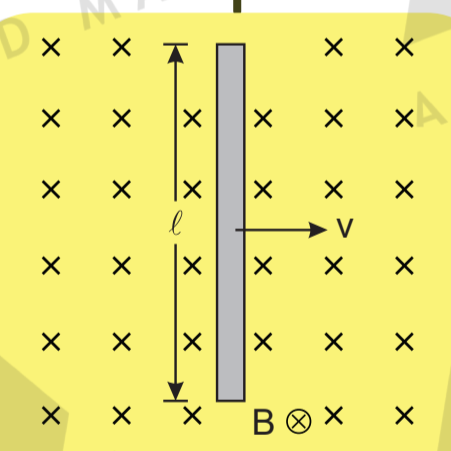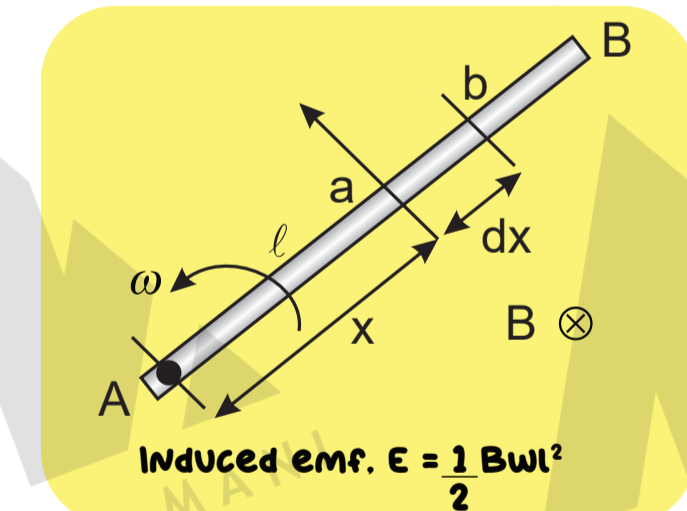

- $\dfrac{1}{L_p} = \dfrac{1}{L_1} + \dfrac{1}{L_2}$

SELF INDUCTANCE

- Inherent property which the change in current.

- Dimensional Formula: $[ML^2 T^{-2} A^{-2}]$

- SI unit: henry, Wb/A or S/A^2

- When current flowing in coil change with respect to time, then Self – inductance:

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

- When current flowing in coil is constant then Coefficient of Self – inductance:

$$L = \frac{\phi_{total}}{I}$$

SOLENOID

- $L = \dfrac{\mu_0 N^2 A}{l}$

A = Cross-Section Area
l = Length
N = No. of turns

MUTUAL INDUCTANCE

The phenomena in which emf is induced in a circuit due to change in magnetic flux in its neighbouring circuit is called Mutual Induction.

- When current in primary coil is constant, then coefficient of mutual inductance:

$$M = \frac{N_2 \phi_2}{I_1} = \frac{N_2 B_2 A_2}{I_1}$$

- When current in primary coil change with respect to time, then coefficient of mutual inductance: $M = \dfrac{-\varepsilon_2}{dI_1/dt}$

AC GENERATOR

- It works on the principle of EMI.

- Magnetic flux, $\phi_B = NBA_{\cos wt}$

- Induced emf $\varepsilon = -\dfrac{d\phi_B}{dt}$

$= NBA\omega \sin wt$

INDUCED ELECTRIC FIELD

When magnetic field in a region varies with time then an electric field will induce within and outside that region.
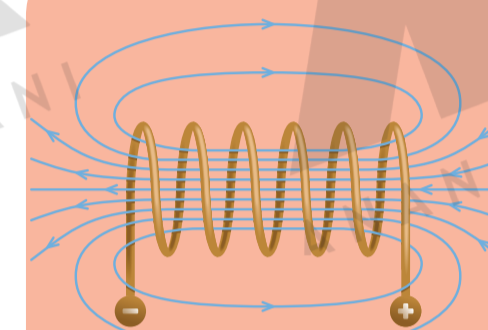
$$\oint \vec{E} \cdot \vec{dl} = \frac{-d\phi}{dt}$$

PROPERTIES

- Induced electric field is different from electric field produced due to stationary charges.

- Induced electric field lines always form closed curves.

- For induced electric field $\oint \vec{E} \cdot \vec{dl} \neq 0$ but for electrostatic field $\oint \vec{E} \cdot \vec{dl} = 0$ always.

- The direction of induced electric field will be same as direction of induced current.

Concentric circular field lines of $\vec{E}_{induce}$ (inside/outside)
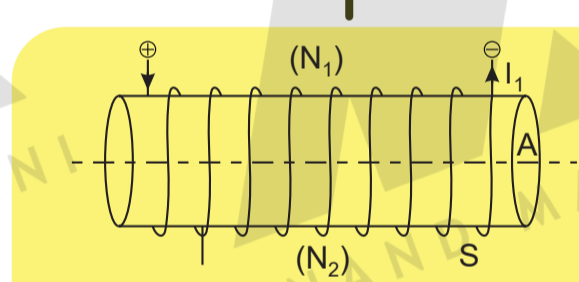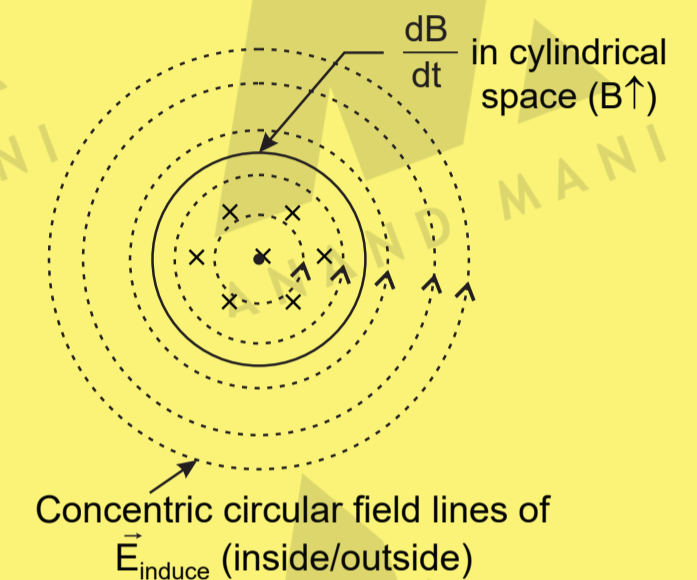
- When coils are Co – axial:
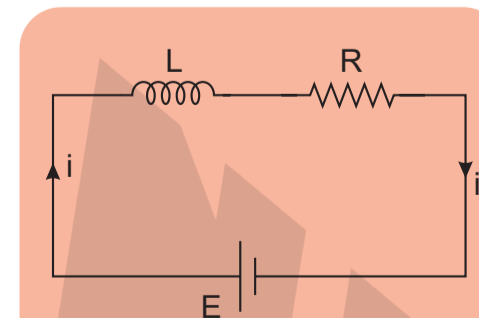
$$M_{12} = \frac{\mu_0 N_1 N_2 A}{l}$$
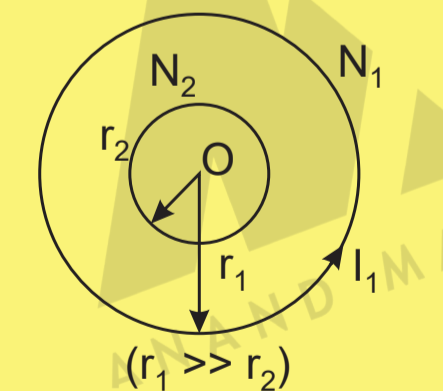
- When coils are concentric and coplanar:

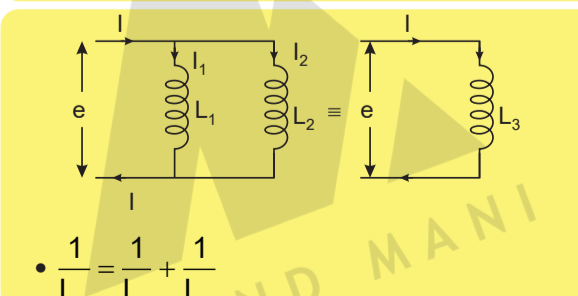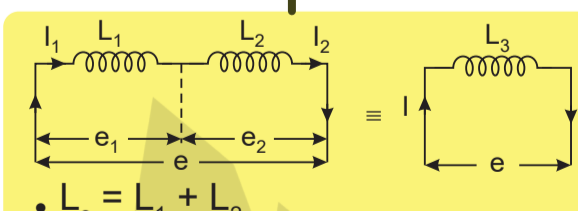$$M = \frac{\mu_0 N_1 N_2 \pi r^2{}_2}{2r}$$

EDDY CURRENT

The current induced in a conductor when placed in a changing magnetic flux is known as eddy currents.