ELECTRO MAGNETIC INDUCTION

* **Magnetic flux** (ϕ_B) ⇒ The number of magnetic field lines passing normally through a given area.

$$\phi_B = B \cdot A = BA\cos\theta$$

θ ⇒ angle between B and A.

B ⇒ Magnetic field

A ⇒ Area vector

* SI unit ⇒ Weber (Wb), scalar quantity

* Faraday's laws of Electromagnetic Induction

First law

- Whenever the amount of magnetic flux linked with a circuit changes, an EMF induced in the circuit. The induced emf lasts only as the change in magnetic flux continues.

Second law

- $$\epsilon = -\frac{d\phi_B}{dt}$$ ⇒ Rate of change of mag. flux

ϵ ⇒ induced emf

- For N turns in a coil;

$$\epsilon = -N\frac{d\phi_B}{dt}$$

* Lenz's law:— The direction of the induced emf or induced current is such that it opposes the cause producing it.

* If the mag. flux increases, the induced current creates a mag. field in the opposite direction to the original field. If mag. flux decreases, the induced current creates a mag. field in the same direction as the original field.

* Motional EMF :- The emf induced across a conductor moving in a uniform magnetic field.

$$F = q\,(v \times B)$$

↑ Force on charge q in the conductor.

$$E = vB$$ ← Electric field produced.

$$\mathcal{E} = EL = vBL$$ ← induced emf

$$\mathcal{E} = BLv\sin\theta$$

* Eddy currents :- circulating currents induced in the bulk piece of a conductor when the magnetic flux linked with it changes.

direction ⇒ follows Lenz's law, opposing the change in magnetic flux.

disadvantages ⇒ Energy loss, Damping

Applications ⇒ magnetic Braking, Electromag. damping, induction furnace.

* self induction :- The phenomenon of production of induced emf in a coil itself due to change in current flowing through it.

* Self inductance ⇒ (L)

$$\phi_B \propto I \Rightarrow \boxed{\phi_B = LI}$$

unit :- Henry (H)

induced emf due to self-Induction;

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

self inductance of a long solenoid;

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

n ⇒ no. of turns per unit length $\left(n = \frac{N}{l}\right)$

Energy stored in an Inductor;

$$U_B = \frac{1}{2} L I^2$$

* Mutual Induction :- The phenomenon of production of induced emf in a coil due to a change in current in a neighboring coil.

* Mutual inductance:—

$\phi_{B_2} \propto I_1 \Rightarrow \boxed{\phi_{B_2} = M I_1}$

$\phi_{B_1} \propto I_2 \Rightarrow \boxed{\phi_{B_1} = M I_2}$

unit ⇒ Henry.

$$\boxed{E_2 = -M \frac{dI_1}{dt}} \longrightarrow \text{Induced emf}$$

$$\boxed{M = \mu_0 n_1 n_2 A_1 l = \mu_0 \frac{N_1 N_2}{l} A_1} \leftarrow \text{Mutual inductance of two coaxial solenoids.}$$

Factors affecting Mutual inductance:—

- Geometry of coil
- Distance between the coil
- nature of the core material within the coils.