ELECTROMAGNETIC INDUCTION

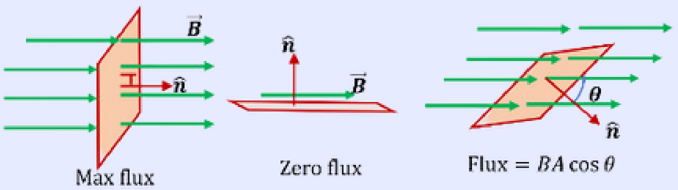
MAGNETIC FLUX:

Number of magnetic field lines passing through any surface, held perpendicular to the field lines, is called magnetic flux which is denoted by **ΦB.**
If **N** number of magnetic field lines pass through the surface of a loop at a certain **angle θ**, held in a perpendicular orientation with the field, then, the magnetic flux through the surface of the loop is:

ΦB = BA cosθ
For a coil of n loops,
ΦB = nBA cosθ

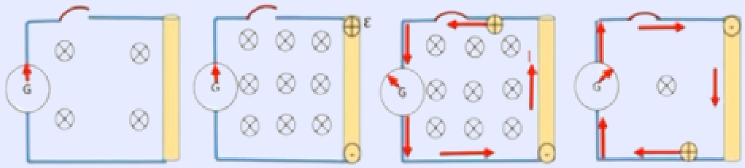
SI unit is Tm2 = Wb (Weber)
1Wb is the magnetic flux if one line of magnetic induction passes through any surface, held perpendicular to the field.

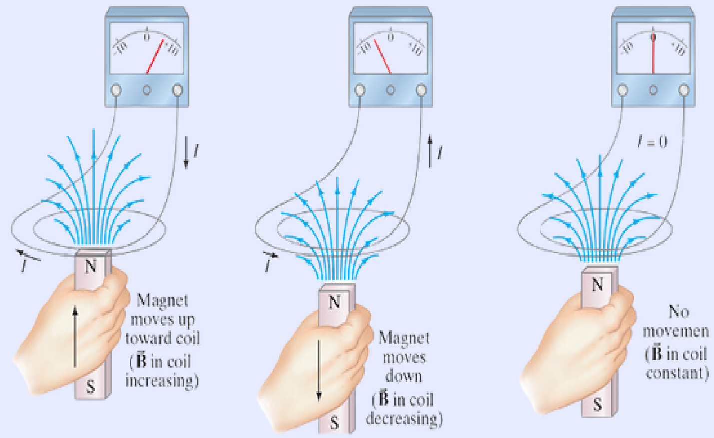
ΦB = max, θ = 0o or 180o, B II A
ΦB = min, θ = 90o, B ⊥ A



INDUCED E.M.F. AND INDUCED CURRENT:

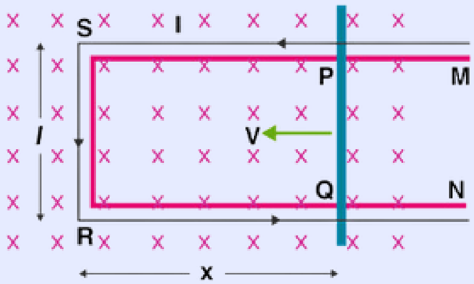
Michel Faraday and Joseph Henry investigated that changing magnetic flux through the surface of an open loop induces an e.m.f. across it, known as **induced e.m.f.** It is denoted by **E.**
When the loop is closed, the induced e.m.f. in it drives current in either a clockwise or anticlockwise direction. It can be determined by the **right hand grip rule** and is denoted by **I.**





DEPENDANCE OF INDUCED CURRENT IN A CLOSED LOOP:

Dependance of Induced current in a closed loop:
Induced current in a closed loop depends on: Angle between the velocity v and the magnetic field B Speed of loop v Number of loops N Area of loop A Magnetic induction B Resistance in loop R Induced e.m.f. across a loop is independent of its resistance



E = vBL sinθ
E = min, θ = 0o or 180o, B II A
E = max, θ = 90o, B ⊥ A

DEPENDANCE OF INDUCED CURRENT IN A CLOSED LOOP:

Induced current in a closed loop depends on:

1. Angle between the velocity v and the magnetic field **B**
2. Speed of loop **v**
3. Number of loops **N**
4. Area of loop **A**
5. Magnetic induction **B**
6. Resistance in loop **R**

Induced e.m.f. across a loop is independent of its resistance

ELECTROMAGNETIC INDUCTION

FARADAY'S LAW:

It states that average induced e.m.f in a coil of **N** loops is directly proportional to the negative rate of changing magnetic flux through it.

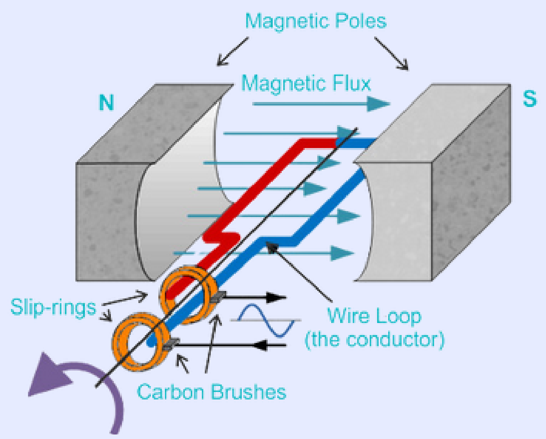
$$\varepsilon \propto -\frac{\Delta \Phi_B}{\Delta t}$$

$$\varepsilon = -N\frac{\Delta \Phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

$$\varepsilon = -N\frac{\Delta B}{\Delta t}A\cos\theta \qquad \varepsilon = -NB\frac{\Delta A}{\Delta t}\cos\theta \qquad \varepsilon = -NBA\frac{\Delta(\cos\theta)}{\Delta t}$$

A.C GENERATOR

A device that converts mechanical energy into electrical energy in A.C. form. It uses Faraday's Law of electromagnetic induction as its principle.
When the coil is rotated by the mechanical device (turbine or engine), magnetic flux changes instantly through it. The changing flux induces instantaneous e.m.f. at the terminals given by:



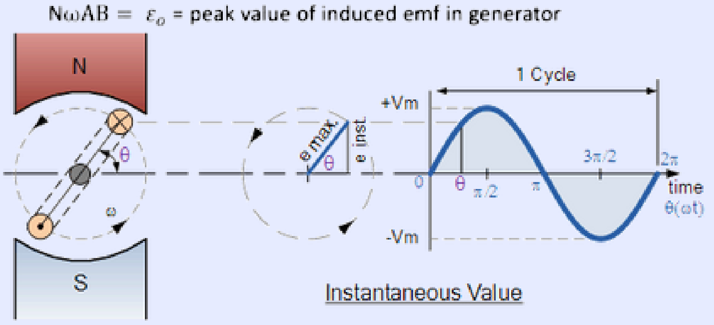
$$I = \frac{\varepsilon}{R} = I_o\sin(\omega t) = I_o\sin(\frac{2\pi}{T}t) = I_o\sin(2\pi f t)$$

θ = phase of A.C = Angle between v and B $= \omega t = \frac{2\pi}{T}t = 2\pi f t$

$$\varepsilon = \varepsilon_o \sin(\omega t) = \varepsilon_o \sin(\frac{2\pi}{T}t) = \varepsilon_o \sin 2\pi f t$$

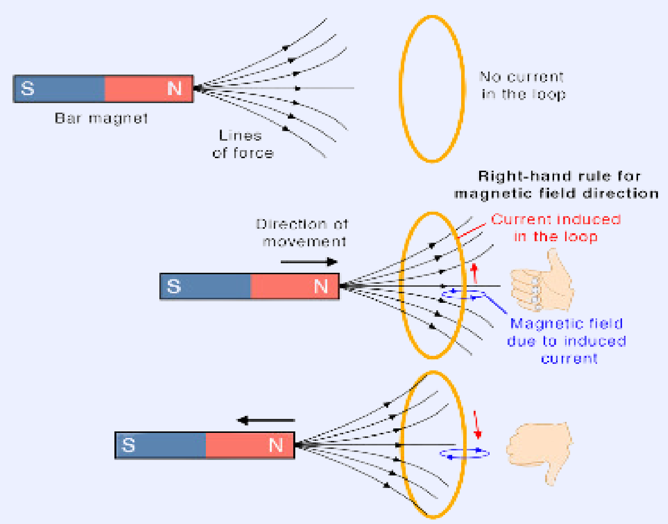
$$\varepsilon = 2vBL\sin\theta = N\omega AB\sin\theta$$

$N\omega AB = \varepsilon_o$ = peak value of induced emf in generator



Average value of A.C. over one cycle is zero.

LENZ'S LAW



The negative sign in Faraday's law was successfully explained by a **Russian scientist Lenz** as follows: The induced current in a closed loop, always induces in such a direction that opposes the cause producing it.

$$\varepsilon \propto -\frac{\Delta \Phi_B}{\Delta t}$$

A.C GENERATOR

Mean square value of emf $= \langle \varepsilon^2 \rangle = \frac{\varepsilon_1^2+\varepsilon_2^2+\varepsilon_3^2+\varepsilon_4^2}{4} = \frac{0+\varepsilon_0^2+0+(-\varepsilon_0)^2}{4} = \frac{2\varepsilon_0^2}{4} = \frac{\varepsilon_0^2}{2}$ similarly, $\langle I^2 \rangle = \frac{I_0^2}{2}$

r.m.s value of emf = ε_{rms} = square root of mean square value of A.C

$\varepsilon_{rms} = \sqrt{\frac{\varepsilon_0^2}{2}} = \frac{\varepsilon_0}{\sqrt{2}} = 0.7\,\varepsilon_o$ or 70 % of peak value similarly, $I_{rms} = \sqrt{\frac{I_0^2}{2}} = \frac{I_0}{\sqrt{2}} = 0.7\,I_o$

r.m.s value of A.C is effective D.C → ED.C = Er.m.s or 70% of the peak value

PP value of emf $= \varepsilon_0 + \varepsilon_0 = 2\varepsilon_0$

TRANSFORMER:

A device that transfers electric power P=VI, from one place to another safely. It can either be step up or step down voltage. It works on the basis of **mutual inductance** in two coils.
When A.C supply is applied across primary, the current changes instantly through it, due to which magnetic flux changes throughout the core at the same rate, giving an induced e.m.f. in coils explained by **Faraday's Law.**

ELECTROMAGNETIC INDUCTION

TRANSFORMER:

$$V_P = -N_P \frac{\Delta\Phi_B}{\Delta t}$$

$$V_S = -N_S \frac{\Delta\Phi_B}{\Delta t}$$

$$\frac{V_P}{V_S} = \frac{-N_P \frac{\Delta\Phi_B}{\Delta t}}{-N_S \frac{\Delta\Phi_B}{\Delta t}}$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$ (Transformer Equation)

$\Rightarrow V \propto N$

If $N_S > N_P$ then $V_S > V_P$ .... step up transformer

f $N_S < N_P$ then $V_S < V_P$ .... step down transformer

POWER LOSSES

Due to power losses in transformer: $P_P > P_S$

For an ideal case:

$$P_P = P_S$$

$$I_P V_P = I_S V_S$$

$$\frac{V_P}{V_S} = \frac{I_S}{I_P}$$

Sources of power losses:

1. Power dissipation in coils
2. Eddy currents in iron sheets of core
3. Hysteresis of core material

EFFICIENCY

Can be improved by:

1. Using coils of copper wires (less resistance)
2. Insulation between sheets (less eddy currents)
3. Making core with iron sheets (less hysteresis)
4. Transformer ratio = **Ns/Np**

$$E = \frac{\text{out put}}{\text{input}} = \frac{P_S}{P_P}$$

For ideal case $P_P = P_S \Rightarrow E = 1$ or equal to 100 %

For practical case $P_P > P_S \Rightarrow E < 1$ or less than 100 %