AC transformer :-

An AC transformer is an electrical device that is Used to Change the voltage in AC electrical circuits.

Construction of Transformer :-

Two basic parts in Transformer Construction.

1. Magnetic core 2. Windings or coils.

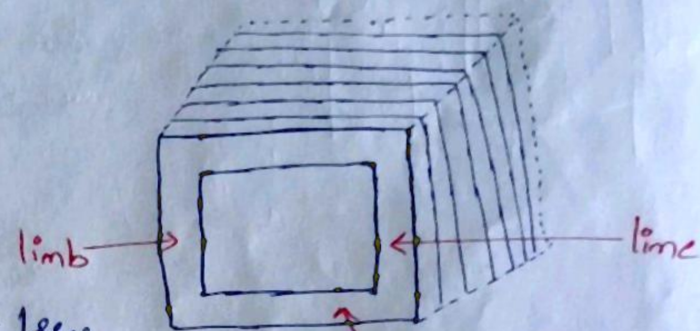
1. Magnetic core :-

→ Core provides path for magnetic flux.(ϕ)

→ Hence there are two types of losses occur in the core.

a) Hysteresis loss
b) Eddy Current loss

} magnetic losses (or) Iron losses.



fig(1)

* Now we need to construct core suchway that these two losses as low as possible.

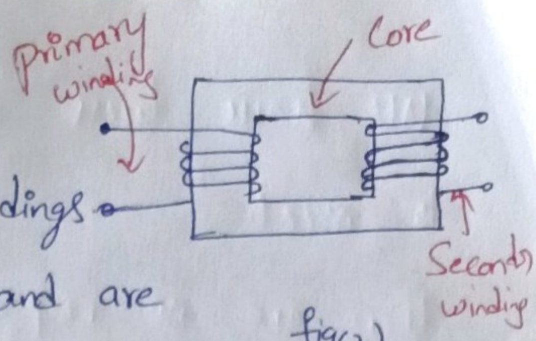
→ Generally core is made up of high grade Silicon Steel (magnetic material with high permeability) to minimize hysteresis losses.

→ Earlier core is made up of iron.

*For eddy current losses reduction:-

→ Core is made up of thin laminations

2) windings (or) Coils :-



→ Electric Current passes through windings.

→ windings are made up of Copper and are wound on the limbs of magnetic core.

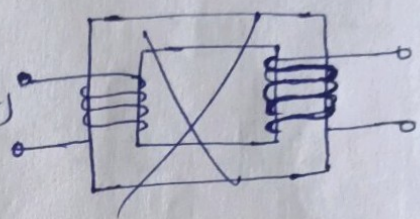
Windings are insulated from each other.

→ windings are Subjected to I^2R losses which are also Called as Copper losses.

fig(2)

* Based on the arrangment of Core & winding, there are two types of transformer.

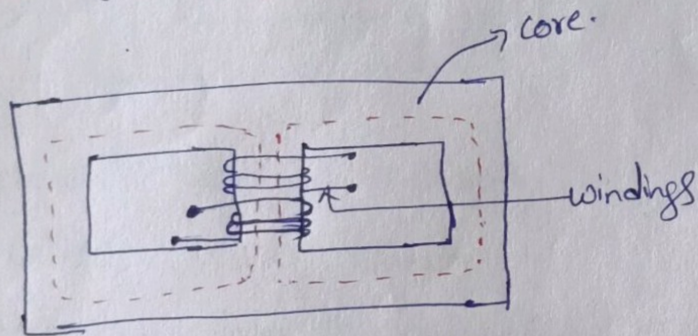
i) Core type transformer :-



Here Core is Surrounded by windings (or) the winding encircles the Core.

Draw fig(2)

ii) Shell type Transformer :-



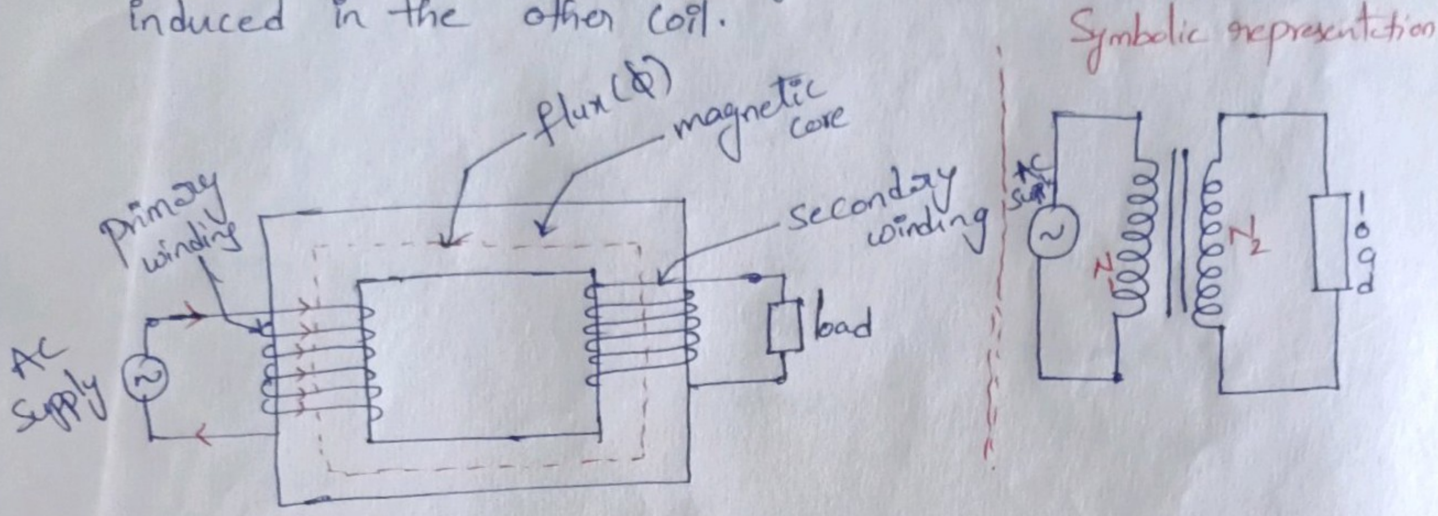
Here the core encircles the windings (or) windings are Surrounded by core.

Working principle of Transformer :-

→ Transformer works on the principle of Mutual Induction.

Mutual Induction :-

The principle of mutual Induction states that, when two coils are inductively coupled and if current in one coil changed uniformly then an e.m.f gets induced in the other coil.



→ Wherever there is a supply connected to coil, that coil is called primary winding.

→ Where ever load is connected that coil is called Secondary winding.

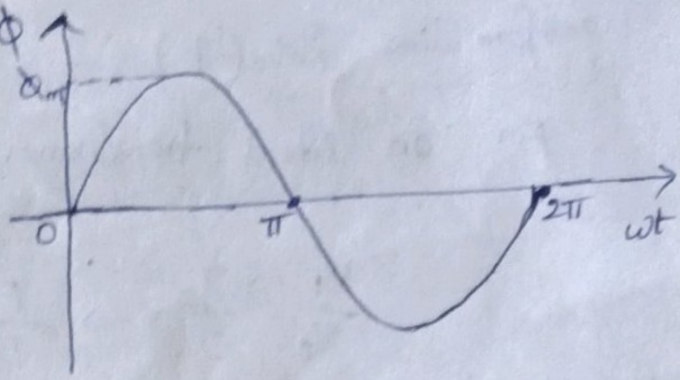
* Because of AC Supply, current will pass through the primary winding. This current gives rise to magnetic flux through the magnetic core.

→ The magnetic flux changing w.r.t time gets linked in primary winding and E.m.f produced in primary winding. That emf is called Self induced e.m.f.

→ Same flux linked in secondary winding and e.m.f produced in secondary coil. This e.m.f is called mutually induced e.m.f.

EMF equation of Transformer :-

$\phi = \phi_m \sin\omega t$



By Faraday's law of electromagnetic induction, e.m.f induced

$$e = N \cdot \frac{d\phi}{dt} \quad -(1)$$

By len'z's law, $e = -N\frac{d\phi}{dt}$ $-(2)$

lenz's law :- e.m.f induced in a conductor will oppose the current which has produced the flux ϕ

E.m.F induced at the primary Side, $e_1 = -N_1 \frac{d\phi}{dt}$

N_1 = no. of turns in primay winding.

$$e_1 = -N_1 \frac{d}{dt}(\phi_m \sin\omega t)$$

$$e_1 = -N_1 \phi_m \cos\omega t \cdot \omega$$

$$e_1 = N_1 \phi_m \omega(-\cos\omega t) \qquad \left[\because -\cos\omega t = \sin(\omega t - 90)\right]$$

$$= N_1 \phi_m \omega \sin(\omega t - 90)$$

$$e_1 = \phi_m 2\pi f N_1 \sin(\omega t - 90) \quad -(3)$$

$$e_1 = E_{m1} \sin(\omega t + \varphi) \quad -(4)$$

Here $E_{m1} = 2\pi f \phi_m N_1$, $\varphi = -90^\circ$.

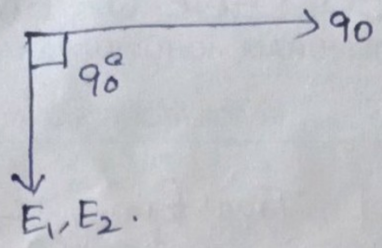
R.M.S Value of e.m.f, $\frac{E_{m1}}{\sqrt{2}} \Rightarrow \frac{2\pi f \phi_m N_1}{\sqrt{2}}$

$$\boxed{E_1 = 4.44\, \phi_m f N_1} \quad -(5)$$

Similaly, Seconday Side e.m.f, $\boxed{E_2 = 4.44\, \phi_m f N_2}$ $-(6)$

E_1 & E_2 lag flux ϕ by 90° (or) $\pi/2$

Phasor diagram :-



Transformation Ratio (k) :-

For an ideal transformer, $V_1 = E_1$

$V_2 = E_2$ and $\cancel{V_1 E_1}$

$V_1 I_1 = V_2 I_2$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} \Rightarrow \frac{E_1}{E_2} = \frac{I_2}{I_1} \quad \text{—} (7)$$

From eq (5) and eq (6),

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \text{—} (8)$$

From eq (7) and eq (8),

$$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k}$$

K = Transformation ratio

D

losses :— in a transformer :—

There are two losses occur in transformer, 1. Core losses
2. copper losses

1. Core losses : Core gets Subjected to alternating flux Causes core losses.

2. Copper losses :— The windings carry Currents when transformer is loaded Causing copper losses.

Core / Iron / constant losses

i) Hystersis losses :— Due to Ac flux Set up in the magnetic core of t/f, it undergoes a cycle of magnetisation and demagnetisation. Due to the process of magnetisation and demagnetisation there is a loss of energy which is Called hystersis losses.

$$\boxed{P_h = K_h B_m^{1.67} f \cdot V}$$

K_h = Hystersis Constant
P_h = Hystersis loss
B_m = Maximum flux density
f = frequency
V = Volume of Core

ii) Eddy Current losses :—

The induced emf in the core tries to Set up eddy Currents in the core and hence responsible for eddy Current losses.

$$\boxed{P_e = K_e B_m^2 f^2 t^2}$$

K_e = Eddy Current Constant ; t = thickness of the core.

* To avoid hystersis losses, magnetic core material is made with "high grade material Silicon Steel"

* To avoid eddy current losses, magnetic core will be made Such way that it will consists of very thin laminations

2. Copper / I^2R / Variable losses :-

Copper losses are due to the power wasted in the form of I^2R loss due to the resistances of the primary and Secondary windings.

$$\boxed{P_{cu} = I_1^2 R_1 + I_2^2 R_2}$$

Copper losses depend upon the amount of load Current which can be changed depends upon the load connected.

Total losses = Constant losses + Variable losses

$$= (P_h + P_e) + I_1^2 R_1 + I_2^2 R_2$$

Efficiency of Transformer :-

Efficiency is denoted by $\eta = \frac{\text{output power}}{\text{input power}} \times 100$

$$\eta = \frac{\text{output power}}{\text{output power} + \text{losses}} \times 100$$

For full load,

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + W_i + W_{cu}}$$

Voltage Regulation :-

The change in terminal voltage from no-load to full load at constant supply voltage w.r.t no-load voltage is known as voltage regulation of the transformer.

$$\% \text{ Voltage regulation} = \boxed{\frac{E_2 - V_2}{E_2} \times 100}$$

$$\boxed{E_2 = V_2 + I_2 Z}$$

E_2 = Secondary Voltage at no-load

V_2 = Secondary Voltage at full-load