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UNIT -3 TRANSFORMERS

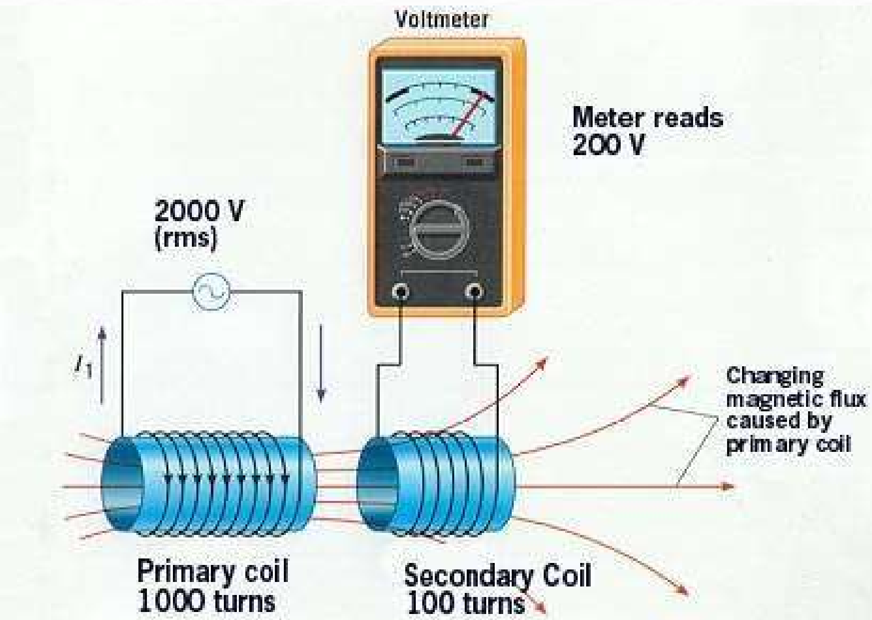
Transformer

An A.C. device used to change high voltage low current A.C. into low voltage high current A.C. and vice-versa without changing the frequency

In brief,

1. Transfers electric power from one circuit to another
2. It does so without a change of frequency
3. It accomplishes this by electromagnetic induction
4. Where the two electric circuits are in mutual inductive influence of each other.

Principle of operation

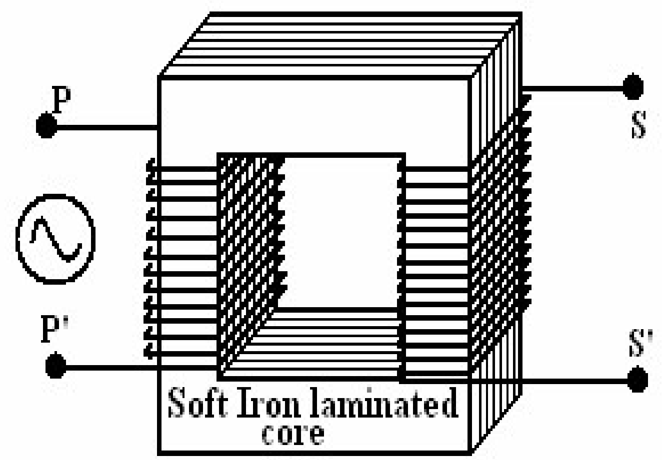


It is based on principle of MUTUAL INDUCTION.

According to which an e.m.f. is induced in a coil when current in the neighbouring coil changes.

Working of a transformer

1. When current in the primary coil changes being alternating in nature, a changing magnetic field is produced
2. This changing magnetic field gets associated with the secondary through the soft iron core
3. Hence magnetic flux linked with the secondary coil changes.
4. Which induces e.m.f. in the secondary.



Single Phase Transformer

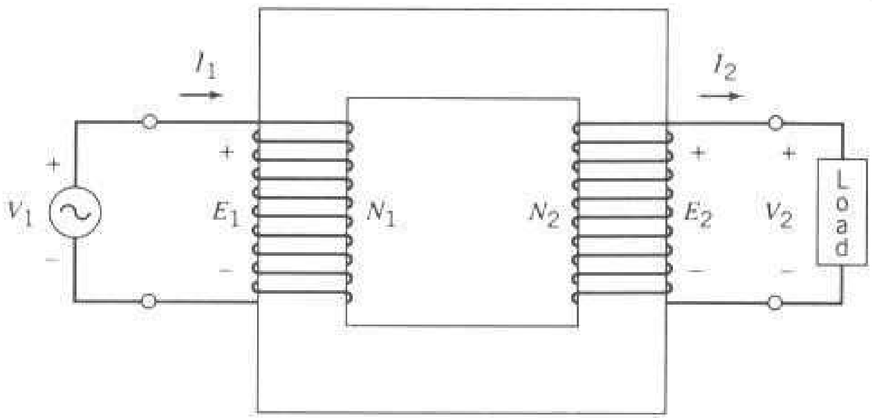


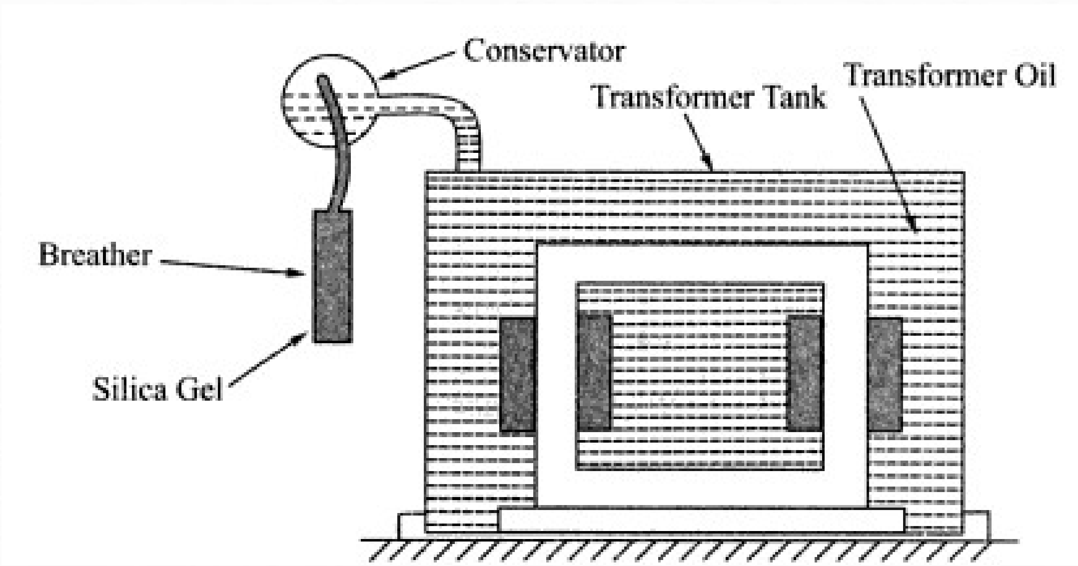
FIGURE 4.8 A transformer circuit.

- A single phase transformer
  - Two or more winding, coupled by a common magnetic core

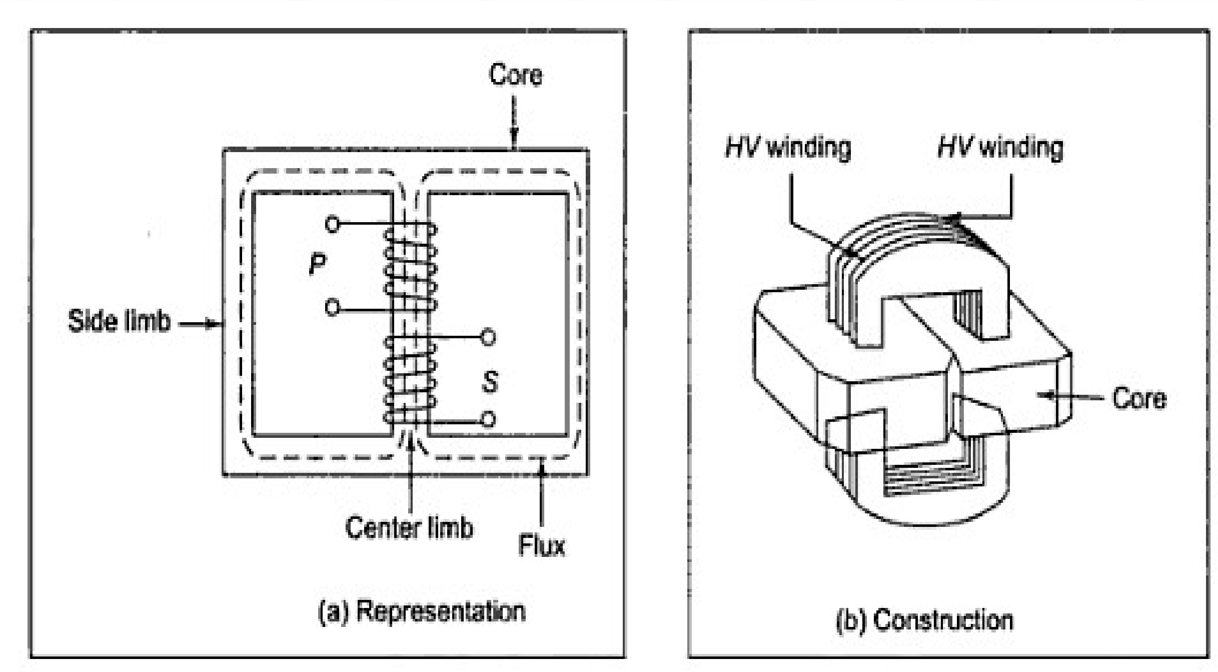
PARTS OF TRANSFORMER

1. Laminated Core
2. Windings
3. Main Tank / Oil Tank
4. Transformer Oil
5. Conservator Tank
6. Buchholz Relay
7. Breather
8. Radiator

Transformer with conservator and breather

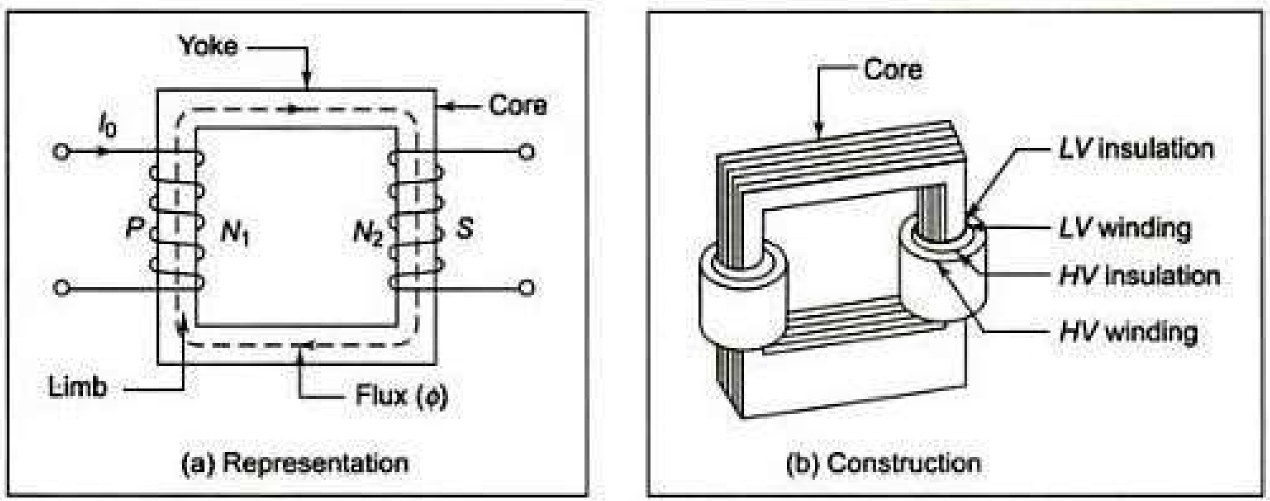


Constructional detail : Shell type



- Windings are wrapped around the center leg of a laminated core.

Core type



- Windings are wrapped around two sides of a laminated square core.

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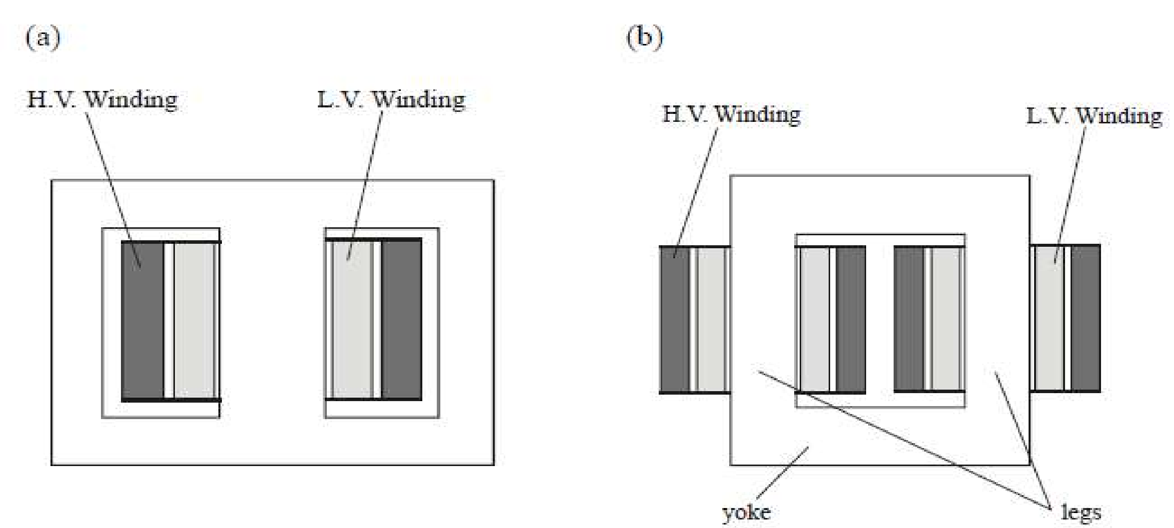
Sectional view of transformers

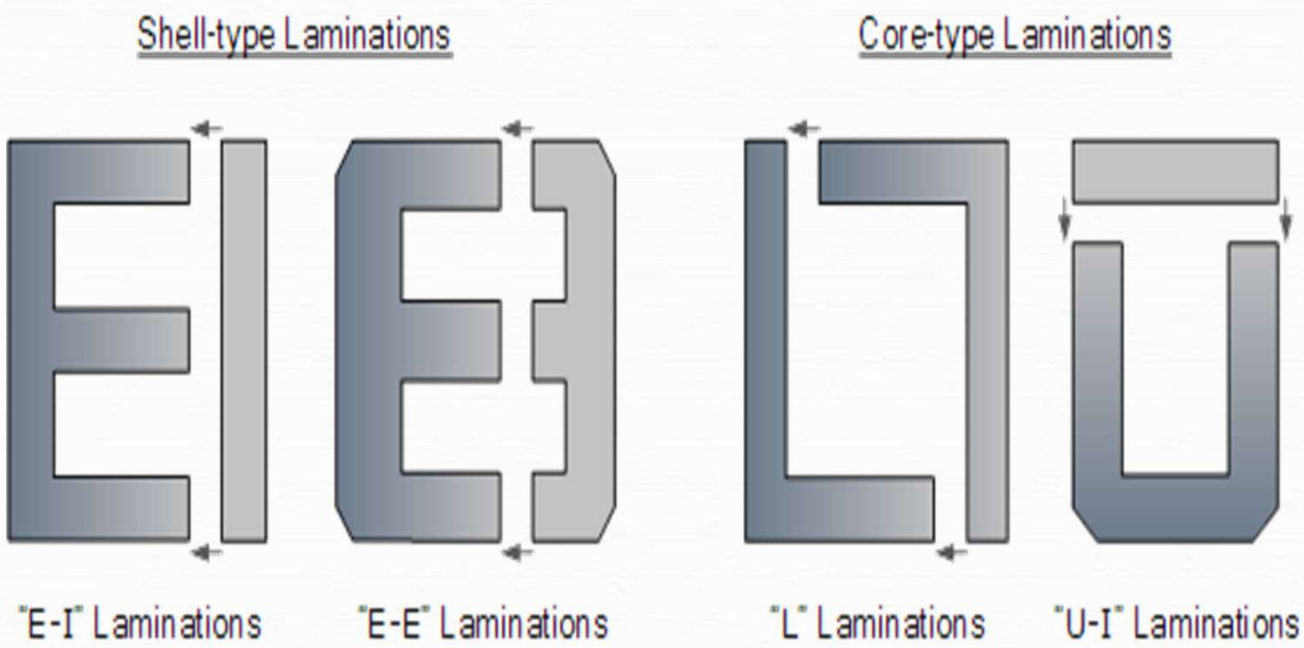


(a) Shell-type transformer. (b) core-type transformer

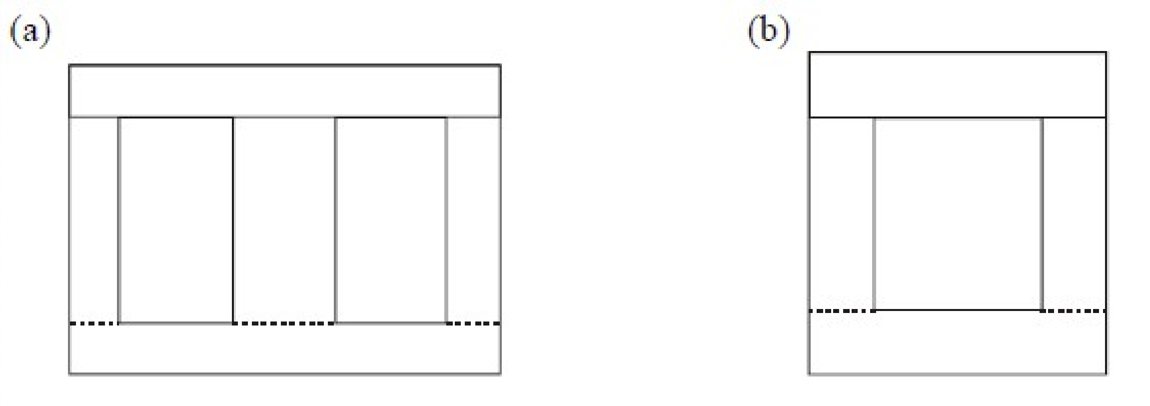
Note:

High voltage conductors are smaller cross section conductors than the low voltage coils

Lamination Shapes of Transformer



Construction of transformer from stampings



(a) Shell-type transformer. (b) core-type transformer

Core type

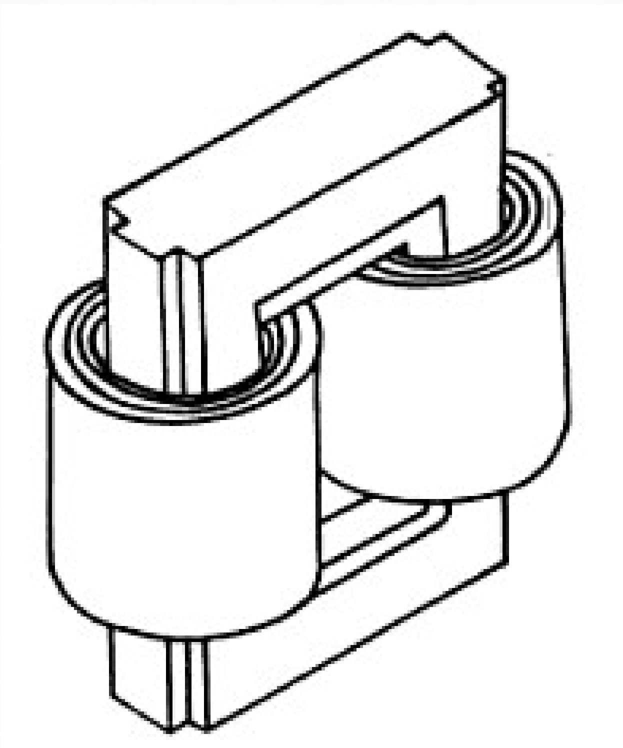


Fig1: Coil and laminations of core type transformer

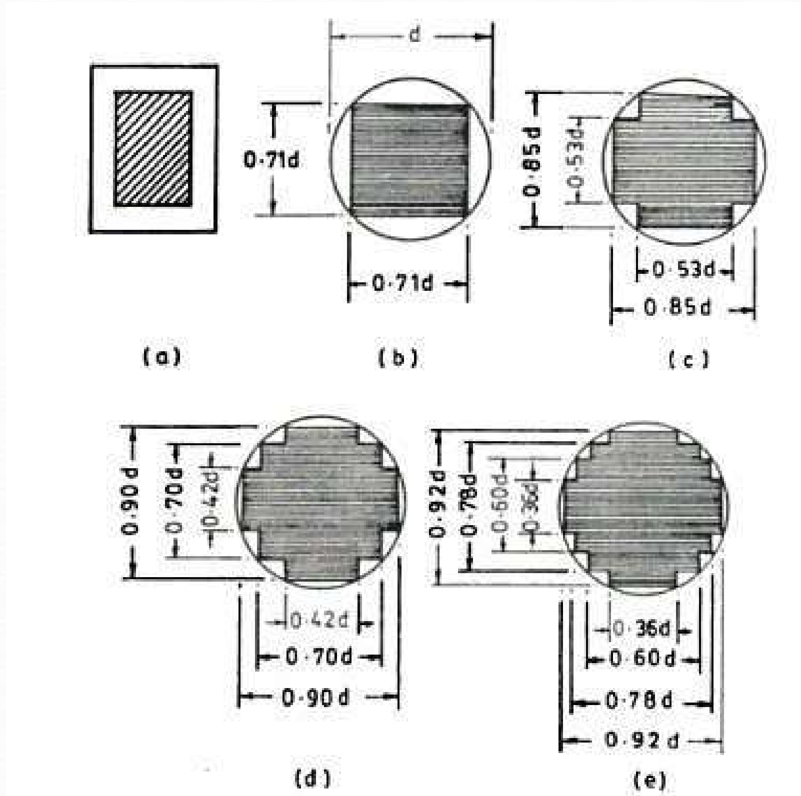


Fig2: Various types of cores

Shell type

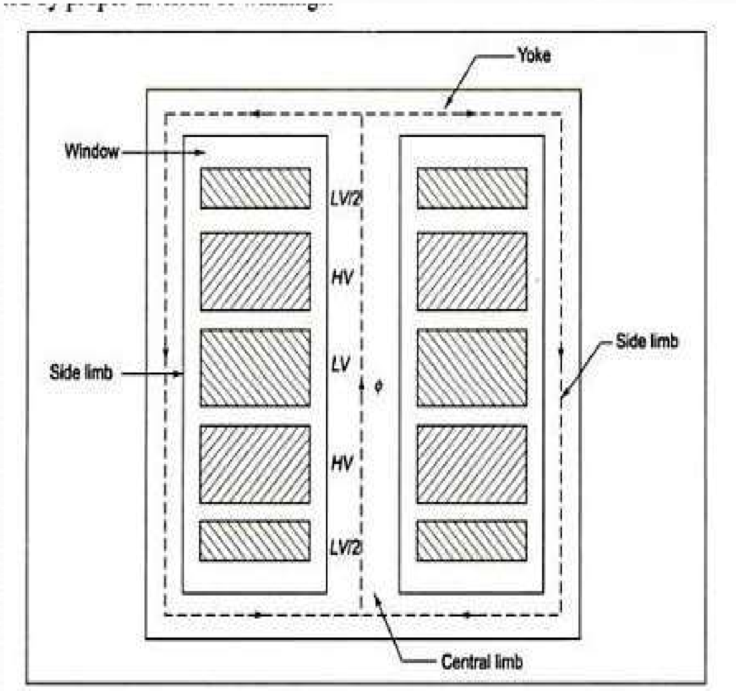


Fig: Sandwich windings

- The HV and LV windings are split into no. of sections
- Where HV winding lies between two LV windings
- In sandwich coils leakage can be controlled

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Definition	The winding surround the core.	The core surround the winding.
Lamination Shape	The lamination is cut in the form of the L strips.	Lamination are cut in the form of the long strips of E and L.
Cross Section	Cross-section may be square, cruciform and three stepped	The cross section is rectangular in shape.
Copper Require	More	Less
Other Name	Concentric Winding or Cylindrical Winding.	Sandwich or Disc Winding

Cont...

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Limb	Two	Three
Insulation	More	Less
Flux	The flux is equally distributed on the side limbs of the core.	Central limb carry the whole flux and side limbs carries the half of the flux.
Winding	The primary and secondary winding are placed on the side limbs.	Primary and secondary windings are placed on the central limb
Magnetic Circuit	Two	One

Cont...

Basis for Comparison	Core Type Transformer	Shell Type Transformer
Losses	More	Less
Maintenance	Easy	Difficult
Mechanical Strength	Low	High
Output	Less	High
Natural Cooling	Does not Exist	Exist

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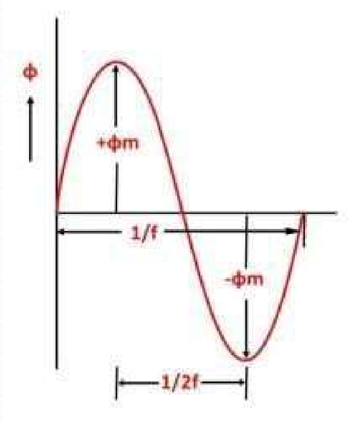
EMF equation of a transformer

Let

- ϕ_m be the maximum value of flux in Weber
- f be the supply frequency in Hz
- N_1 is the number of turns in the primary winding
- N_2 is the number of turns in the secondary winding
- Φ is the flux per turn in Weber

As shown in the above figure that the flux changes from $+\phi_m$ to $-\phi_m$ in half a cycle of 1/2f seconds.



By Faraday's Law

Let E_1 is the emf induced in the primary winding

$$E_1 = -\frac{d\psi}{dt} \dots \dots \dots (1)$$

Where $\Psi = N_1\phi$

Therefore, $E_1 = -N_1 \frac{d\varphi}{dt}$ ....(2)

Since ϕ is due to AC supply $\phi = \phi_m$ Sinwt

$$E_1 = -N_1 \frac{d}{dt} (\varphi_m \, \text{Sinwt})$$

$$E_1 = -N_1 \, w\varphi_m \, \text{Coswt}$$

$$E_1 = N_1 w\varphi_m \, \text{Sin}(wt - \pi/2) \dots \dots \dots (3)$$

So the induced emf lags flux by 90 degrees.

Maximum valve of emf

$$E_1 max = N_1 w \varphi_m \ldots\ldots\ldots.(4)$$

But w = 2πf

$$E_1 max = 2\pi f N_1 \varphi_m \ldots\ldots\ldots.(5)$$

Root mean square RMS value is

$$E_1 = \frac{E_{1max}}{\sqrt{2}} \ldots\ldots\ldots..(6)$$

Putting the value of E_1max in equation (6) we get

$$E_1 = \sqrt{2}\pi f N_1 \varphi_m \text{........(7)}$$

For a sinusoidal wave

$$\frac{\text{R.M.S value}}{\text{Average value}} = \text{Form factor} = 1.11$$

$$E_1 = 4.44 f N_1 \varphi_m \ldots \ldots \ldots (8)$$

$$E_2 = \sqrt{2}\pi f N_2 \varphi_m$$

Or

$$E_2 = 4.44 f N_2 \varphi_m \ldots \ldots \ldots (9)$$

$$\frac{E_2}{E_1} = \frac{4.44 f N_2 \varphi_m}{4.44 f N_1 \varphi_m}$$

Or

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

Ideal Transformers

- **Zero leakage flux:**

  -Fluxes produced by the primary and secondary currents are confined within the core

- **The windings have no resistance:**

  - Induced voltages equal applied voltages

- **The core has infinite permeability**

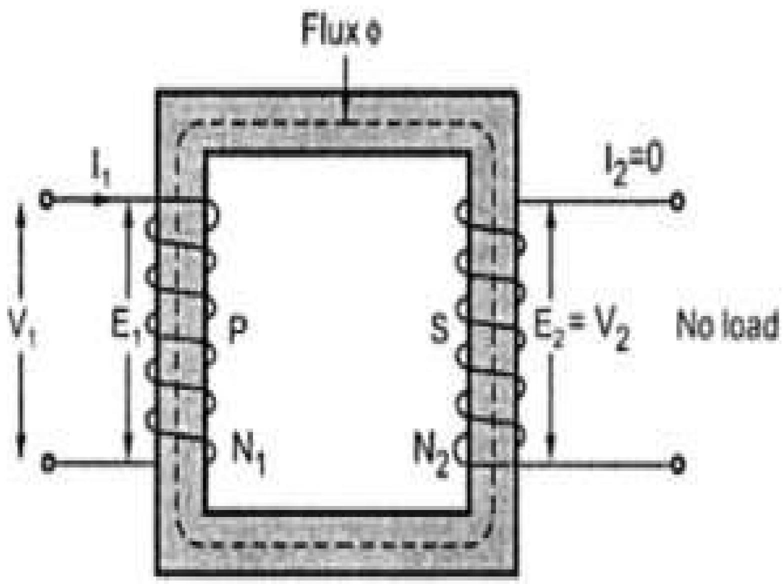
  - Reluctance of the core is zero

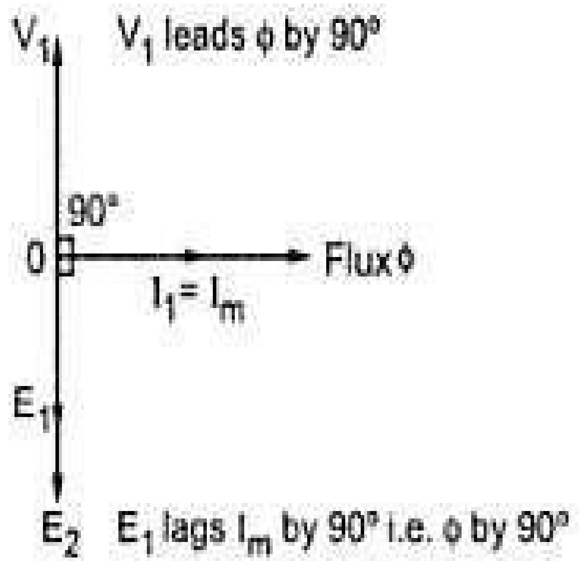
  - Negligible current is required to establish magnetic flux

- **Loss-less magnetic core**

  - No hysteresis or eddy currents

Ideal transformer





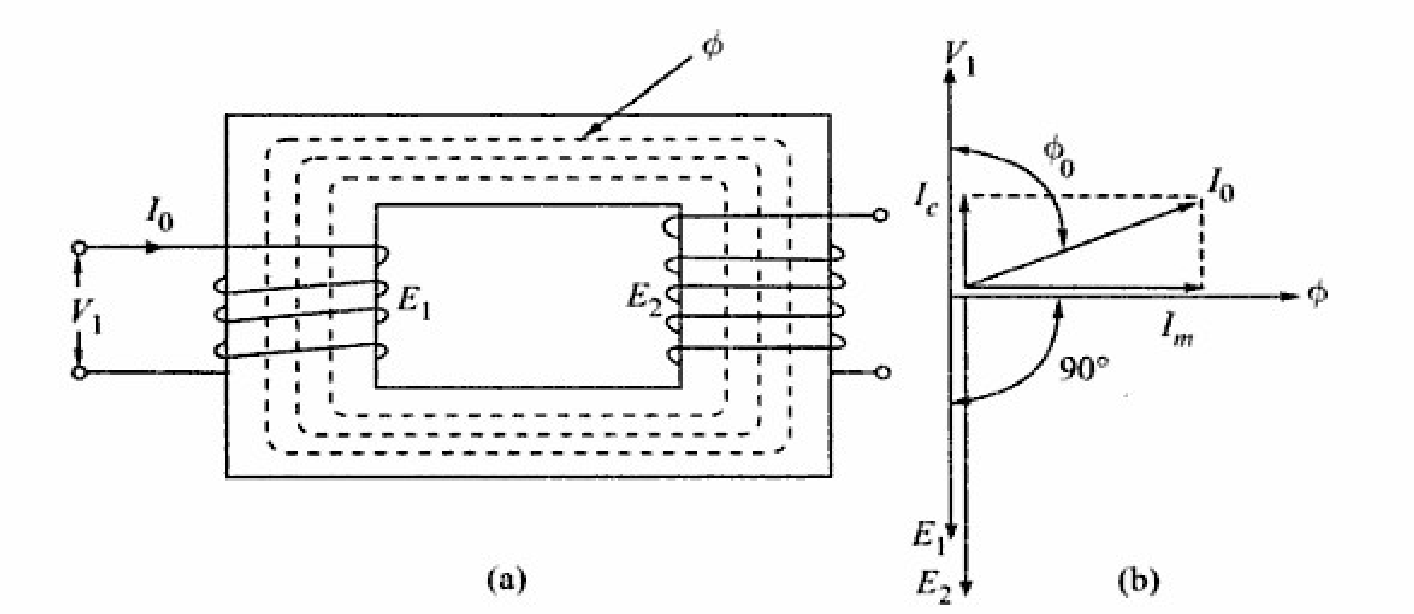
V_1 – supply voltage ; I_1- noload input current ;

V_{2}- output voltgae; I_2- output current

I_m- magnetising current;

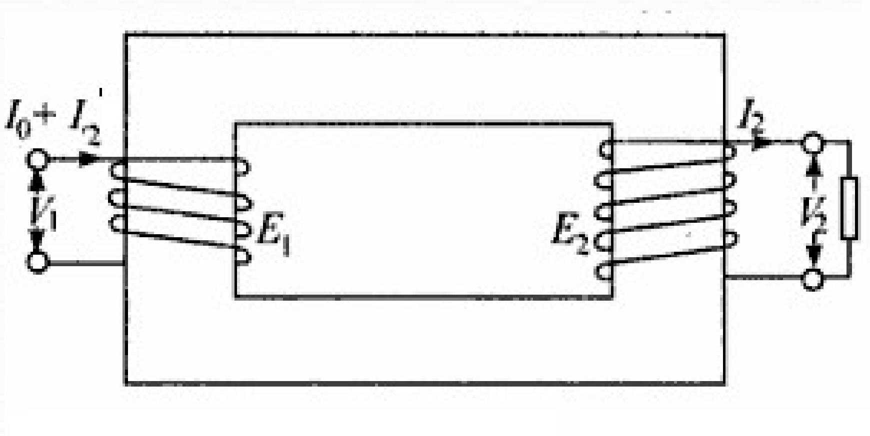
E_1-self induced emf ; E_2- mutually induced emf

Phasor diagram: Transformer on No-load



(a) Transformer on no-load (b) Phasor diagram of a transformer on no-load

Transformer on load assuming no voltage drop in the winding



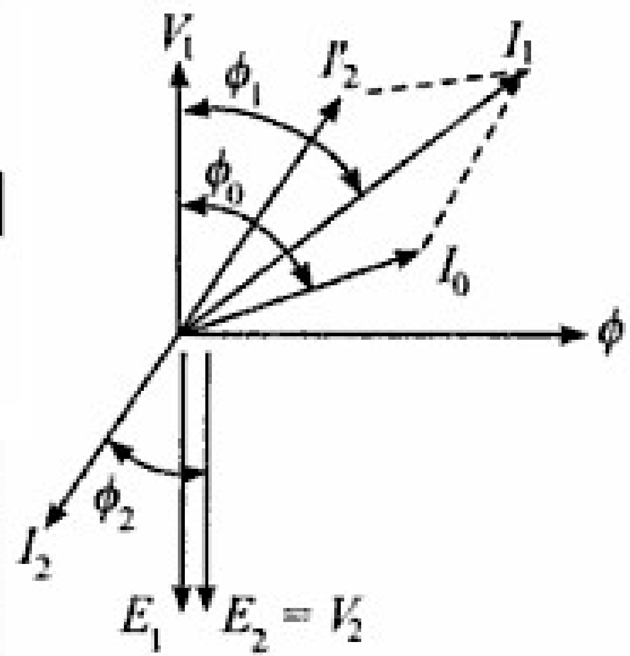


Fig shows the Phasor diagram of a transformer on load by assuming

1. No voltage drop in the winding
2. Equal no. of primary and secondary turns

Transformer on load

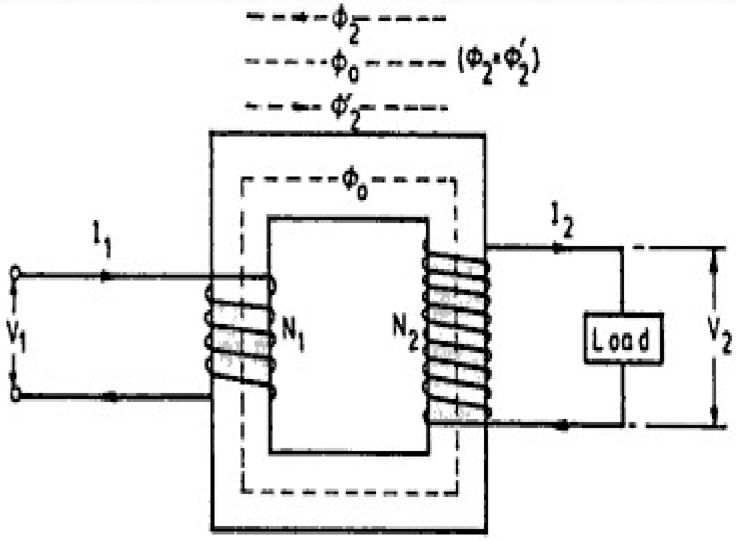


Fig. a: Ideal transformer on load

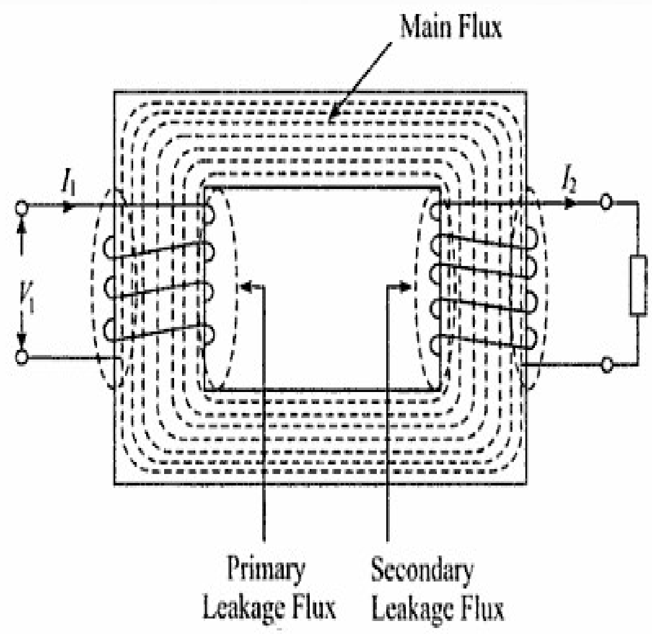
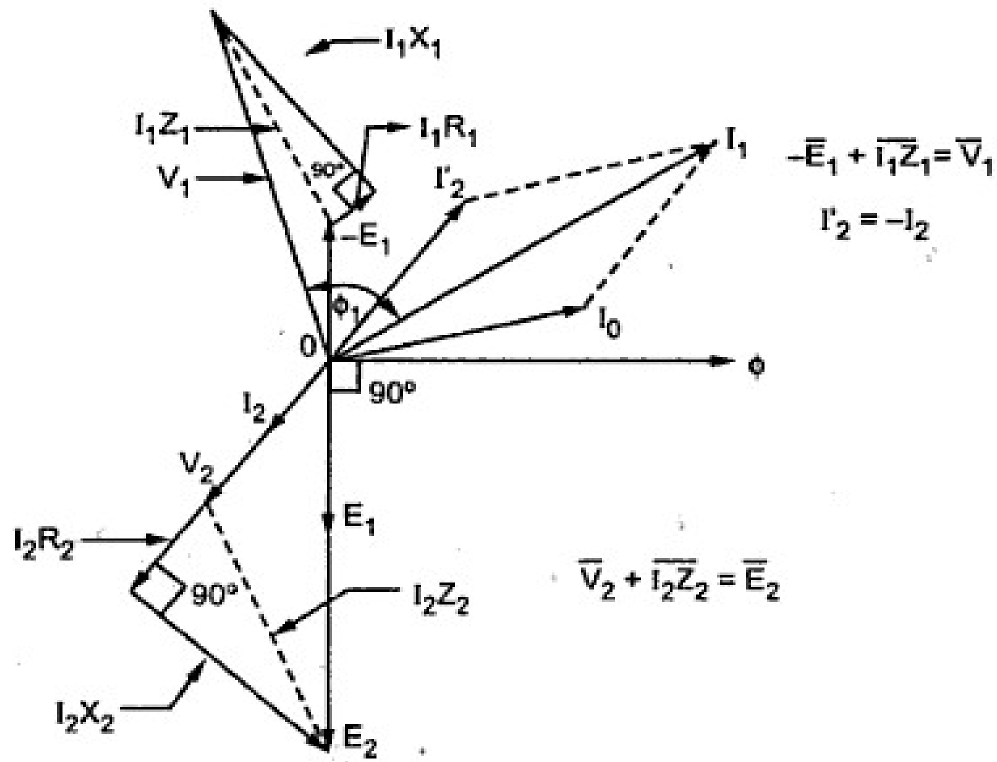


Fig. b: Main flux and leakage flux in a transformer

Phasor diagram of transformer with UPF load



Phasor diagram of transformer with lagging p.f load