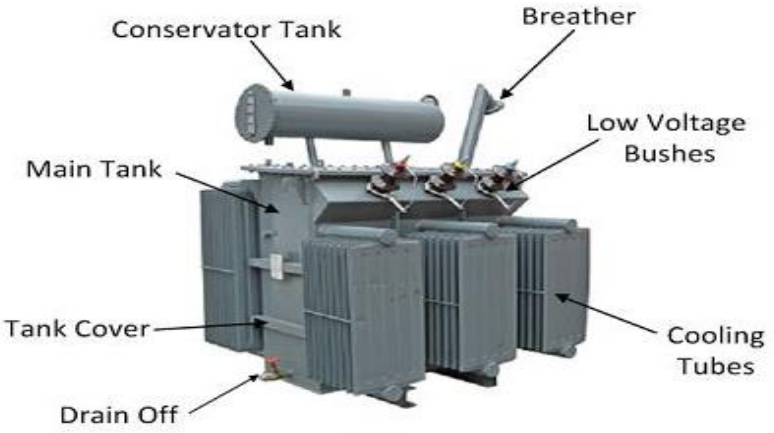
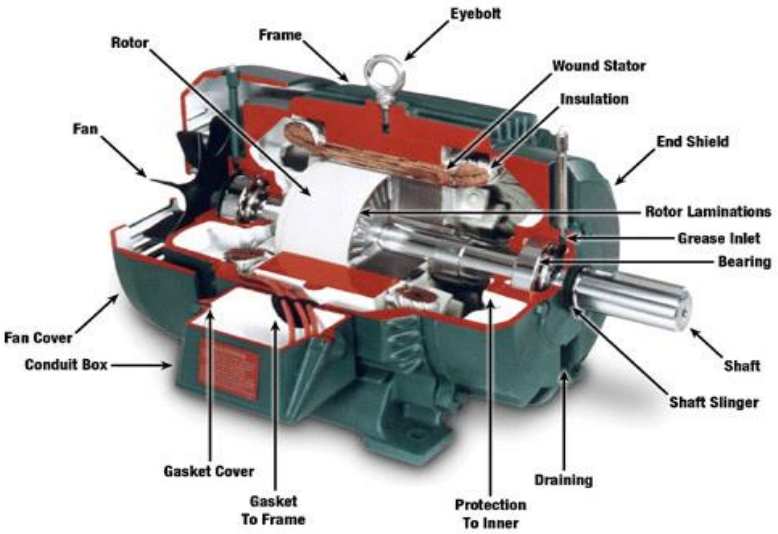
UNIT-III: Fundamentals of Electrical Machines

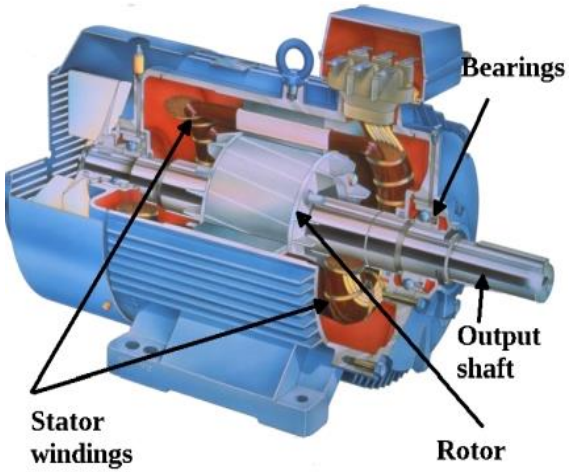
TRANSFOREMR



DC MACHINE



INDUCTION MOTOR



TRANSFORMER

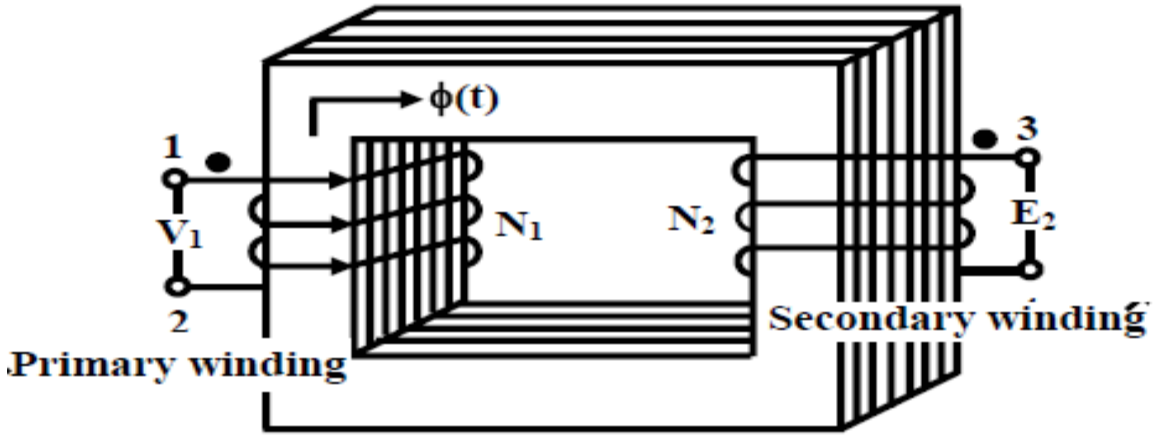
Principle of Operation: Mutual inductance and mutual coupling phenomena in transformer

- Construction
- Working
- Concept of Turns Ratio
- Applications
- Transformer on DC
- Autotransformer
- Instrument transformers

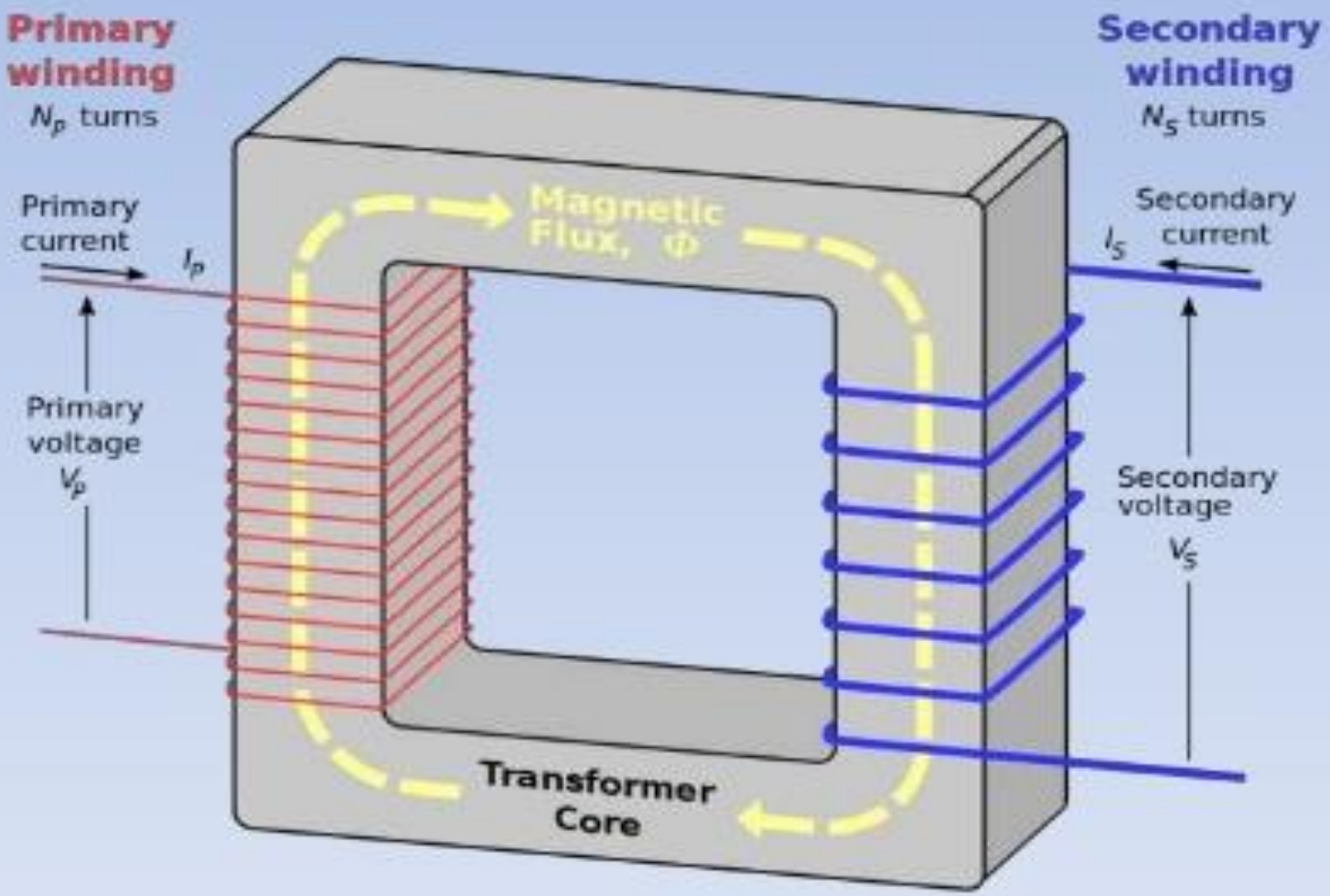
What is Transformer?

- Transformer is an ac machine that
  - Transfers electrical energy from one electric circuit to another electric circuit
  - It basically changes the level of voltages from one value to the other at constant frequency.
  - Work on principle of electromagnetic induction

- Since the construction of a transformer requires no moving parts it is known as static transformer.



Transformer Construction



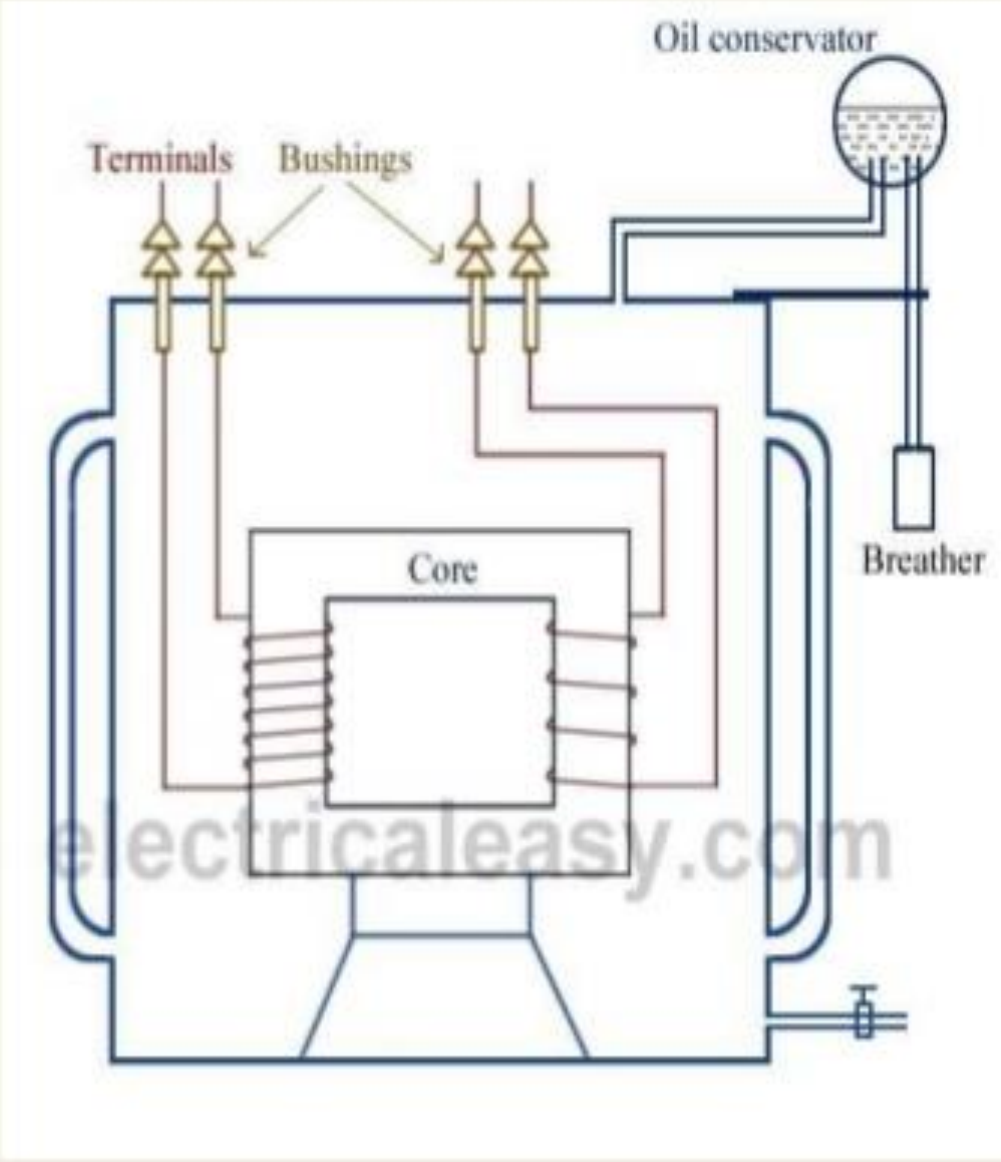
Construction of Transformer

•Basically a transformer consists of two inductive windings and a laminated steel core. The coils are insulated from each other as well as from the steel core.

•core is constructed by assembling laminated sheets of steel, with minimum air-gap between them (to achieve continuous magnetic path).

•The silicon steel used is to provide high permeability and low hysteresis loss.

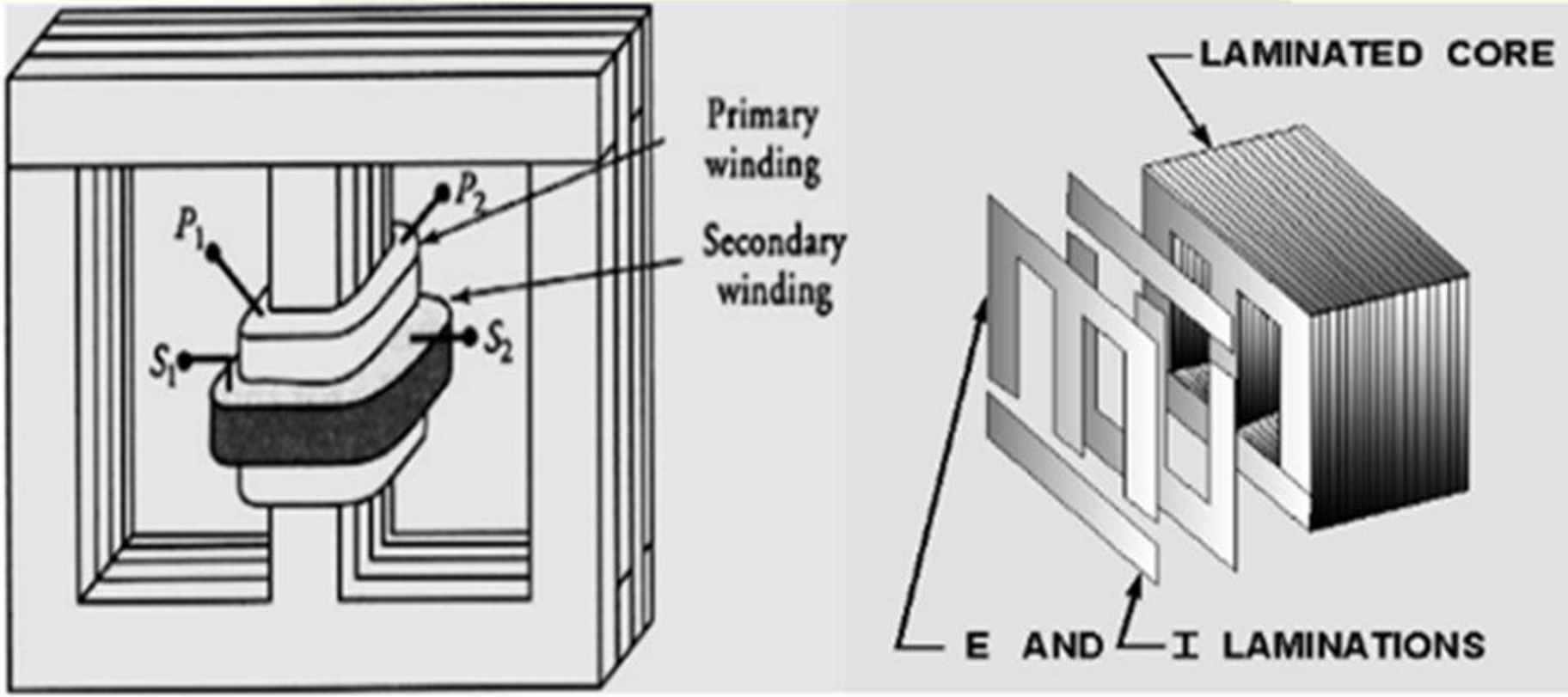
•Laminated sheets of steel are used to reduce eddy current loss.



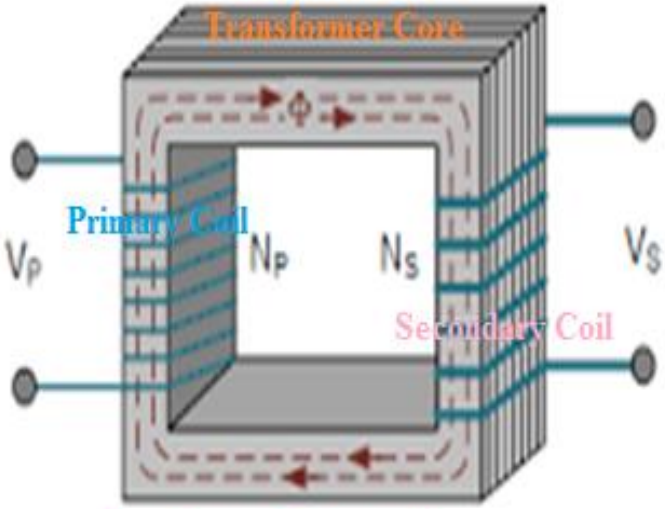
Transformer Construction

Core is made up of laminations to reduce the eddy current losses.

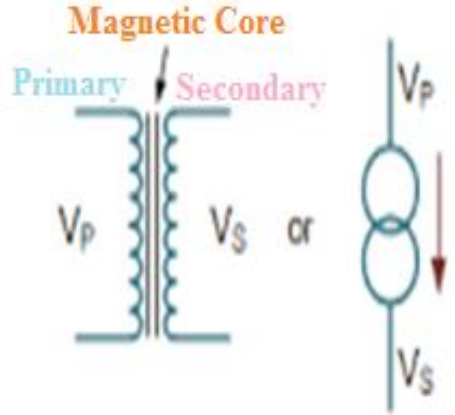
The thickness of laminations is usually 0.4mm.



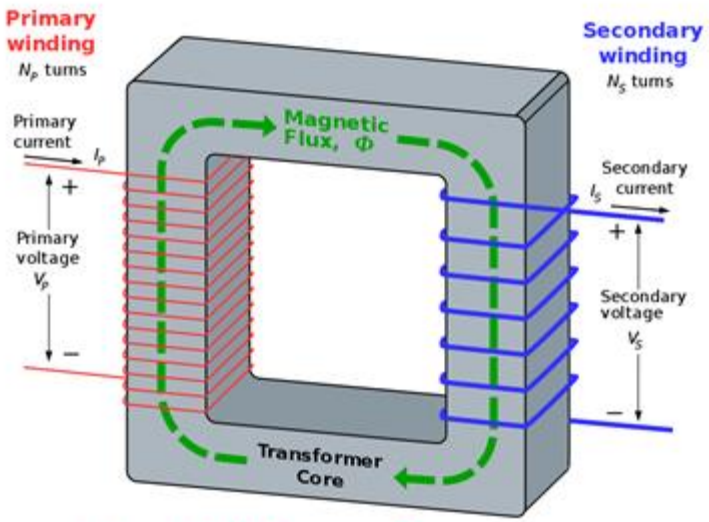
TRANSFORMER SYMBOLS



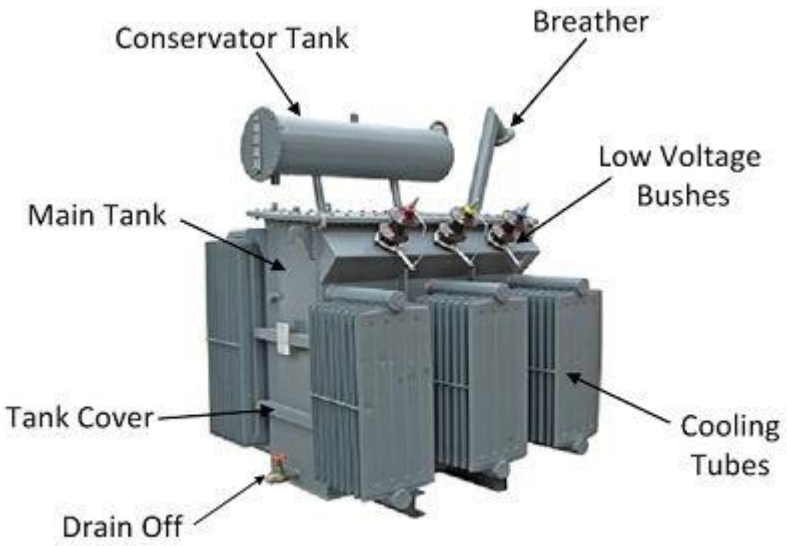
Transformer Construction



Transformer Symbol

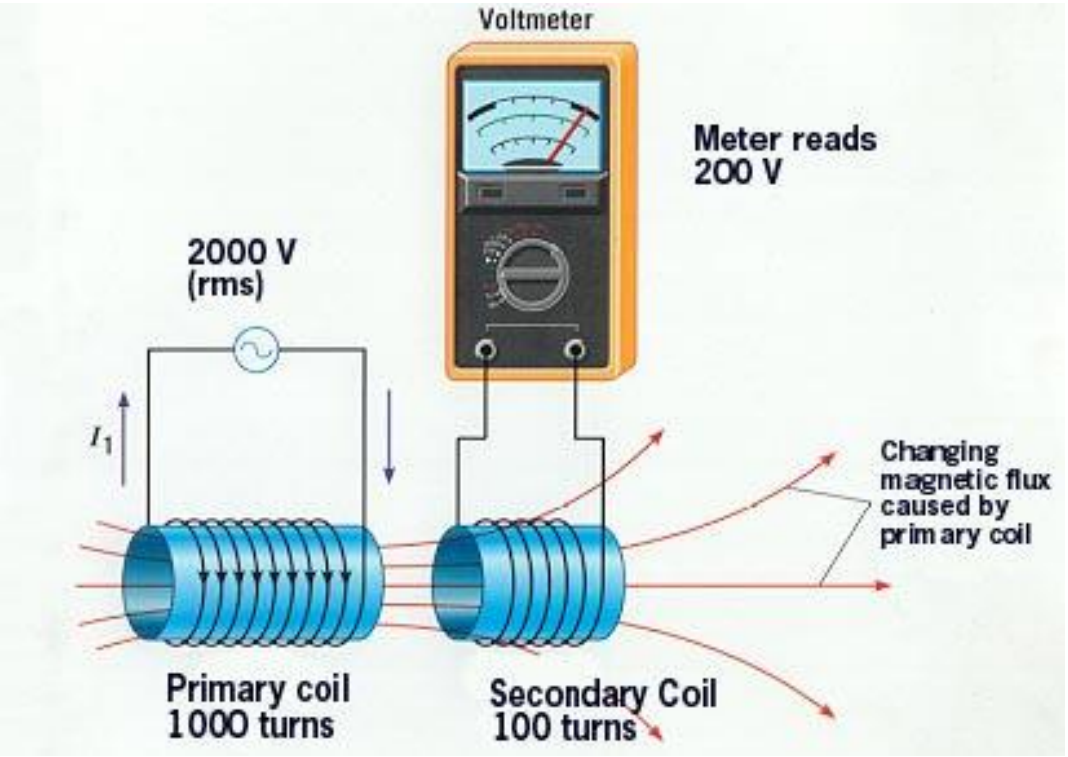


Inside Transformer



Outside Transformer

Principle of operation



It is based on principle of MUTUAL INDUCTION.

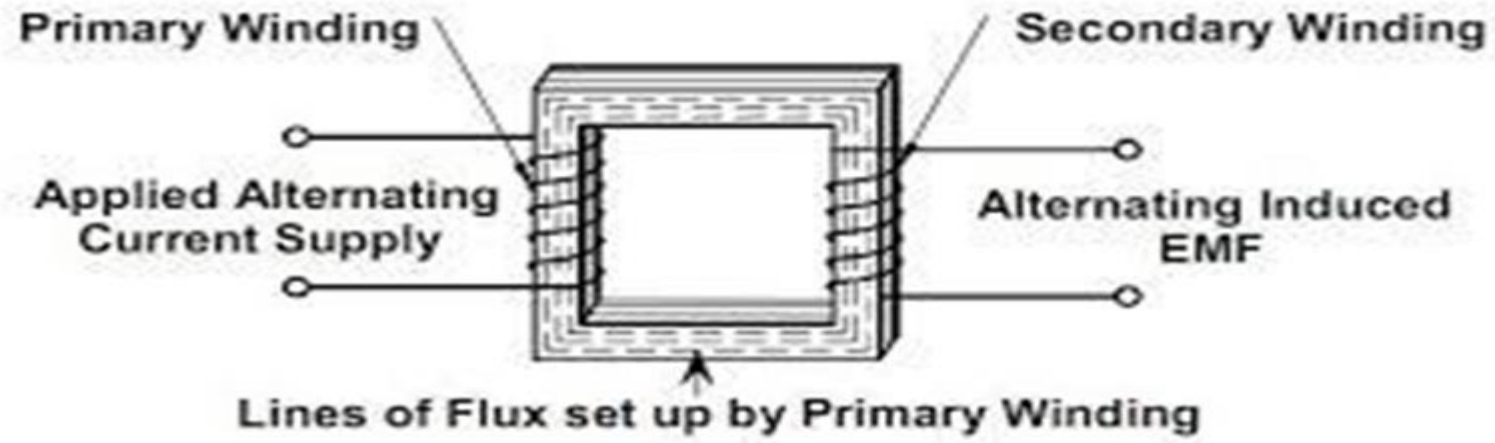
According to which an e.m.f. is induced in a coil when current in the neighbouring coil changes.

Principle of Transformer

- The transformer works on the principle of mutual induction

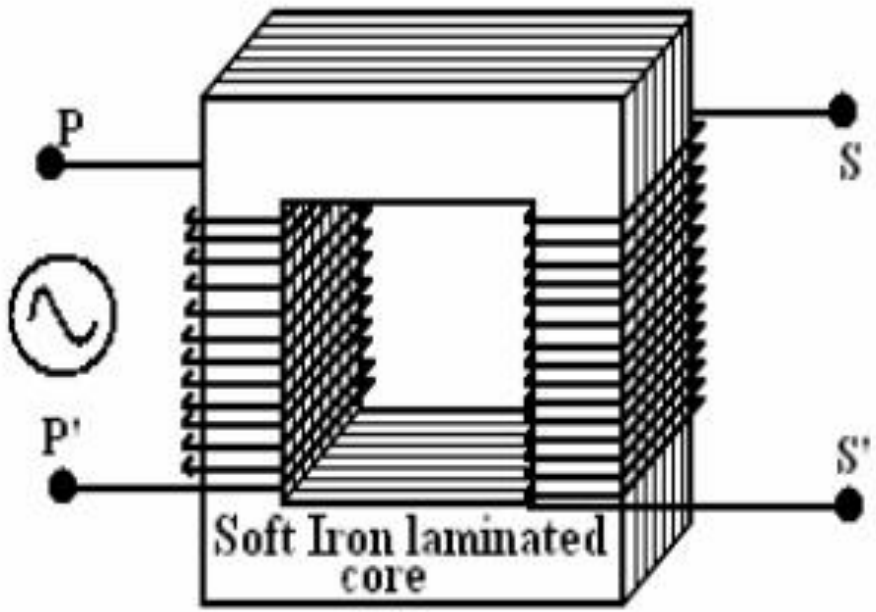
"The principle of mutual induction states that when the two coils are inductively coupled and if the current in coil change uniformly then the e.m.f. induced in the other coils. This e.m.f can drive a current when a closed path is provide to it."

- When the alternating current flows in the primary coils, a changing magnetic flux is generated around the primary coil.
- The changing magnetic flux is transferred to the secondary coil through the iron core
- The changing magnetic flux is cut by the secondary coil, hence induces an e.m.f in the secondary coil



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.



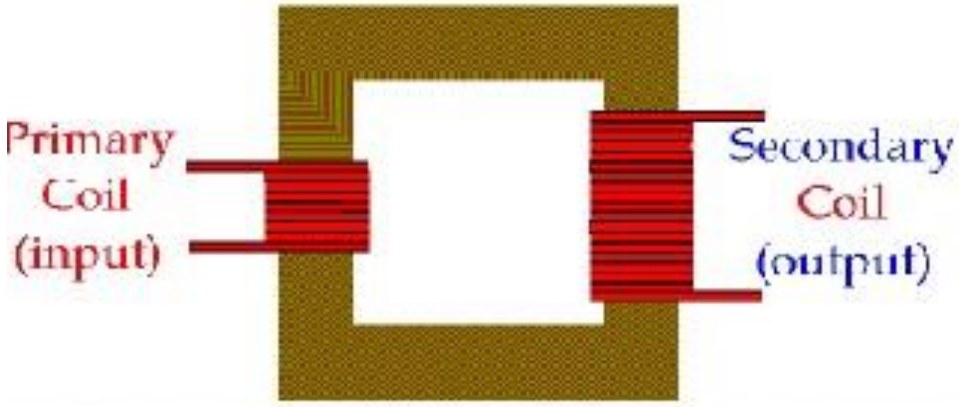
Types of transformers

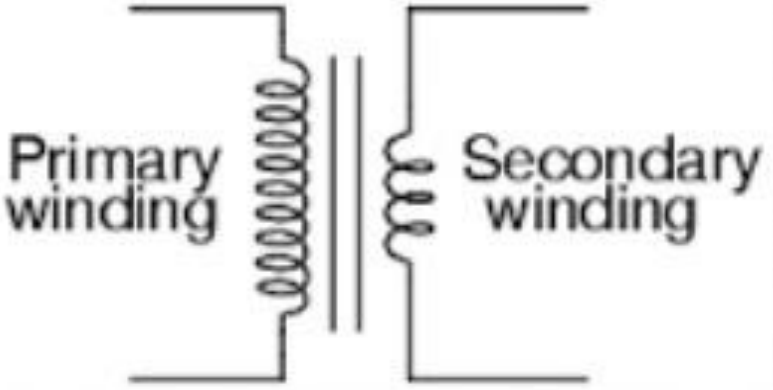
- Step up transformers

In step up transformers no. of turns of primary windings are less as compared to no. of turns of secondary windings .

- Step down transformers

In step down transformers no. of turns of primary windings are more as compared to no. of turns of secondary windings

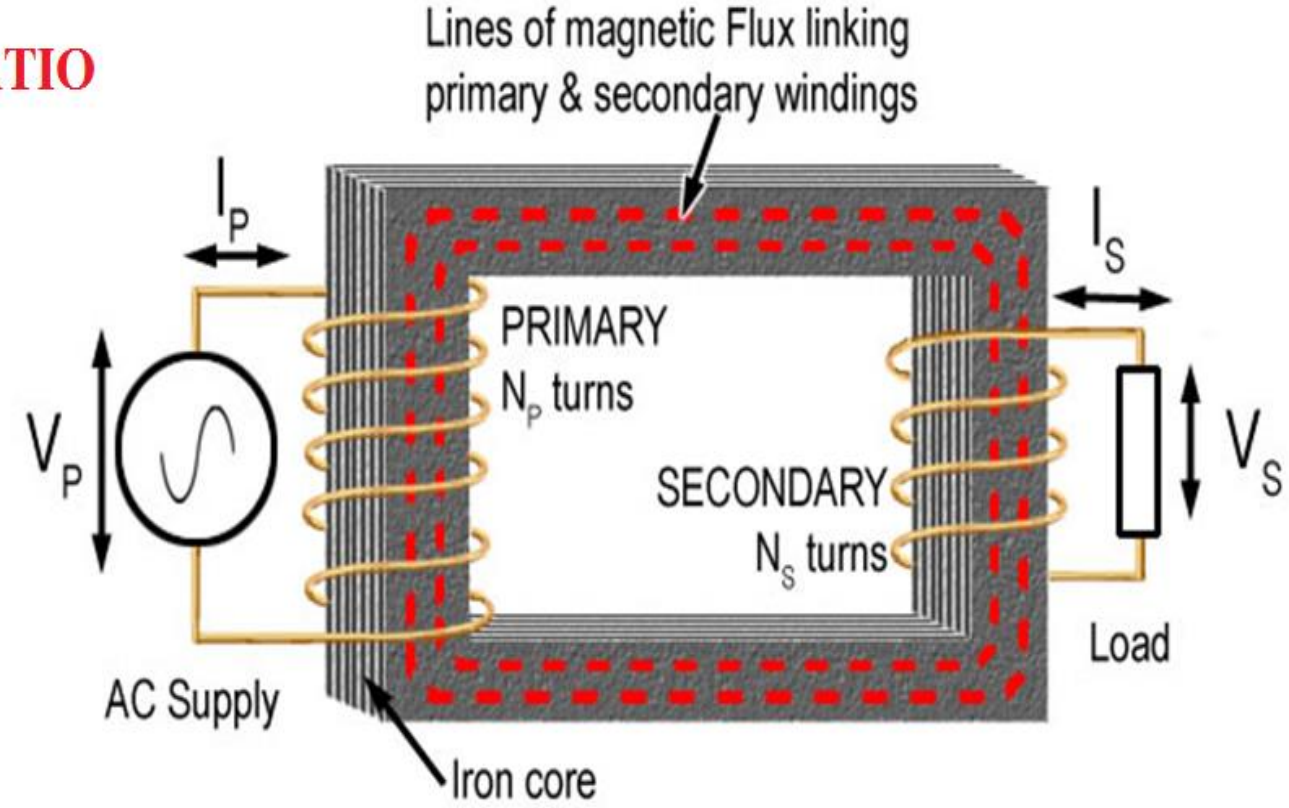




CONCEPT OF TURN RATIO

$$a = \frac{n_1}{n_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

where: a = turns ratio of transformer
n_1 = number of turns on primary
n_2 = number of turns on secondary
V_1 = primary voltage
V_2 = secondary voltage
I_1 = primary current
I_2 = secondary current



$$\frac{\text{The number of primary turns } N_P}{\text{The number of secondary turns } N_S} = \frac{\text{The primary voltage } V_P}{\text{The secondary voltage } V_S}$$

$$\frac{\text{The number of secondary turns } N_S}{\text{The number of primary turns } N_P} = \frac{\text{The primary current } I_P}{\text{The secondary current } I_S}$$

EXAMPLE: A transformer has 400 turns on the primary and 1200 turns on the secondary. If 120 volts of AC current are applied across the primary, what voltage is induced into the secondary?

Given

$E_S = ?$

$E_P = 120\,V$

$N_S = 1200$ turns

$N_P = 400$ turns

Solution

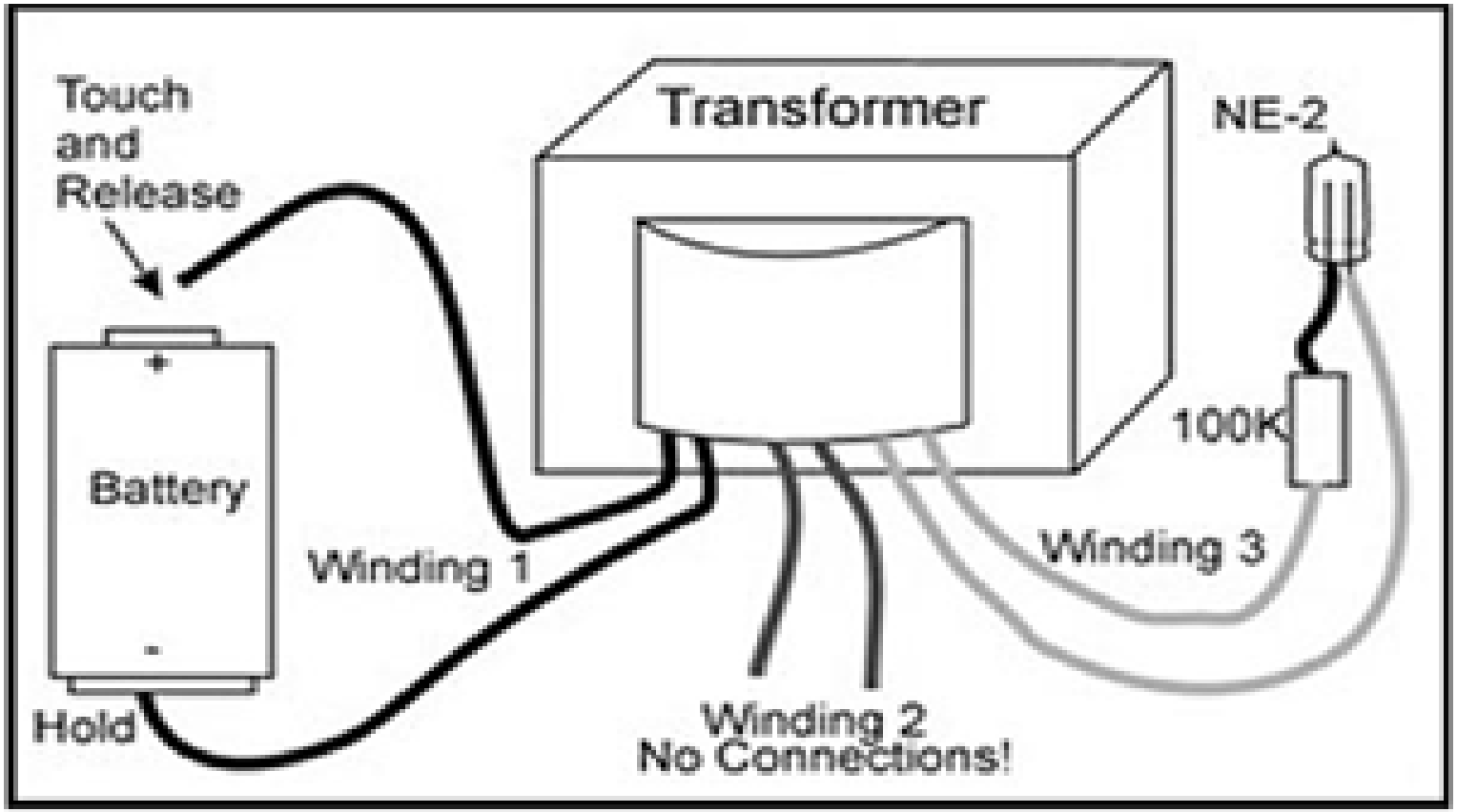
$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

$$\frac{E_S}{120} = \frac{1200}{400}$$

$$E_S = 360\,V$$

TRANSFORMER ON DC SUPPLY

- What will happen if the Primary of a Transformer is Connected to D.C. Supply????



Transformer on DC

- Transformer can not work on DC
- because if the dc voltage is applied to the primary of the transformer then the flux linking with the primary will not vary and will remain constant in magnitude. Therefore no emf is induced in the secondary.

- Also there is no self induced emf in primary. The **resistance of primary coil is very low** and a **high current** will flow across **the primary** which will result burning of primary coil according to ohm's law.

$$V=IR$$

This is the reason that DC is never applied to transformers.

Losses in transformer

(I) Core Losses Or Iron Losses

a) Hysteresis loss

b) Eddy current loss

(ii) Copper loss

Copper loss is due to ohmic resistance of the transformer windings. Copper loss for the primary winding is $I_1^2R_1$ and for secondary winding is $I_2^2R_2$. Where, I_1 and I_2 are current in primary and secondary winding respectively, R_1 and R_2 are the resistances of primary and secondary winding respectively.

Applications of Transformer.

- **Why do we need transformer ?**

(a) Step Up.

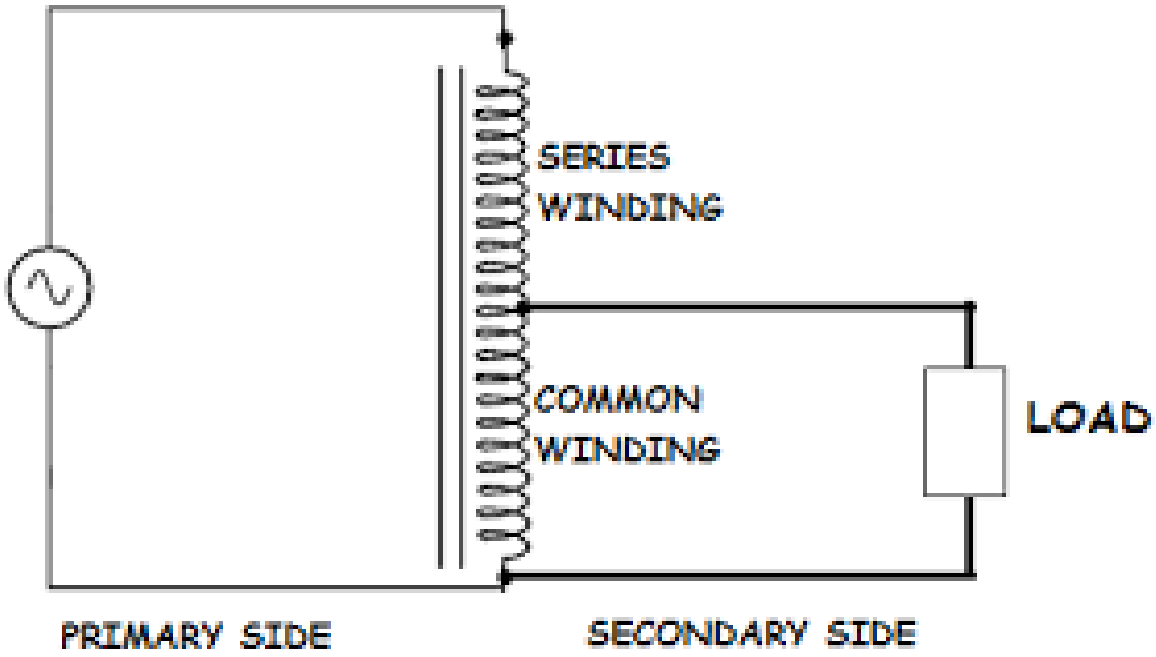
- ***Step up*** transformer, it will ***decrease*** the current to keep the power into the device equal to the power out of it.
- In modern power system, electrical power is ***generated*** at voltage of 12kV to 25kV. Transformer will ***step up*** the voltage to between 110kV to 1000kV for ***transmission*** over long distance at very low lost.

(b) Step Down.

- The transformer will ***stepped down*** the voltage to the 12kV to 34.5kV range for ***local distribution*** in the ***homes***, offices and factories as low as 120V (America) and 240V (Malaysia).

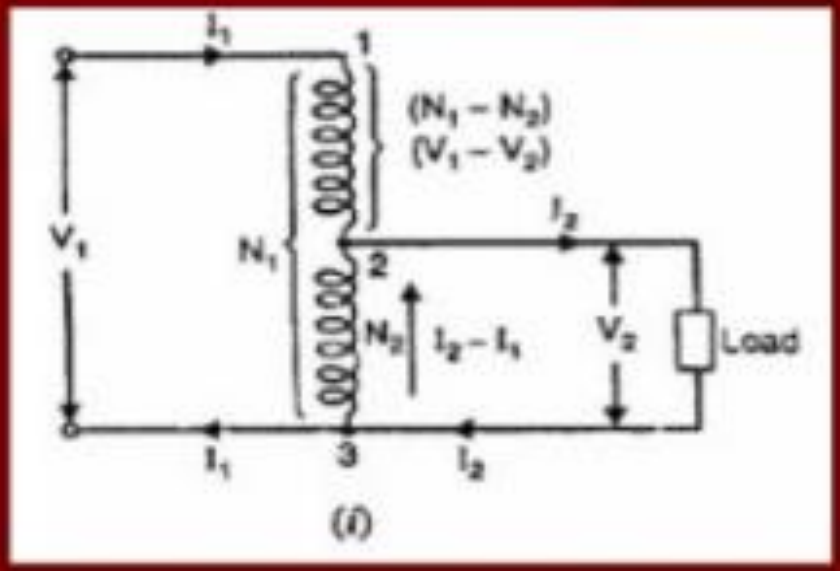
Auto-Transformer

- An Auto-transformer is an electrical transformer with only one winding.
- It is a special transformer connection that is useful in power system, motor starters,and other applications.



Theory of Autotransformer

- N1=primary turn(1-3)
- N2=secondary turn(2-3)
- I1=primary current
- I2=secondary current
- V1=primary voltage
- V2=secondary votage



(i)

From the above fig. We get

$$\frac{V_2}{V_1 - V_2} = \frac{N_2}{N_1 - N_2}$$

$$V_2(N_1 - N_2) = N_2(V_1 - V_2)$$

$$V_2N_1 - V_2N_2 = N_2V_1 - N_2V_2$$

$$V_2N_1 = N_2V_1$$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

Advantages Of Autotransformers

- An autotransformer requires less Cu than a two-winding transformer of similar rating.
- An autotransformer operates at a higher efficiency than a two-winding transformer of similar rating.
- An autotransformer has better voltage regulation than a two-winding transformer of the same rating.
- An autotransformer has smaller size than a two-winding transformer of the same rating.

INSTRUMENT TRANSFORMER

- Instrument transformers are other type of transformers which is mainly use for measuring purposes.

- To Measure high voltages and high currents these kind of instrument transformers are widely used.

- Ammeters and Voltmeters are use for measure the voltage and currents of Direct Current but in High voltage alternative Current instruments are difficult to measure by using ammeters and voltmeters.

- So to solve these problems instrument transformers are use to measure these kinds of large alternative currents and voltages.
- Normally Instrument Transformers can divide in to two sections such as Current Transformers and Potential Transformers.

Instrument Transformers

- The original magnitude can be determined by just multiplying the result with the transformation ratio. Such specially constructed transformers with accurate turns ratio are called as **Instrument transformers**.
- These instruments transformers are of two types –

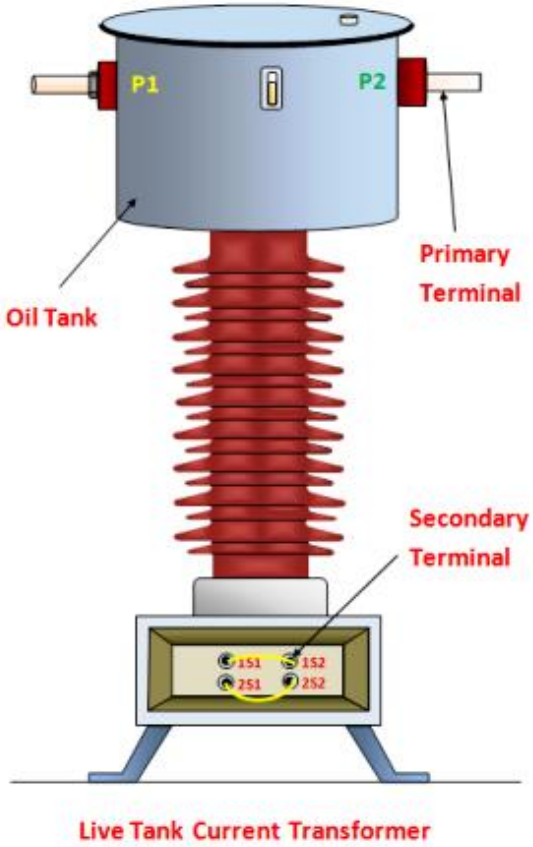
  (i) **Current Transformers (CT)** and

  (ii) **Potential Transformers (PT)**.

Current Transformers

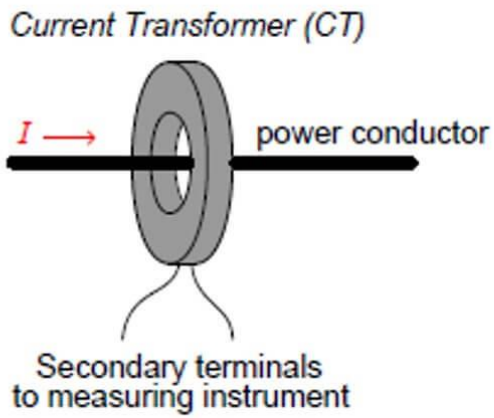
Construction of C.T.:

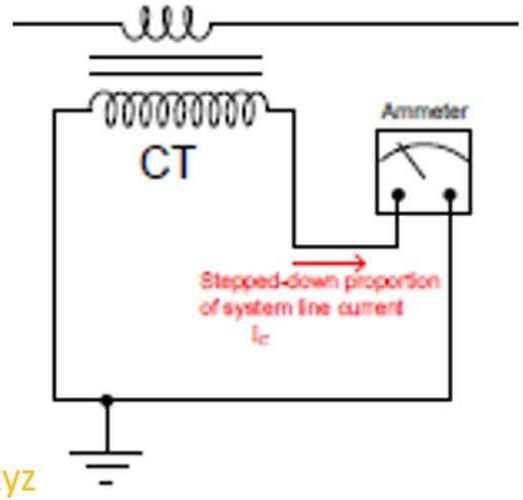
- C.T. has a primary coil of one or more turns made of thick wire connected in series with the line whose current is to be measured.
- The secondary consists of a large number of turns made of fine wire and is connected across an ammeter



Live Tank Current Transformer

Current transformer





Potential Transformers

Construction and working of P.T.:

Construction

- A potential transformer has many primary winding turns but few number of secondary winding turns that makes it a step-down transformer.
- A Voltmeter is connected to the secondary winding is usually a voltmeter of 150 V.

Working (Measurement):

- Primary terminals are connected in parallel across the line to which the voltage is to be measured.
- The voltmeter reading gives the transformed value of the voltage across the secondary terminals.

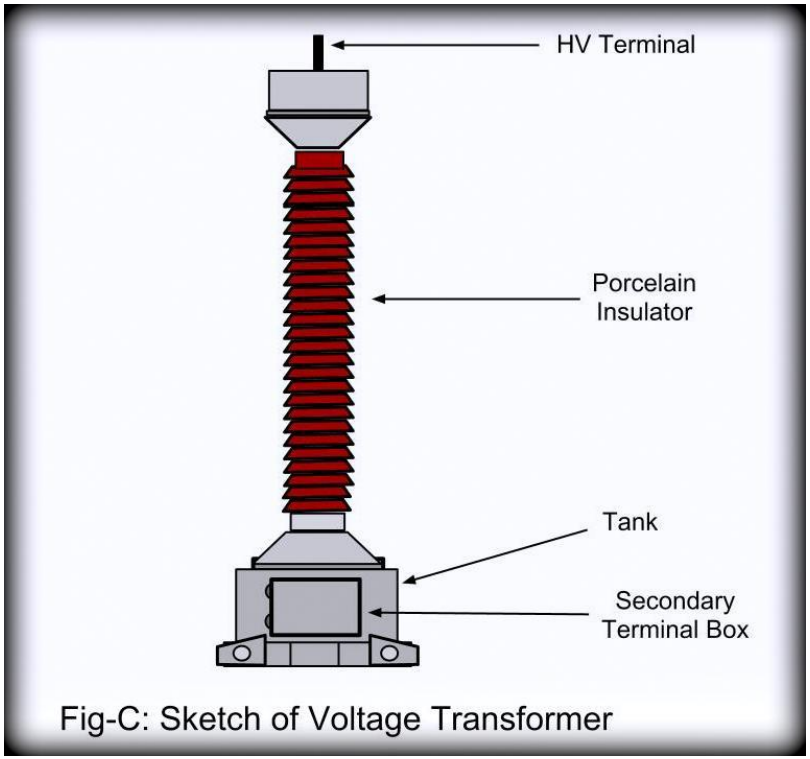
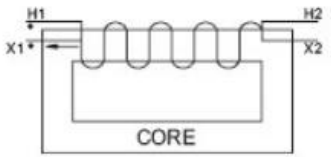


Fig-C: Sketch of Voltage Transformer

Potential Transformer

Voltage Transformer



Voltage Example
Primary 7200 Volts
Ratio 60:1 or 7200:120 Volts