Transformer:

If we arrange two electrically isolated coils in such a way that the time-varying flux due to one of them causes an electromotive force (emf) to be induced in the other, they are said to form a transformer. In other words, a transformer is a device that involves magnetically coupled coils.

A transformer is a stationary apparatus by which electric power in one circuit is transformed to another with the same frequency but without any direct electrical connection between input and output.

Construction:

The essential components of the transformer are

(1) Magnetic Core

(2) Two windings, namely primary and secondary.

(3) A time varying magnetic flux.

(i) Magnetic circuit:

The core of the transformer forms the magnetic circuit.

In order to keep the hysteresis loss to minimum, the core of the transformer is built up of highly permeable ferromagnetic material such as silicon steel.

In order to reduce the eddy current loss, core is built up of thin laminations with thickness varying from 0.014 inch to 0.024 inch. A thin coating of varish is applied to both sides of lamination in order to provide high interlamination resistance.

Electrical Circuit:

primary and secondary windings form the electrical circuit. These windings are made of copper and it's cross-section can be either circular or rectangular, based on the voltage level.

According to the core construction and the manner in which these windings are wound, transformers are classified as

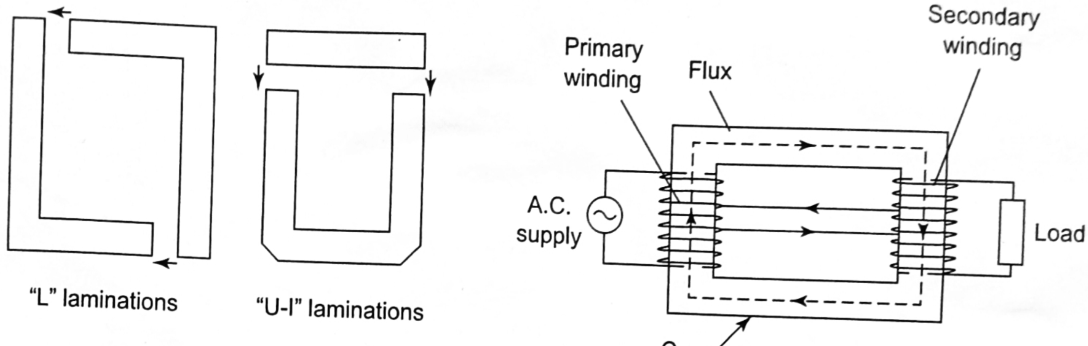
(i) core-type

(ii) Shell type.

(i) Core-type transformer:

In this type, rectangular frame laminations are formed to build the core of the transformer. The laminations of having 'I', 'L' and 'U' Shapes are used to construct the core.

The "L-L" or "U-I" Combinations are used to construct the core as shown below.

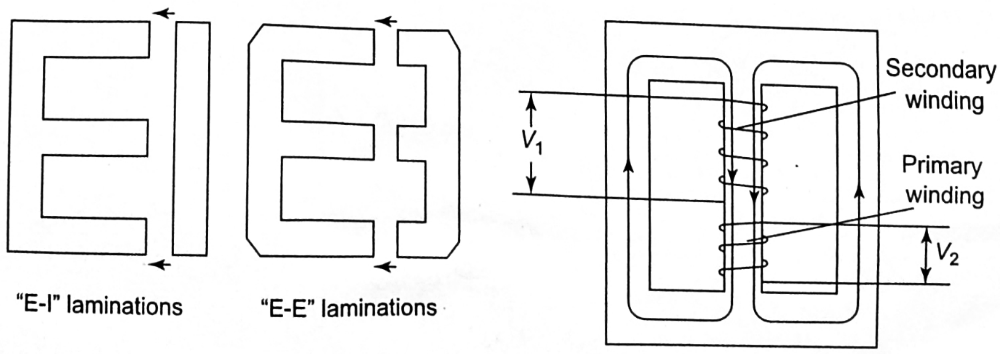


(a) (b)

For simplicity, the primary and secondary windings are locate on the seperate limbs of the core.

(ii) Shell-type Transformer:

The shell type transformer is obtained using the laminations of type "E" and "I", as "E-I" or "E-E" laminations as shown below.



(a) (b)

This type of transformer has three limbs or legs. width of the

Central limb is twich the width of the outer limbs. The two windings of the transformer are wound on the central limb & hence the central limb carries the whole flux whereas the side limbs carry only half of the flux.

Cooling Mechanism:

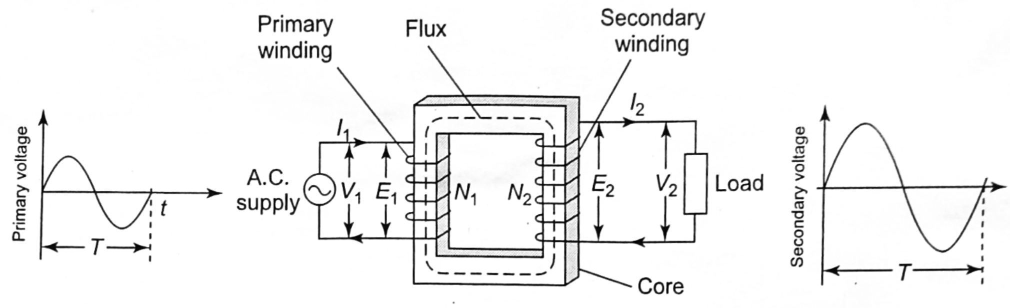
Both the core loss (hysteresis and eddy-current loss) and the copper loss (electrical loss) generate heat which in turn, increases the operating temperature of the transformer.

For low-power applications, natural air cooling may be enough to keep the temperature of the transformer within acceptable range.

For medium power applications, transformer is cooled by forced-air circulation. When forced-air circulation is not enough, transformer core is immersed in a tranformer oil which carries the heat to the walls of the tank. Cooling fins are provided on the outer side of the tank to increase the heat dissipation into the atmosphere.

Working principle:

A two-winding transfor with each winding acting as a part of a seperate electric circuit is shown below.



Let N_1 and N_2 be the number of turns in the primary and secondary windings. The primary winding is Connected to a time-varying voltage source V_1 of frequency, f while the secondary winding is left open.

According to Faraday's Law of induction, the magnetic flux ϕ in the core induces an emf e_1 in the primary winding that opposes the applied voltage, V_1. we can write $e_1 = N_1 \frac{d\phi}{dt}$ $\rightarrow$ (1)

Similary, the induced emf in the secondary winding is

$$e_2 = N_2 \frac{d\phi}{dt}$$

from eqns. 1 + 2, we can write

$$\frac{V_1}{V_2} = \frac{e_1}{e_2} = \frac{N_1 \frac{d\phi}{dt}}{N_2 \frac{d\phi}{dt}}$$

$$\frac{e_1}{e_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} \longrightarrow (3)$$

$\therefore$ Ratio of primary to secondary induced emfs is equal to the ratio of primary to secondary turns.

This ratio is called as transformation ratio.

For sinusoidal variations in the applied voltage, magnetic flux in the core also varies sinusoidally. If the flux in the core at any instant, t is given as

$$\phi = \phi_m \sin\omega t \longrightarrow (4)$$

$\therefore$ Induced emf in the primary is

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

$$e_1 = N_1 \omega \phi_m \cos\omega t \rightarrow (5)$$

$$e_1 = E_m \sin\omega t \longrightarrow (6)$$

$\therefore$ RMS value of induced emf is

$$E_1 = \frac{E_m}{\sqrt{2}} = \frac{N_1 \omega \phi_m}{\sqrt{2}} = \frac{N_1 2\pi f \phi_m}{\sqrt{2}} = 4.44 f N_1 \phi_m \rightarrow (6)$$