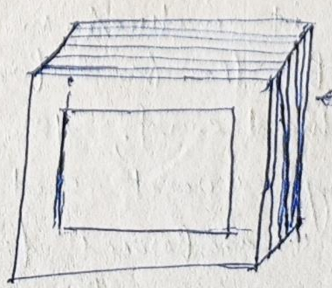
Transformer:-

The transformer is a device for transferring electrical energy from one alternating current circuit to another without a change in frequency. A transformer may receive energy at one voltage and deliver it at a higher voltage, ~~it~~ in which case it is called a step-up transformer. When the energy is received at a higher voltage and delivered at a lower voltage, it is called a step-down transformer.

The electric circuit which receives energy from the supply mains, is called primary winding, and the other circuit which delivers electric energy to the load, is called the secondary winding.

Construction:- The simple elements of a transformer consists of two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and the steel core. Other necessary parts are — some suitable container for the assembled core and windings, a suitable medium for insulating the core and its windings from its container, suitable ~~b~~ bushings (either of porcelain, oil-filled or capacitor type) for insulating and bringing out the terminals of windings from the tank.

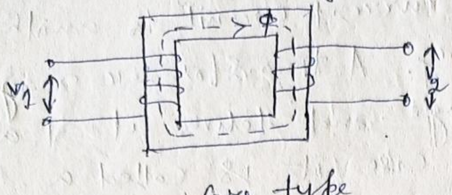
The magnetic core is a stack of thin silicon-steel laminations about 0.35 mm. thick for 50 Hz. transformers. In order to reduce the eddy current losses, these laminations are insulated from one another by thin layers of varnish.



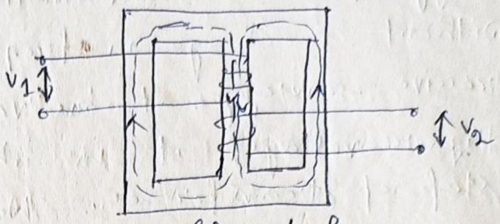
← Laminated Steel core.

Constructionally the transformers are of two general types :- ① Core type and ② Shell type.

In the core type, the windings surround a considerable part of steel core. In the shell type, the steel core surrounds a major part of the windings.



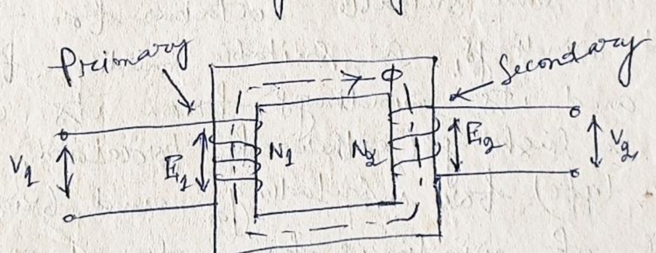
Core type



Shell type

In actual construction, primary and secondary windings are always interleaved to reduce leakage flux.

Transformer Principle:- The transformer is based on the principle that energy may be efficiently transferred by induction from one set of coils to another by means of a varying magnetic flux, provided that both sets of coils are on a common magnetic circuit. Electromotive forces are induced by change in flux linkages.

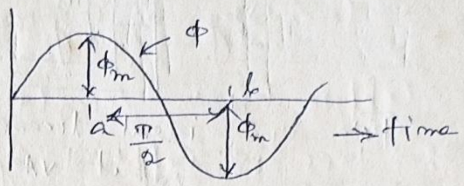


Here, an a.c voltage is applied to the primary winding. As this winding is linked with an iron core, its m.m.f. produces an alternating flux φ in the core. This alternating flux links the turns of the secondary winding. As this flux is alternating, it induces in the secondary winding an e.m.f. of the same frequency as the flux. Because of this induced e.m.f, the secondary winding is capable of delivering current and energy. The energy therefore, is transferred from the primary to the secondary, by means of magnetic flux.

E.m.f. equation of a transformer:-

Let, N_1 = No. of turns in primary

N_2 = No. of turns in secondary.



ϕ_m = Maximum flux in core in webers

$= B_m \times A$

where, B_m = Maximum flux density (wb/m^2) in the core

A = Area of cross section of the core.

Above figure shows the mutual flux ϕ varying sinusoidally with time. Between points a and b, the total change of flux is $2\phi_m$ ~~wb.~~ webers.

This change of flux occurs in a half cycle or in a time $\frac{T}{2}$ sec., where T is the time period.

Average induced e.m.f. in the primary winding,

$$e_1 = -N_1 \frac{2\phi_m}{T/2} = -N_1 \cdot \frac{2\phi_m}{\frac{1}{2f}}$$

$$= -4fN_1\phi_m \text{ Volts.}$$

Since, the form factor for a sine wave is 1.11,

r.m.s. induced e.m.f. is, $E_1 = -4.44fN_1\phi_m$.

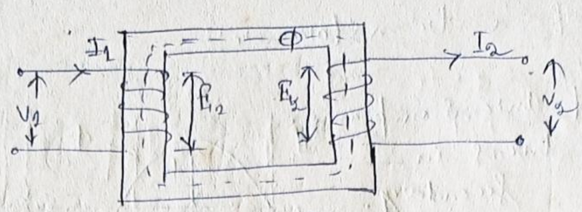
$$\Rightarrow \boxed{E_1 = -4.44fN_1B_mA} \text{ Volts.}$$

Similarly, Voltage induced in the secondary winding,

$$\boxed{E_2 = -4.44fN_2B_mA}$$

So, $$\boxed{\frac{E_1}{E_2} = \frac{N_1}{N_2}}$$

So, Transformation ratio, $$\boxed{K = \frac{E_1}{E_2} = \frac{N_1}{N_2}}$$



For an ideal transformer,

input VA = output VA.

$$\therefore V_1 I_1 = V_2 I_2$$

$$\therefore \frac{I_2}{I_1} = \frac{V_1}{V_2} = K = \frac{N_1}{N_2} = \frac{E_1}{E_2}.$$

~~So,~~ $\cancel{\frac{V_1}{V_2}}$

Transformer on No-load :-

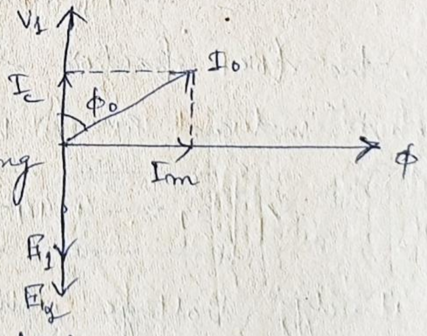
When an actual transformer is put on load, there is iron loss in the core and copper loss in the windings.

When the transformer is on no-load, the primary input current is not wholly reactive. The primary input current under no-load conditions has to supply (i) iron losses in the core i.e, hysteresis loss and eddy current loss and (ii) a very small amount of copper loss in primary winding.

Hence no-load primary current, I_0 lags behind V_1 by an angle $\phi_0 < 90^\circ$.

No-load input power,

$$W_0 = V_1 I_0 \cos\phi_0.$$



I_c - is called active or working or iron loss component, because it mainly supplies the iron loss plus small quantity of primary cu-loss.

I_m - is called magnetising component, because its function is to sustain the alternating flux in the core.

I_0 - is very small in comparison to full load primary current. It is about 3% of full load current.