Transformer on No load:-

→ A T/R is Said to be on no load when the Secondary winding is open-circuited.

→ The Secondary current is thus zero.

→ When an alternating voltage is applied to the primary, a small current I_0 flows in the primary.

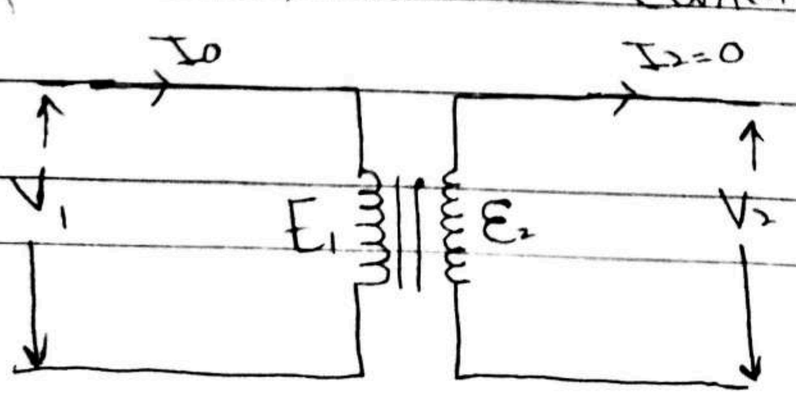
→ The current I_0 is called the no-load current of the transformer.

→ It is made up of two components I_μ and I_w.

→ The component I_μ is called the magnetizing component.

→ It magnetizes the core. In other words, it sets up a flux in the core and therefore I_μ is in phase with ϕ_m.

→ The current I_μ is also called reactive or wattless component of no-load current as it does not consume any power.



→ The component I_w supplies the hysteresis and eddy current losses in the core and the negligible I^2R loss in the primary winding.

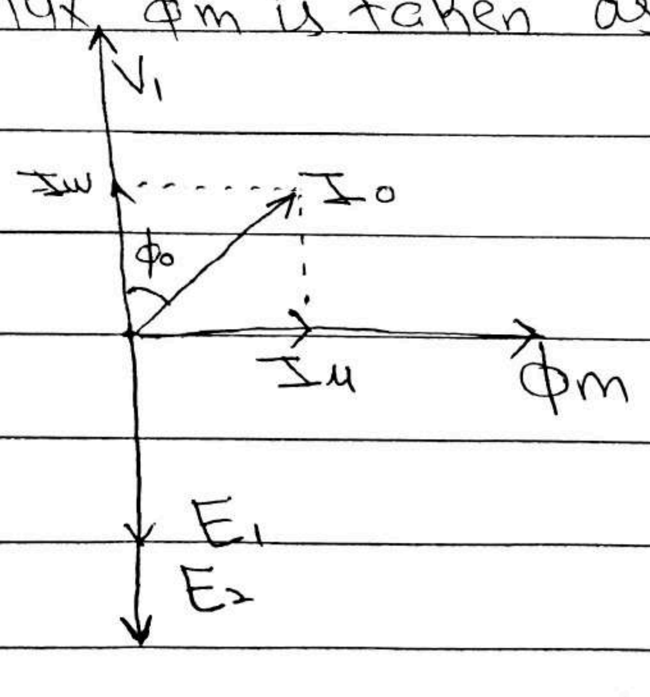
→ The current I_w is called the active component or wattful component of no-load current I_o and is in phase with the applied voltage V_1.

→ The no-load current I_o is small of the order of 3 to 5 percent of the rated current of primary.

<u>Phasor Diagram at No load:-</u>

→ An approximate phasor diagram for a T/R under no-load condition is shown below.

→ The flux ϕ_m is taken as the reference phasor.



→ Since E_1 and E_2 are induced by the same flux ϕ_m hence they will be in phase with eachother and other will lag ϕ_m by 90°.

→ If voltage drops in the primary winding are neglected, E_1 will be equal and opposite to the applied voltage V_1.

→ I_μ is in phase with ϕ_m and I_w is in phase with V_1.

→ The phasor sum of I_μ and I_w is I_o.

→ Angle ϕ_o is called the no-load angle.

from the phasor diagram:

$$I_w = I_o \cos\phi_o$$

$$I_\mu = I_o \sin\phi_o$$

$$I_o = \sqrt{I_w^2 + I_\mu^2}$$

Also core loss $= V_1 I_o \cos\phi_o = V_1 I_w$ watts

magnetizing (reactive) Volt Amperes

$= V_1 I_o \sin\phi_o = V_1 I_\mu$ VAR

Also power factor, $\cos\phi_o = \frac{I_w}{I_o}$

Practical Transformer:-

→ In an ideal T/R, certain assumptions were made which are not valid in a practical T/R.

→ for example, in a practical T/R, the windings have resistance, the core has finite permeability and there is a leakage of flux

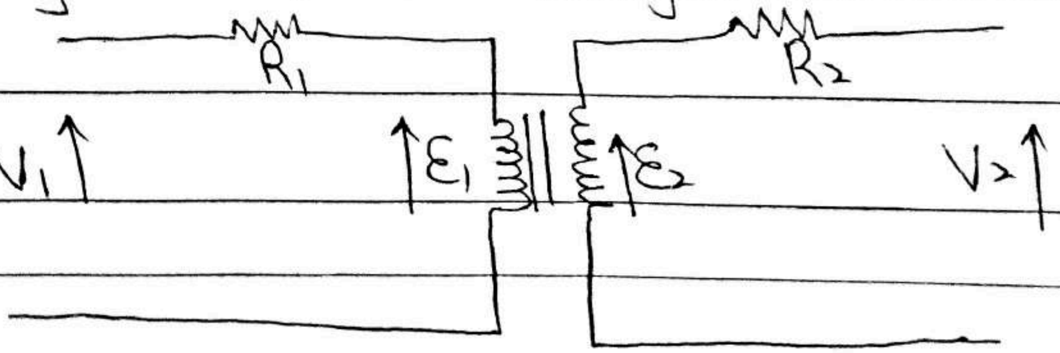
→ The efficiency of a practical T/R is not 100 percent due to losses.

→ Therefore, in a practical T/R, we shall consider all these imperfections.

Winding Resistance:

→ An ideal T/R is supposed to have no resistance but in actual T/R, there is always some resistance of both primary and secondary windings.

→ The effect of resistance is equivalent to an ideal T/R with resistances connected in series with each winding as shown in the figure below:



Leakage Reactance:-

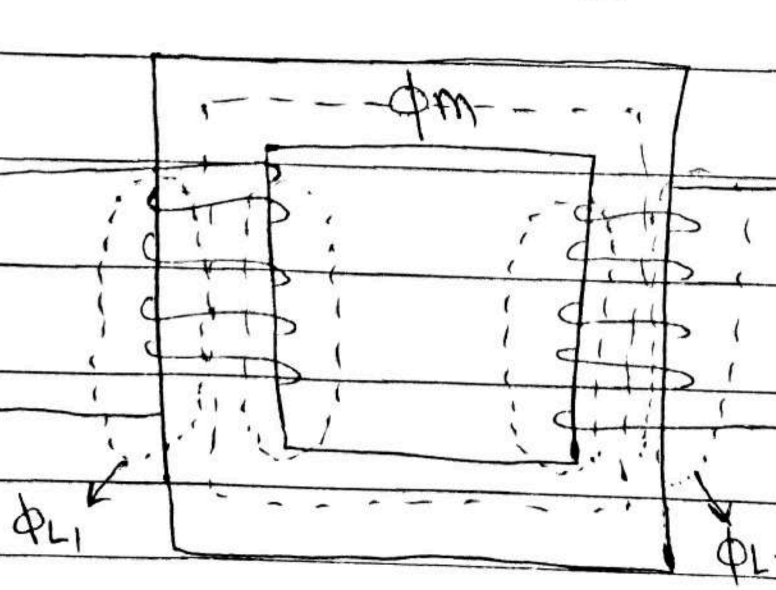
→ In an ideal T/R, is was assumed that all the flux produced by the primary winding links both the primary and Secondary winding.

→ However, in an actual T/R, not all the flux remains with in the magnetic core.

→ A portion of this flux is diverted to the surrounding air of the winding as the surrounding medium also has some permeability (although it is very much less than that of the core.

→ The small portion of the flux, which flows in the surrounding path is known as primary leakage flux denoted by ϕ_{L1} as shown in the fig below.

→ The flux ϕ_{L1} links only the primary turns and induces an emf E_{L1} in the primary winding.



→ Also, the Secondary current I_2 produces a flux ϕ_2 which opposes the main flux ϕ_m.

→ A portion of this flux is also diverted to the surrounding medium. This leakage flux is called the secondary leakage flux ϕ_{L2}, It only links the Secondary turns and induces an emf E_{L2} in the Secondary.

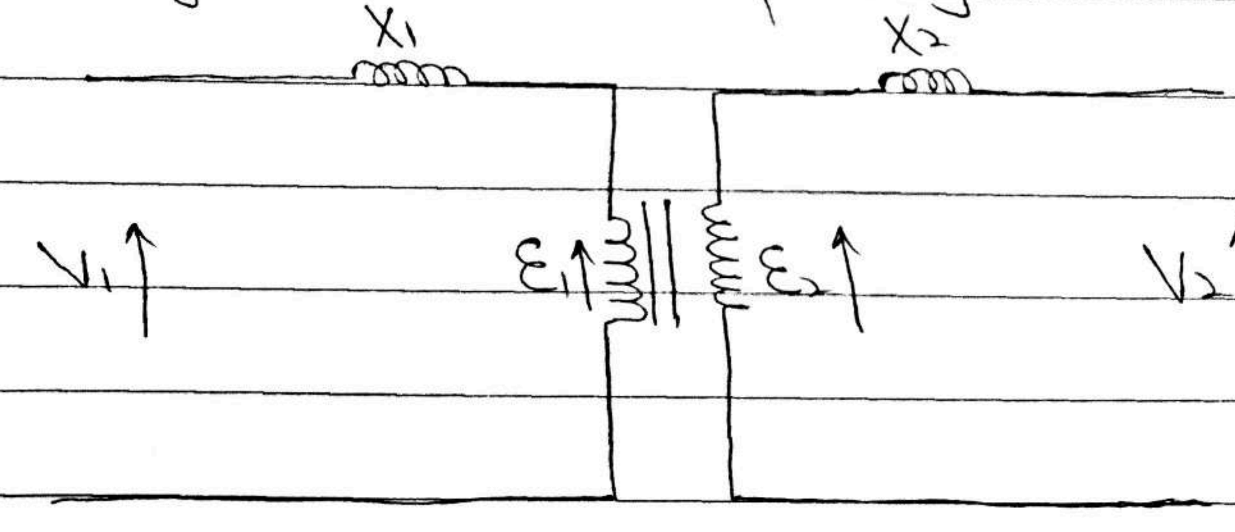
→ Thus, each leakage flux links one winding only and it is caused by the current in that winding alone.

→ The flux which passes completely through the core and links both windings is called mutual flux and is shown as ϕ_m.

→ It should be noted that the induced voltages E_{L1} and E_{L2} due to leakage fluxes ϕ_{L1} and ϕ_{L2} are different from induced voltage E_1 and E_2.

→ As the leakage flux linking with each winding produces a self induced emf in that winding, hence the effect of leakage flux is equivalent to an inductance in series with each winding such that the voltage drop in each series inductance is equal to that produced by the leakage flux.

→ In other words, a T/R with magnetic flux leakage is equivalent to an ideal T/R with inductive reactance X_1 and X_2 connected in series with the primary and secondary windings respectively. as shown in the below figure. The quantities X_1 and X_2 are known as primary and secondary leakage reactances respectively



Transformer on Load:

→ As discussed earlier, when the Secondary of the T/R is kept open, it draws the no-load current from the main supply.

→ This no-load current I_o sets up the flux ϕ_m in the core of the T/R.

→ Now, when the load is connected to the secondary of the T/R, I_2 current flows through the secondary winding.

→ This secondary current I_2 sets up the flux ϕ_2 in the T/R core.

→ This flux ϕ_2 opposes the main flux ϕ_m according to Lenz's law.

→ As the flux ϕ_2 opposes the main flux ϕ_m, the resultant flux of the T/R decreases and this flux reduces the induced emf E_1. Thus, the strength of V_1 is more than E_1.

→ In order to restore the original value of the main flux in the core, an additional primary current I_1'

is drawn from the main supply.

→ This additional current is used for restoring the original value of the main flux so that $V_1 = E_1$. Thus, it is called the primary counter-balancing current.

→ The additional current I_1' induces & sets up a flux ϕ_1' so that it cancels the flux ϕ_2.

→ The direction of ϕ_1' is same as that of ϕ_m.