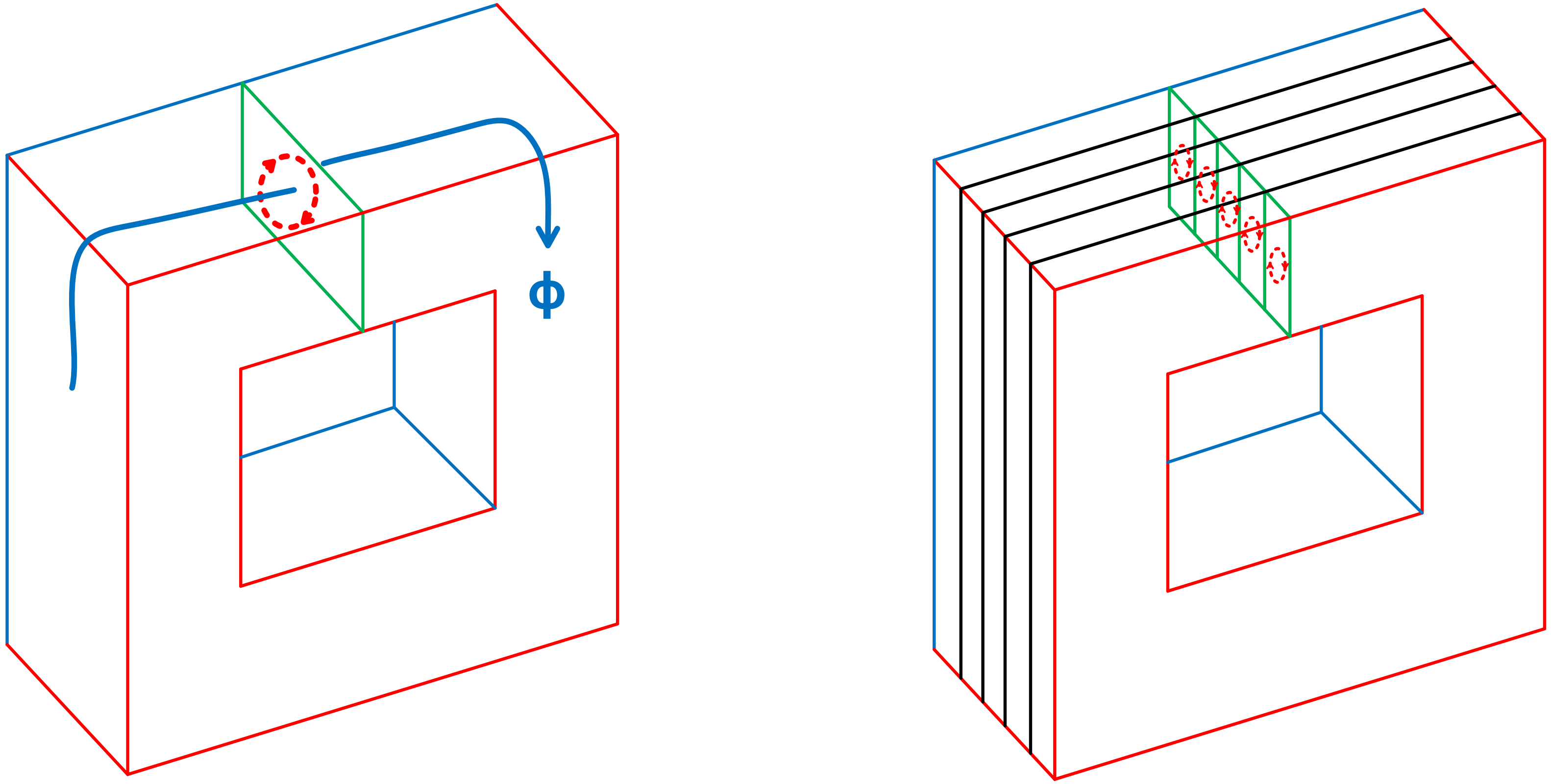
Lecture-25

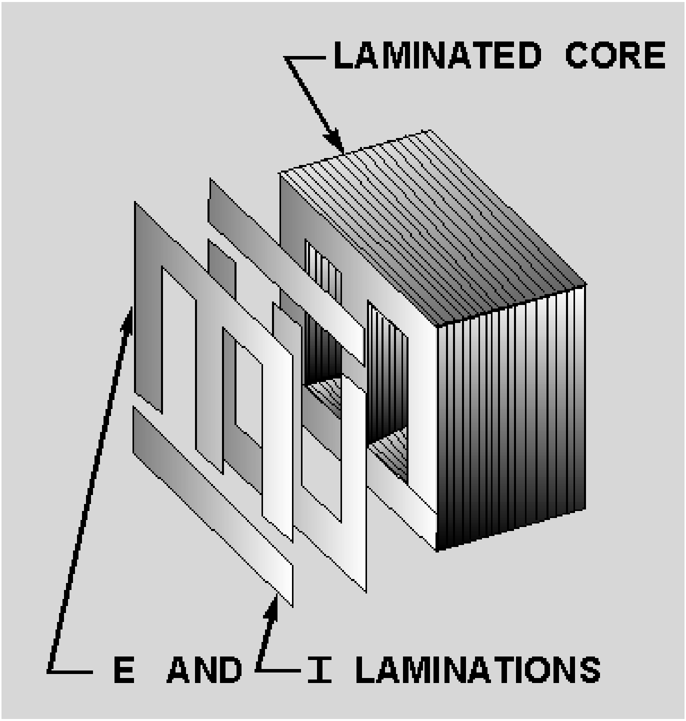
On

INTRODUCTION TO ELECTRICAL ENGINEERING (ESO203)

- Transformer equivalent circuit.
- Open circuit test.

Transformer Working (cont…)



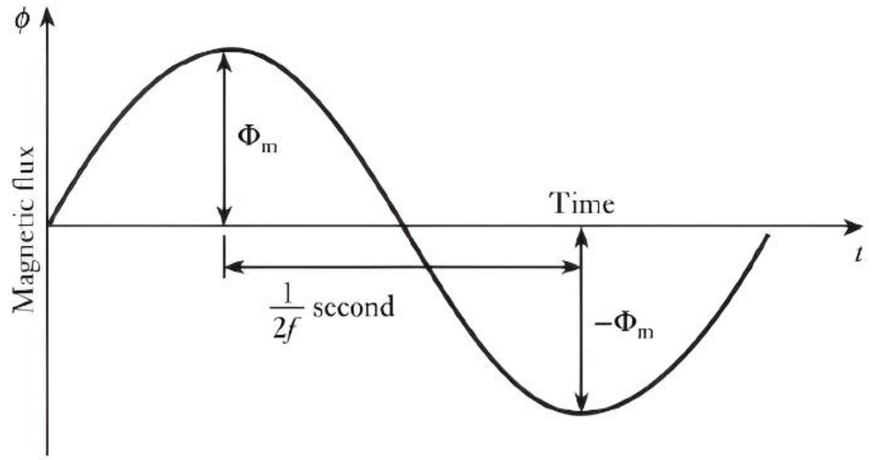


0.35–0.7 mm thick

Fig. Eddy current loss

❑ E.M.F. Equation of a Transformer

- Consider the sinusoidal waveform as shown



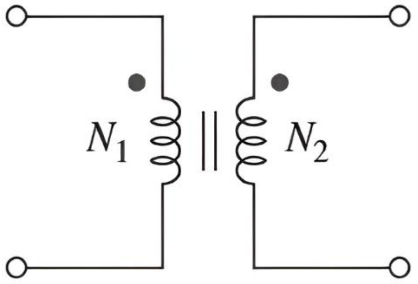
- Hence

$$\phi = \phi_m cos\omega t$$

- Therefore,

$$\frac{d\phi}{dt} = \phi_m \omega sin\omega t$$

- So, the maximum value of induced e.m.f. per turn is = $2\pi f \phi_m$.
- Then, the r.m.s. value of induced e.m.f. per turn is = $0.707 \times 2\pi f \phi_m = 4.44 f \phi_m$.
- Hence r.m.s. value of primary e.m.f. is $E_1 = 4.44 N_1 f \phi_m$.
- Hence r.m.s. value of secondary e.m.f. is $E_2 = 4.44 N_2 f \phi_m$.



❑ Example

A 250 kVA, 11000 V/400 V, 50 Hz single-phase transformer has 80 turns on the secondary. Calculate:

(a) the approximate values of the primary and secondary currents.

(b) the approximate number of primary turns.

(c) the maximum value of the flux.

Solution:

(a) Full-load primary current = 250x1000/11000 = 22.7 A

and full-load secondary current = 250x1000/400 = 625 A

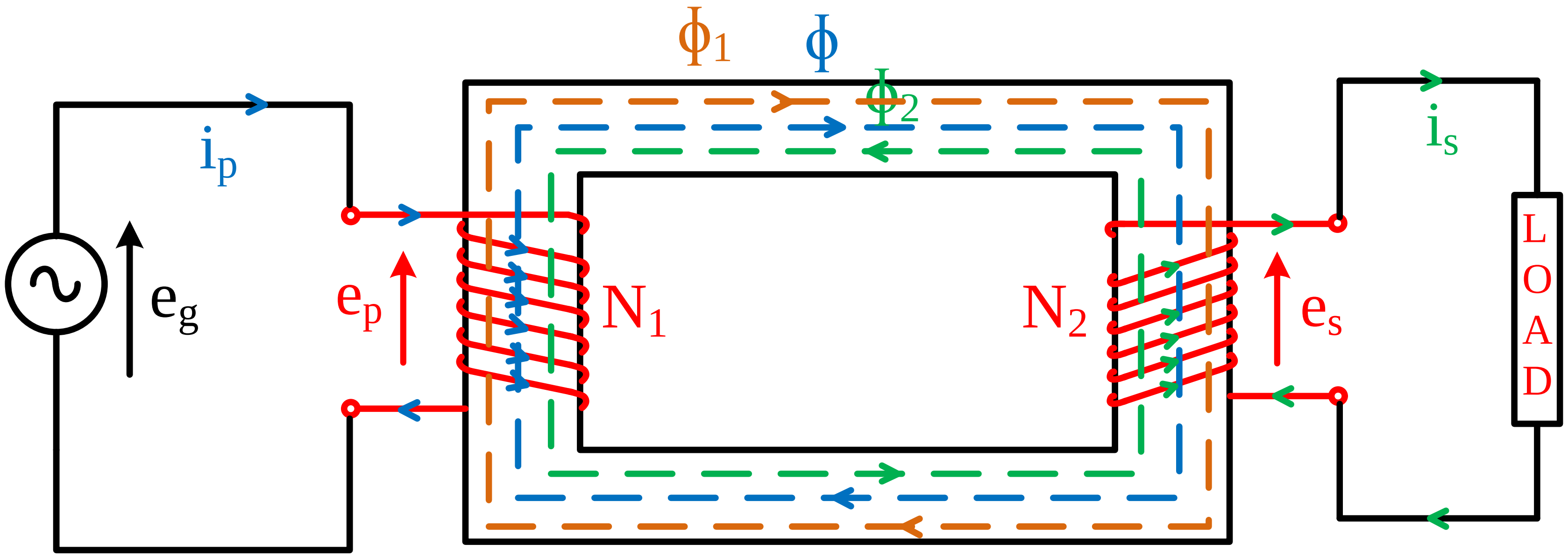
(b) No. of primary turns = 80x11000/400 = 2200

(c) $E_2 = 4.44 N_2 f \phi_m$

$\Rightarrow 400 = 4.44 \times 80 \times 50 \times \phi_m$

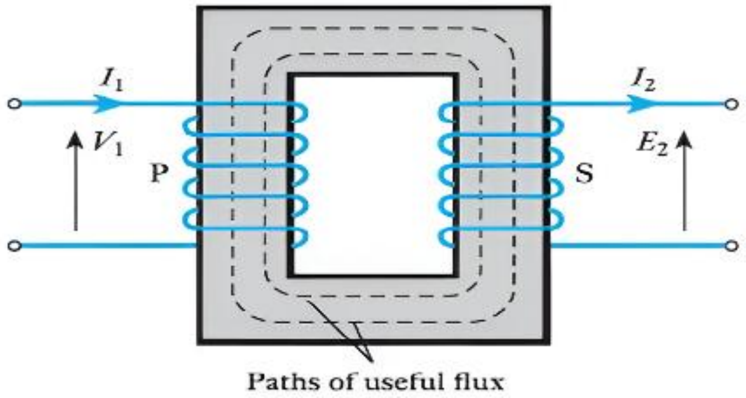
$\Rightarrow \phi_m = 22.5 mWb$

Transformer Equivalent Circuit

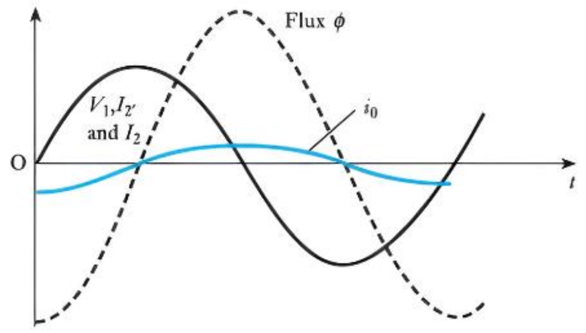


Transformer Equivalent Circuit (cont…)

❑ Flux on No Load Condition:



The current taken by the primary winding is responsible for setting up the magnetic flux and providing a very small power component to supply the loss in the core.



❑ Transformer on No Load:

The no-load current, I_0, taken by the primary consists of two components:

1. A reactive or magnetizing component, I_{0m}, producing the flux and therefore, in phase with the latter.
2. An active or power component, I_{01} , supplying the hysteresis and eddy current losses in the core and the negligible I^2R loss in the primary winding.

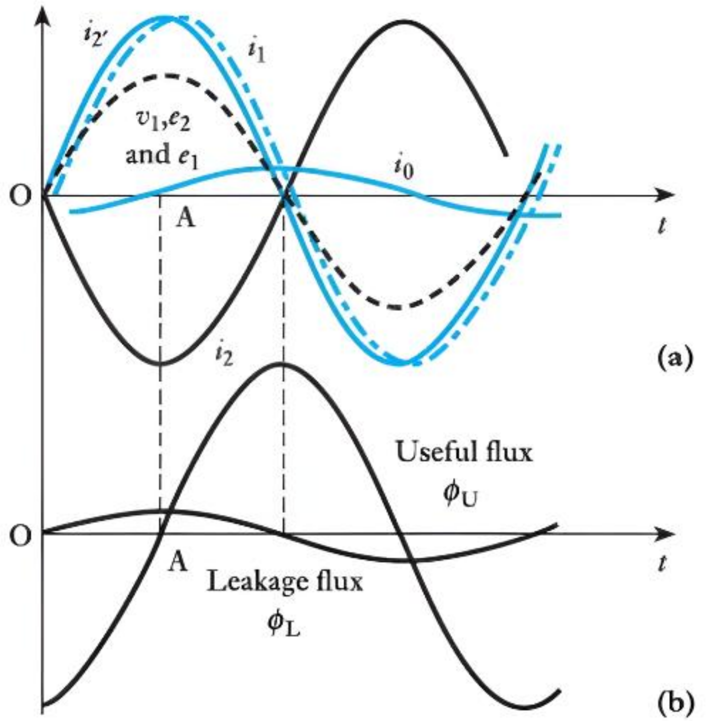
$$I_{01}V_1 = core\ loss$$

- This component is usually very small compared with I_{0m}, so that the no-load power factor is very low.

❑ Flux on Load:

I_1 must have two components:

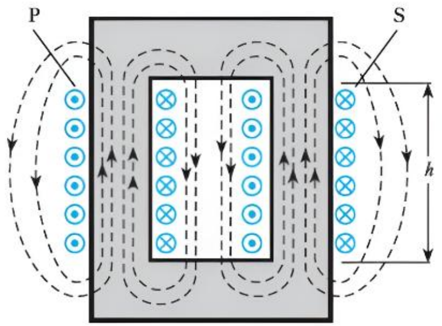
1. I_{0m} to maintain the useful flux, the maximum value of which remains constant within about 2 percent between no load and full load.



2. A component, I_2' , to neutralize the demagnetizing effect of the secondary current, as we assume a load having a power factor such that the secondary current is in phase with E_2.

Transformer Equivalent Circuit (cont…)

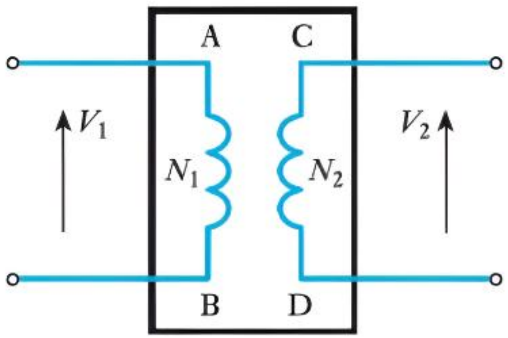
❑ Leakage Flux:

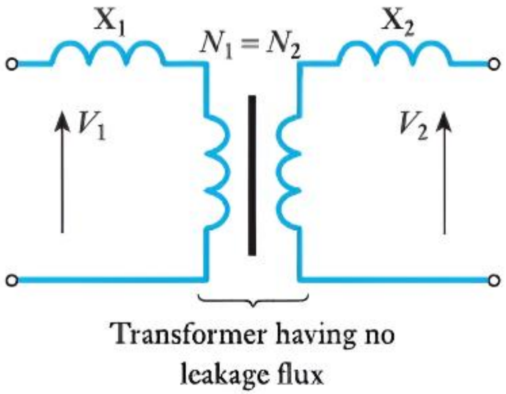


1. The useful flux, ϕ_U, linked with both windings and remaining practically constant in value at all loads.
2. The leakage flux, ϕ_L, half of which is linked with the primary winding and half with the secondary, and its value is proportional to the load.

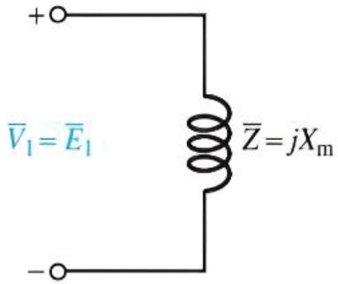
The reluctance of the paths of the leakage flux is very high, so that the value of this flux is relatively small even on full load when the values of I_2' and I_2 are about 20–30 times the magnetizing current I_{0m}.

❑ Leakage Reactance:





❑ Non-ideal Transformer:



$$R_1 + jX_1$$

Non ideal effects of primary windings.

Iron core excited by an AC mmf

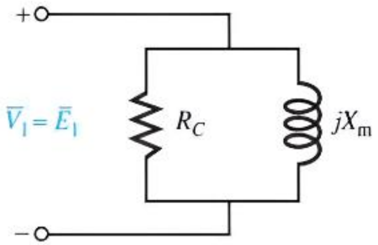
$$P_e = K_e (B_{max} f \delta)^2$$

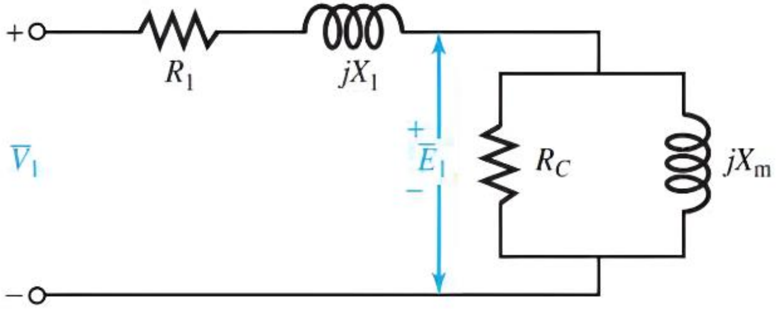
δ = lamination thickness

B_{max} = maximum flux density

f = frequency

K_e = proportionality constant

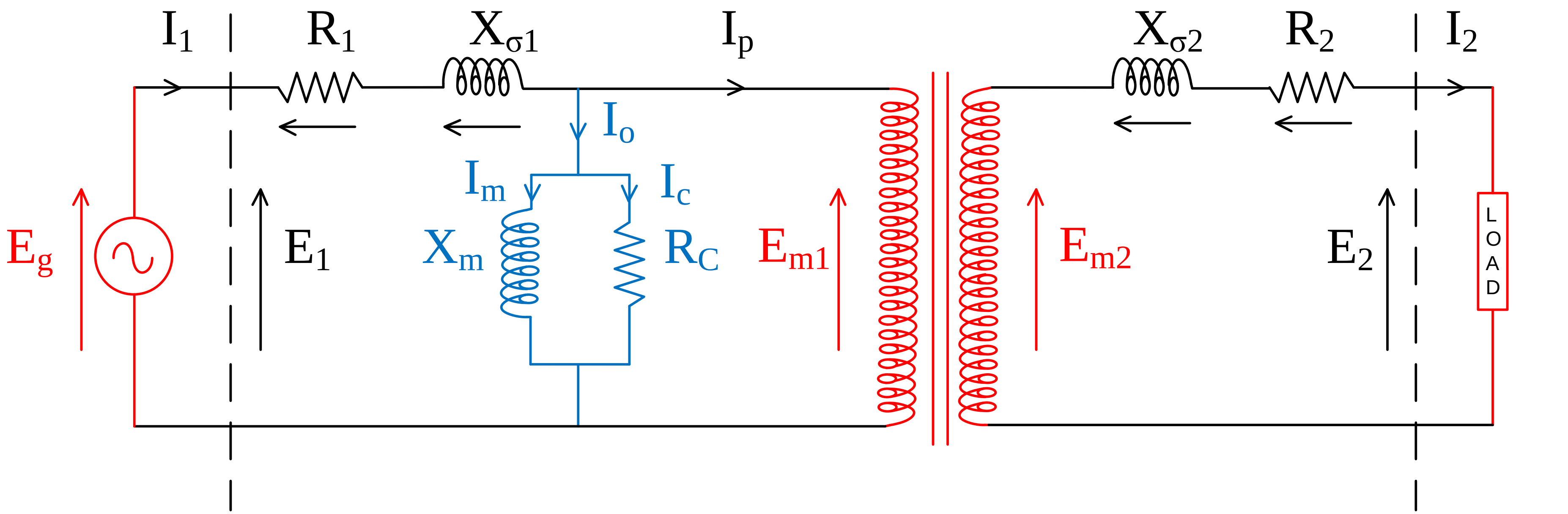




$$P_h = K_h f B_{max}^n$$

K_h is a proportionality constant dependent on characteristics and volume of iron; the exponent n ranges from 1.5 to 2.5

Transformer Equivalent Circuit (cont…)



$I_1 R_1$ = Voltage drop due to primary resistance

$I_1 X_{p1}$ = Voltage drop due to primary leakage reactance

$I_1 Z_1$ = Voltage drop due to primary impedance

$E_g = E_{m1} + I_1 Z_1$ = Supply voltage

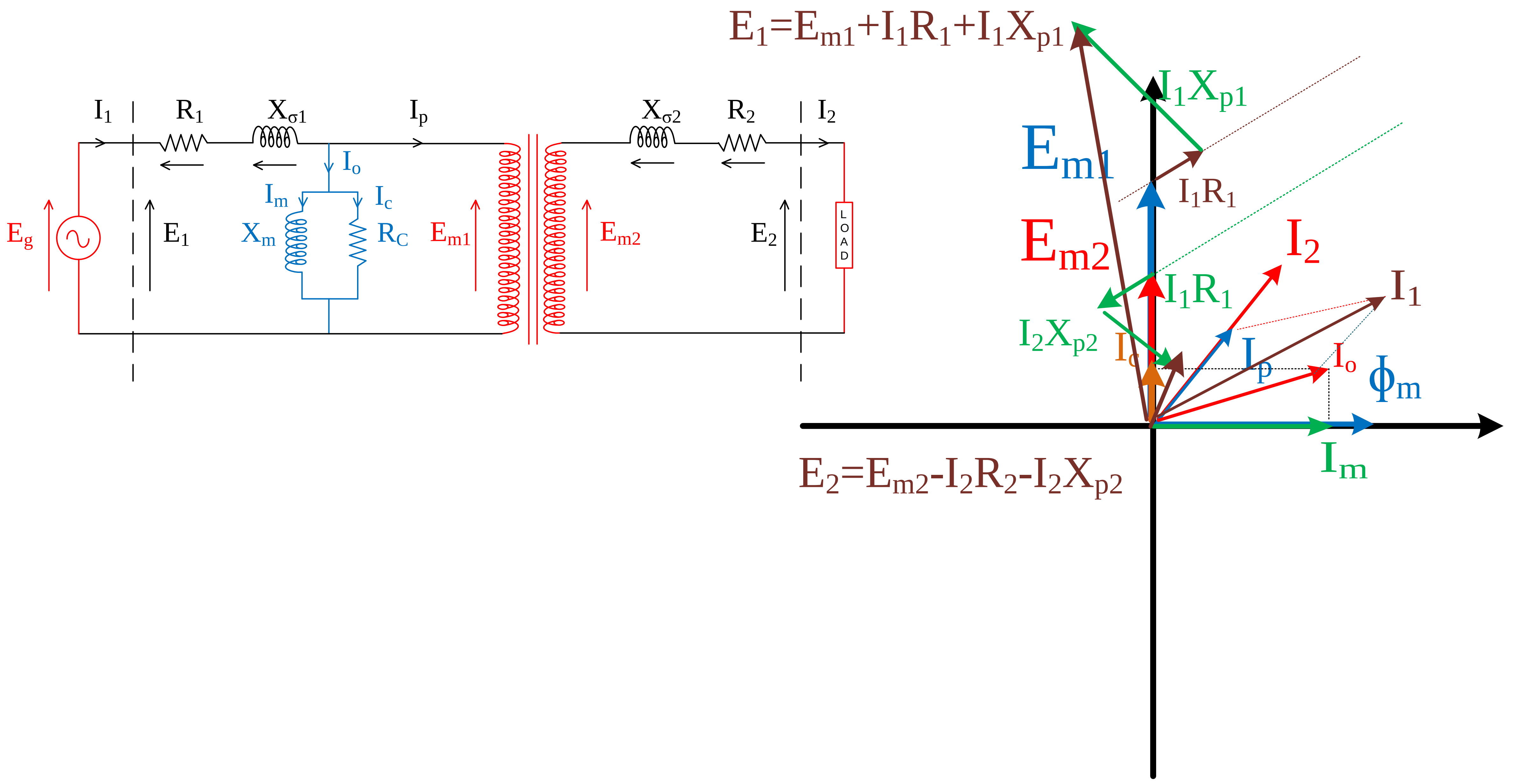
$I_2 R_2$ = Voltage drop due to secondary resistance.

$I_2 X_{p2}$ = Voltage drop due to secondary leakage reactance.

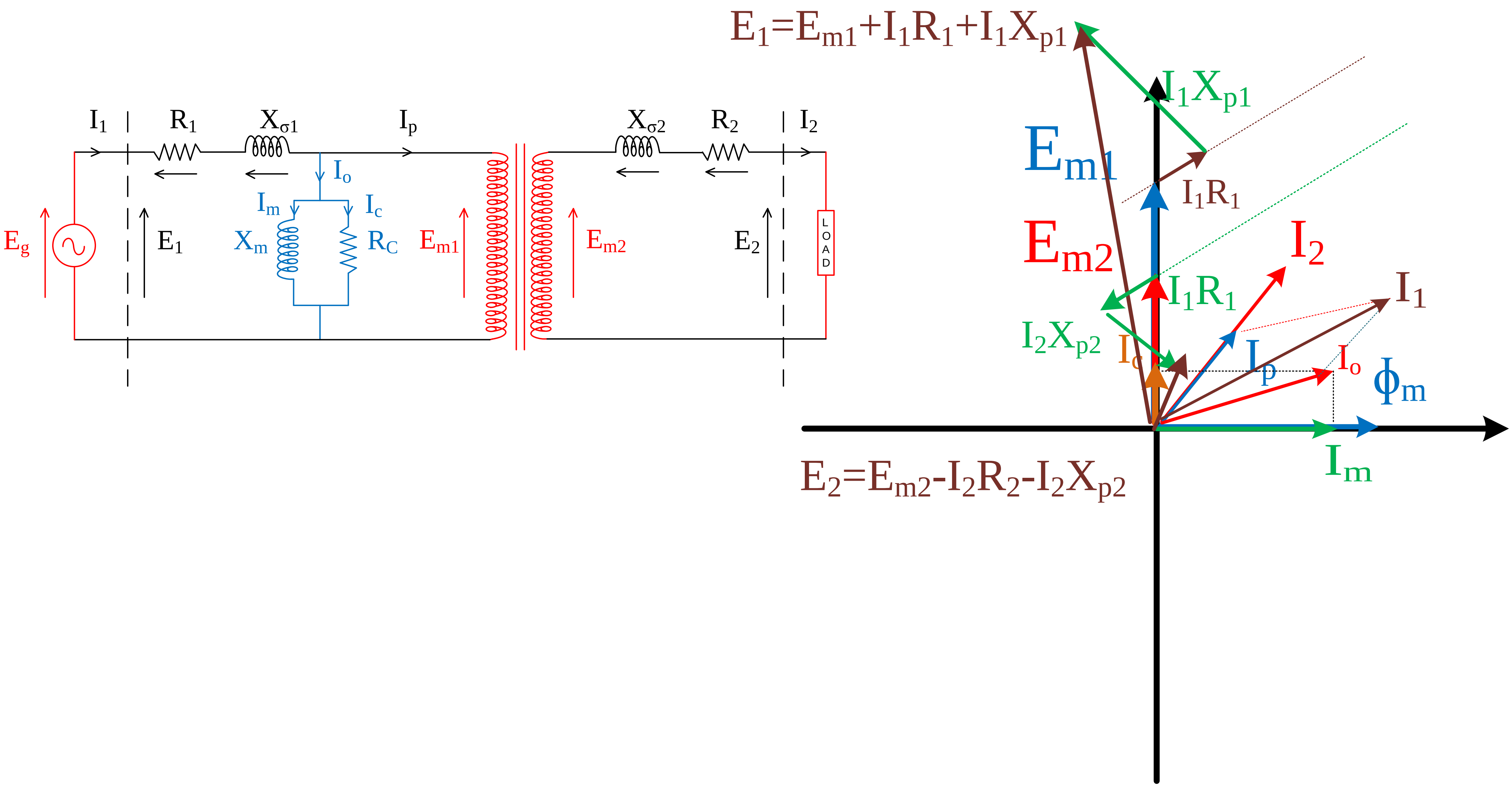
$I_2 Z_2$ = Voltage drop due to secondary impedance.

$E_2 = E_{m2} - I_2 Z_2$ = secondary output voltage

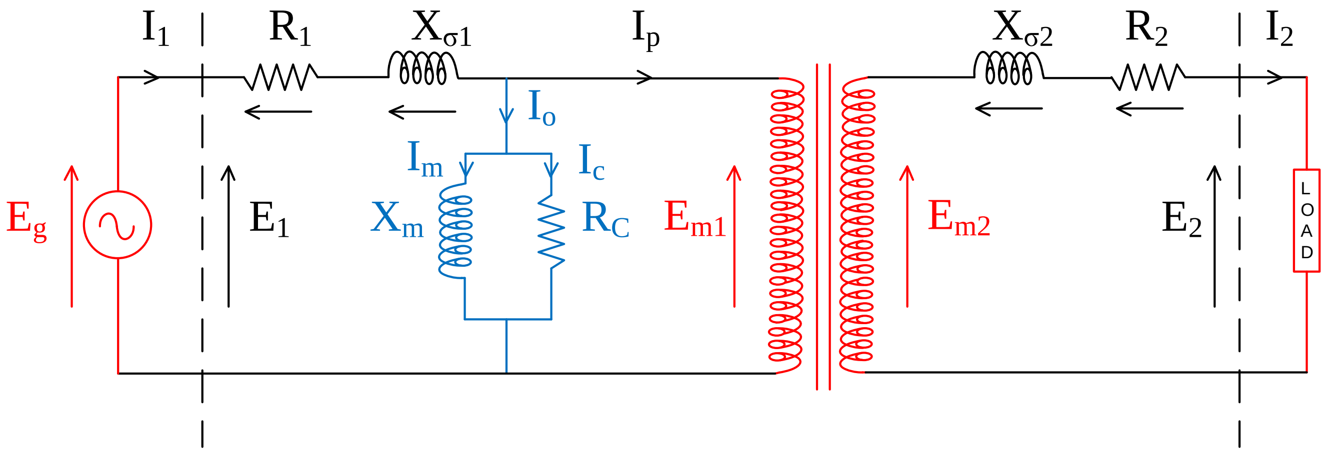
Transformer Phasor diagram

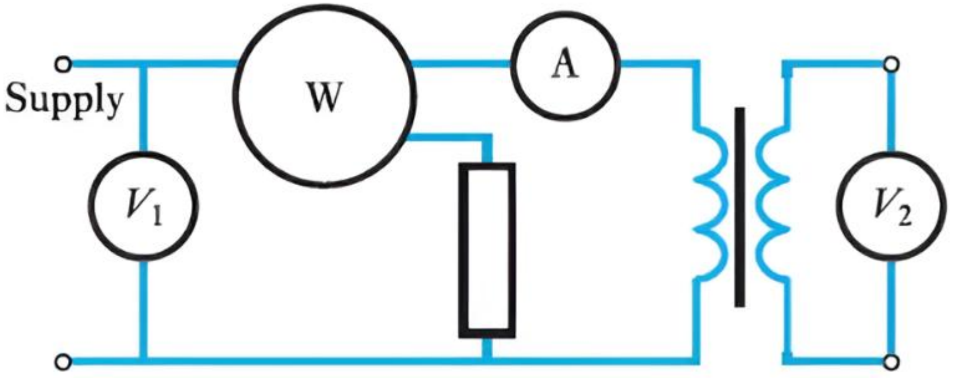


Transformer Phasor diagram



Open Circuit Test





- Primary supplied at rated voltage and frequency.
- The primary current on no load is usually less than 3 to 5 percent of the full-load current.
- Wattmeter reading ≅ the core loss of the transformer.


THANKS
FOR YOUR
ATTENTION