Biismillah Hir Rahmanir Rahim.

Chapter 1.

Introduction of Machinery Principles.

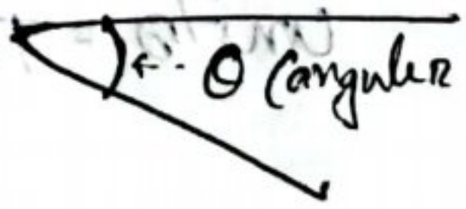
Eletric Machines → It can convert.
- Mechanical energy to electric energy.
- or electric energy to mechanical energy.

Mechanical energy → Electric energy ⇒ GENERATOR.

Electric energy → Mechanical energy ⇒ Motor.

- Al-most all the motors and generators convert energy from one from another. through the magnatic field.

Anguler position, θ: It is an object's the angle at which it is oriented (দিকে), measured (পরিমাপ) from some willingly (সেচ্ছায়) reference point.



[measured in radins or degree].

Angular velocity, ω: It is the rate of change in angular position with respect to time.

(+) হলে তখন counterclockwise

(−) " " clockwise হবে

Linear velocity defined as the rate of change of the displacement along line (r) with respect of time.

$$V = \frac{dr}{dt}$$ dr – distance, dt – taken time.

Angular velocity এর units are rad/s.

angular velocity ⇒ $\omega = \frac{d\theta}{dt}$ $d\theta$ – angular position, dt – time.

Angular Acceleration: (α), It is defined as the rate of change in angular velocity (ω) with respect of time.

$$\alpha = \frac{d\omega}{dt}$$ $d\omega$ – angular velocity

units = rad/s^2.

Torque : τ : Torque is known as a rotational force applied to a rotating body giving angular acceleration called twisting force.

τ = force × perpendicular distance

$= F \times r\sin\theta$

Work, W : Work is defined as the application of force through a distance.

$W = \int F dr$. [বড় কোনো কিছু হিসাবে Line upper lower এখানে কিভাবে done).

$W = Fr$.

$W = \int \tau d\theta$ [for rotating bodies].

if τ is constant then $W = \tau\theta$.

Power, P : It is defined as rate of doing work.

$P = \frac{dW}{dt}$ (watts).

if apply it rotating bodies.

$P = \frac{d}{dt}(\tau\theta)$

$= \tau \frac{d\theta}{dt}$ } $\omega = \frac{d\theta}{dt}$ ← angular velocity হয়।

$= \tau\omega$

Newton's Law of Rotation: Newton's Law for objects moving in a straight line gives a relationship between the force applied to the object and the acceleration (ত্বরণ) experience by the object as the result of force applied to it.

$$F = ma$$

m = mass of object, a = acceleration.

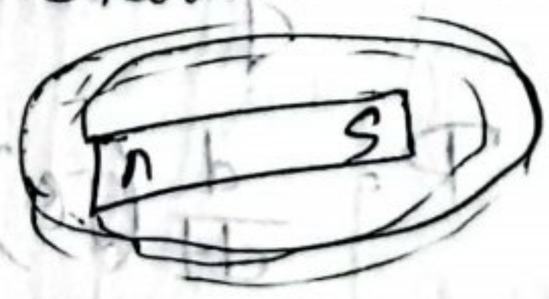
applying it on rotating bodies,

$$\tau = I\alpha \ (Nm)$$

α = angular acceleration, I = moment of inertia

The magnetic field: It is the fundamental mechanism by which energy is converted from one from to another in motors, generators and transformers.

basic principle: The current carrying wire produces a magnetic field in area around it.



Production of a magnetic field:

Ampere's Law: the basic Law governing the production of a magnetic field by a current.

$$\underset{\text{line of integration.}}{\oint} H\,dL = I_{net}$$

length

net current.

ampere turns per meter

If, Ampere Law in the mean path Length then I_e used. then current passing path integration I_{net} is then Ni

কত সংখ্যক বিন্দু, বলতে (N turns)

$$\Rightarrow H l_e = Ni$$

current প্রবাহিত হচ্ছে বিন্দুর

H defined magnetic field intensity.

$$\therefore \boxed{H = \frac{Ni}{l_e}}$$

If magnetic field flux density (বায়ু) বললে

$$B = \mu H$$

μ: permeability of material.

B: magnetic field flux

H: intensity.

FARADAYS Law:

induced voltage from a time changing magnetic field.

Directly proportional to the rate of changes in the flux with respect time.

induced voltage → $e_{ind} = \frac{d\phi}{dt}$ ← flux passing through coil. ← time

If N number of turns in the coil বললে

$$\boxed{e_{ind} = N\frac{d\phi}{dt}}$$

[এখানে (-) use হবে না math এ (-) যোগ দিয়ে দিবে বুঝাই Lenz এর Law এ (-) use হবে]

Lenz Law: Lenz' Law states that the direction of the electric current induced in a conductor by changing magnetic field so such that the magnetic field created by the induced current opposes changes in the initial magnetic field.

$$E_b = -N\left(\frac{\Delta\theta}{\Delta t}\right).$$

$\boxed{S\ N}$ $\left(\begin{matrix} \uparrow \\ N \\ \downarrow \end{matrix}\right)$ এখানে N clock wise এজন্য N হয়েছে but বিপরীত অবস্থান হলে S Cole আসবে So that বিপরীত অবস্থান হলে চাপাইতে দিবে না Same অবস্থান হলে আসতে দিবে না.

Math

$\phi = 0.05 \sin 377t$ Wb If there are 100 turns on core what voltage is produced at the terminal of the coil.

here $\theta = 0.5 \sin 377t$ wb. , $N = 100$ turns.

we know

$$e_{ind} = N \frac{d}{dt} \theta.$$

$$= 100 \cdot \frac{d}{dt}(0.05 \sin 377t)$$

$$= 100 \cdot 0.05 \frac{d}{dt}(\sin 377t)$$

$$= 5 \cdot \cos 377t$$

$$= (5 \cdot 377) \cos 377t \cdot \frac{d}{dt}(377t).$$

শেষে দাও

$$= 1885 \cos 377t \text{ V}$$

② A coil that 700 turns develops an average induced voltage of 50V what must be the change in the magnetic flux occur to produce such voltage if the time interval of this change 0.7s

here, $N = 700$.

$e_{ind} = 50V$.

$dT = 0.7s$.

Short note
$d\theta$ unit $\Rightarrow$ wb
e_{ind} " $\Rightarrow$ V

Since we know

$$e_{ind} = N\frac{d\theta}{dt}$$

$$d\theta = \frac{e_{ind} \cdot dt}{N}$$

$$= \frac{50 \times 0.7}{700}$$

$$= 0.05 \text{ wb}.$$

③ The magnetic flux linked with a coil having 250 turns is changed from 1.4 wb to 2.0 wb in 0.4 s calculate induced emf (eind) the coil.

here

$N = 250$

$d\theta = (2 - 1.4)$ wb

$= 0.6$ wb.

$dt = 0.4s$

we know that

$$e_{ind} = N\frac{d\phi}{dt}$$

$$= 250 \times \frac{0.6}{0.4}$$

$$= 375V. \text{ (Ans)}.$$

Production of Induced Force ON Wire.

here $F = i(L \times B)$

i → current flow of conductor.

L → direction of current flow

B → magnetic field density.

If the current conductor is position at an angle to the magnetic field then

$$\boxed{F = iLb\sin\theta}$$

Math

- If magnetic flux density is 0.25 T, directed into this page. If the wire is 1.0 m long and carries 0.5 A of current in the direction from the top of the pages to the bottom of the page what are the magnitude and direction of the force ~~up the~~ induced on the wire.

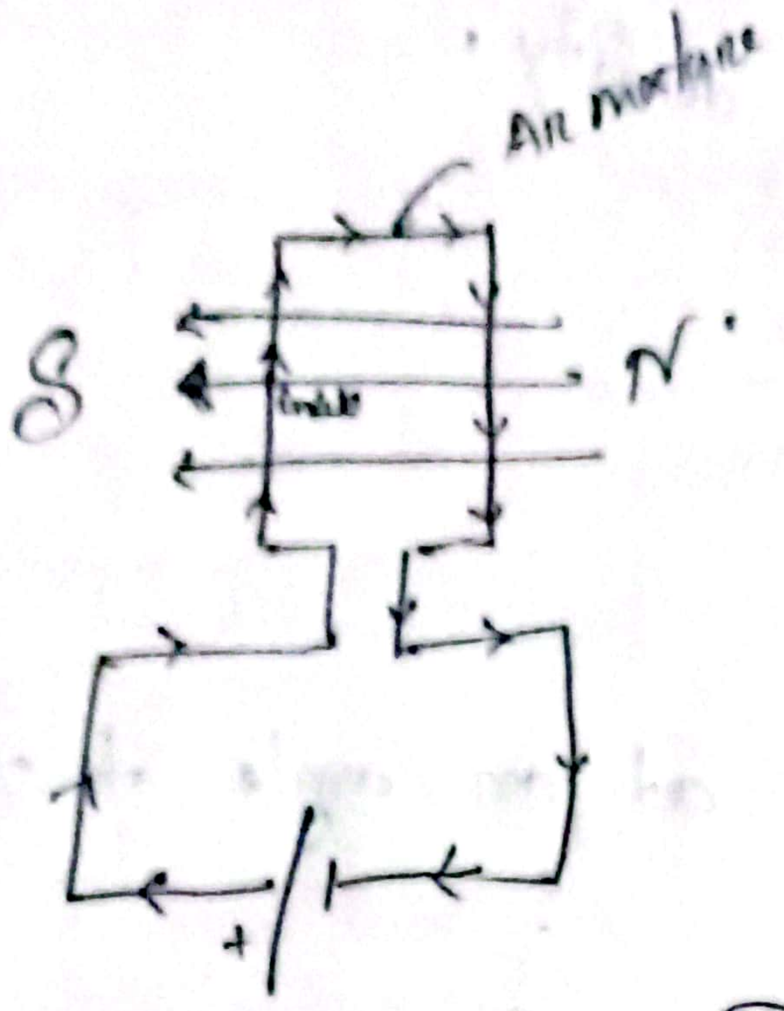
we know $F = iLb\sin\theta$

$= 0.05 \times 1 \times 0.25 \sin 90°$

$= 0.125\,N$ (directed to right)

How to Motor work. / Construction (*)

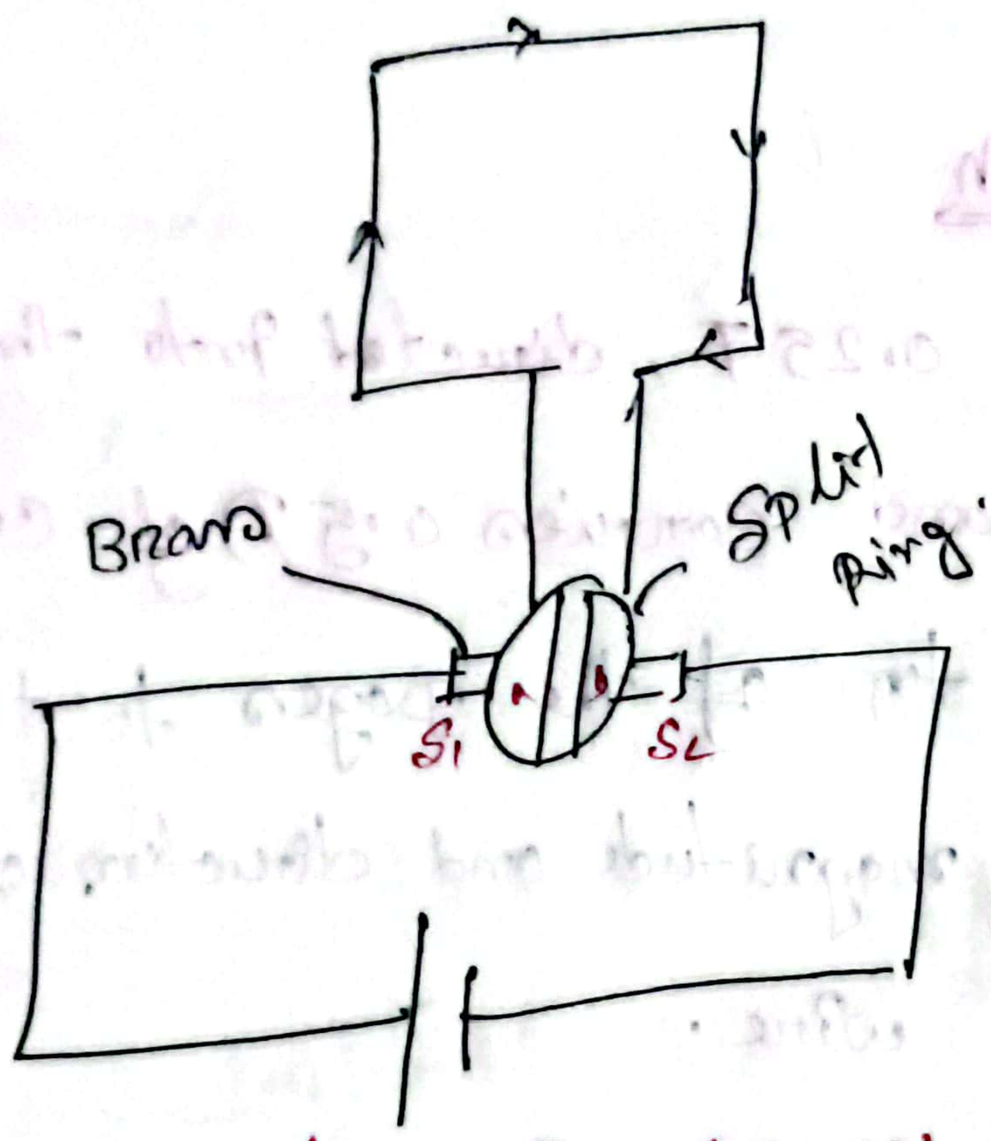
Some way to generate torque



Motor => Fleming L. Hand Rule

Generator -> " Right " "

- Left hand ব্যবহার করলে Fleming ratio দুবার হয় for flow



① তার পেঁচানো হাত থেকে বাঁকা তার নড়ে বসলে ঘুরে 180° পড়ে যায়

② তার motion change হলে current flow ও তার direction change হয়

- Continuous Rotation এর জন্য যা করার

- Split ring এর যদি S1 এ flow যে a দিয়ে then split ring ঘুরলে b এর S1 এ তখন Same current flow হবে.

[এমনভাবে flow always Same flow এ হবে]

Linear DC Machine.

- $F = i(lb\sin\theta$ — magnitude wire, length of wire, flux density
- $e_{ind} = VBl\cos\theta$ [exp page describe]
- $V_B - Ri - e_{ind} = 0$ ← $V_B = e_{ind} = Ri$ ← force 0 এলে
- $i = \frac{V_B - e_{ind}}{R}$
- F = ma :- Newton law for bar acceleration
- $i = \frac{V_B}{R}$

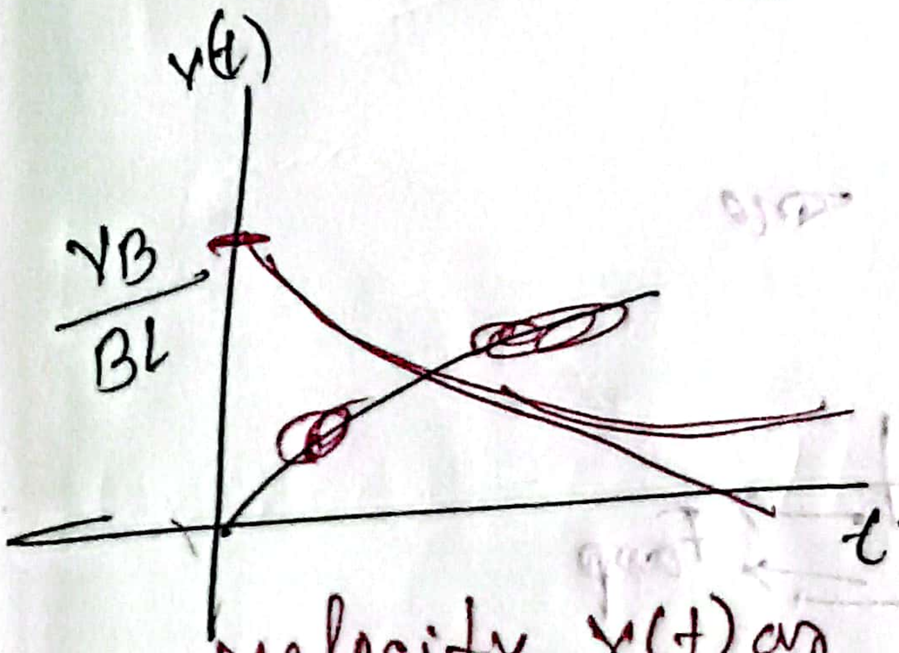
Kirchhoff's voltage law

force বাড়লে e_{ind} বাড়ে (movement বাড়বে)

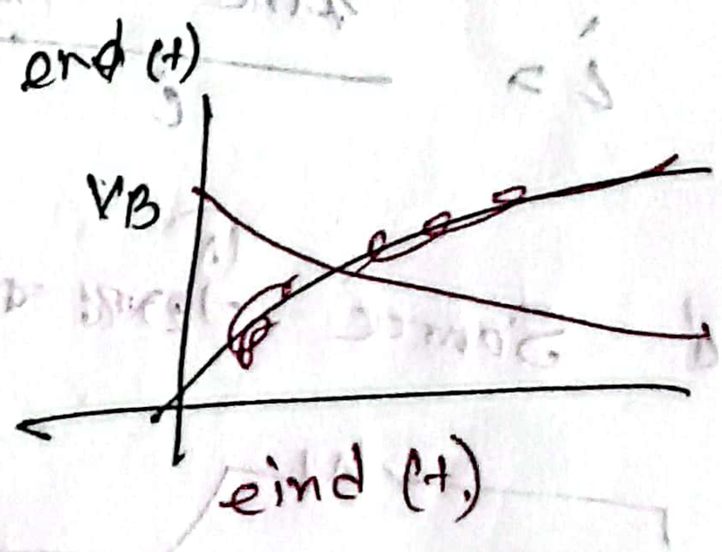
Statistic condition = $e_{ind} = V_B = VSSBL$.

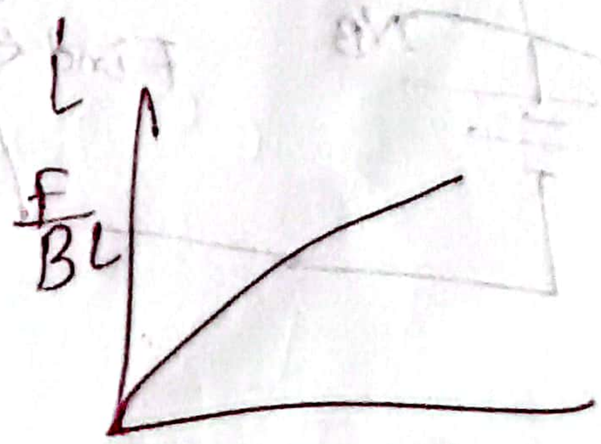
$e_{ind} = VBL$

- $F = iLb$
- $i = \frac{V_B}{R}$ → the current flow rotating 90.



velocity v(t) as function time





(i) current.

Induced voltage on a conductor moving in magnetic field.

. The voltage induced in the wire given by.

$$e_{id} = (V \times B) \cdot L$$

L — length of conductor

V — velocity

B — mag flux density

Transformer

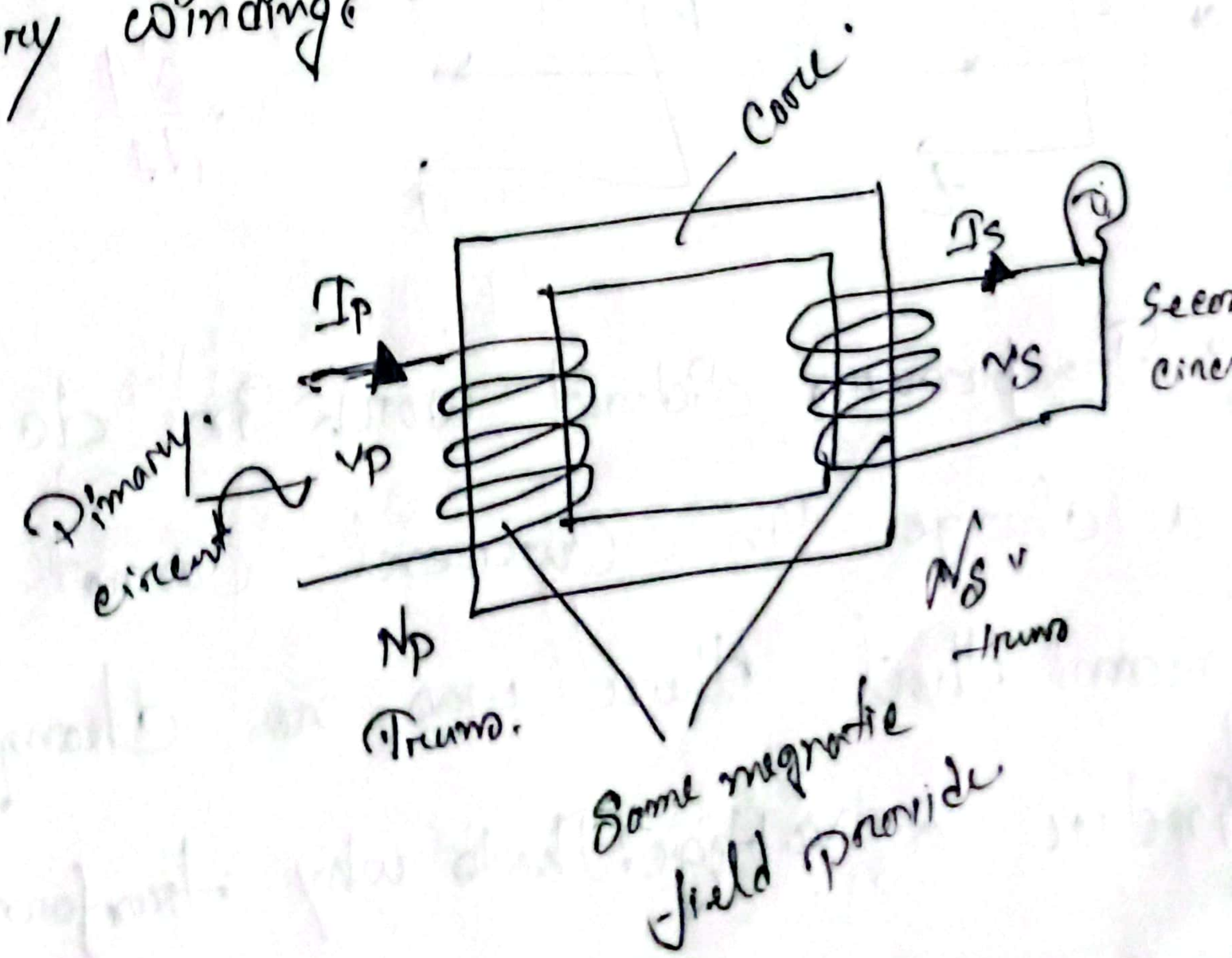
- The transformer is a static device which change the voltage level and current level without changing the frequency.

Use:
1. Used to increase or decrease the current level.
2. To adjust the voltage into proper level.
3. It is static device, as it has no moving parts. (voltage up down করে)

Construction:

Transformers are mainly three parts.

- Core
- Primary winding.
- Secondary winding → load connected থাকবে



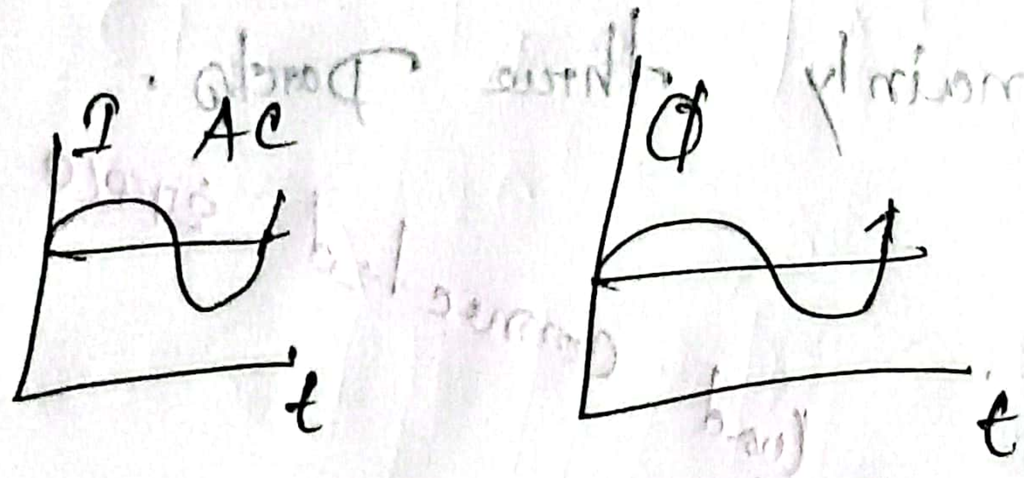
Faraday's law's of electromagnetic induction.

1st law Faraday's: whenever a conductor is placed in a varying magnetic field an voltage is induced. If the conductor circuit is closed, the current is induced which called induced current.

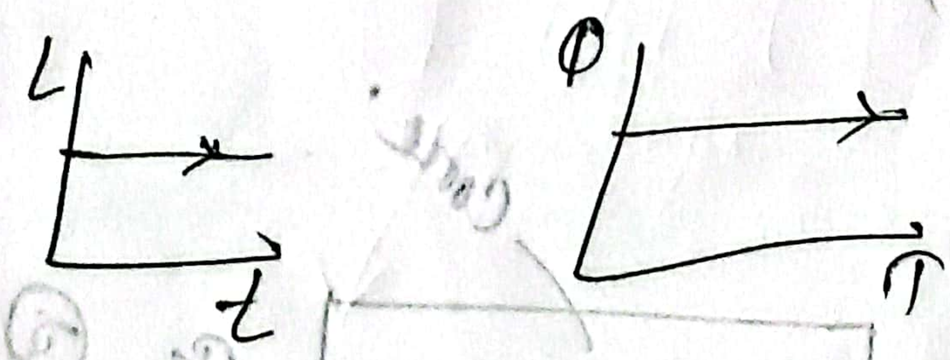
2nd law Faraday's: The induced e.m.f in a coil is equal to the rate of change of flux linkage.

$$\epsilon = -\frac{d\phi}{dt}$$ ← magnetic flux

$$\epsilon = -N\frac{d\phi}{dt}$$ ← turns.

* 

$\frac{d\phi}{dt} \neq 0$ in AC (transformer AC তে কাজ করে)

* 

$\frac{d\phi}{dt} = 0$ in DC (" DC তে কাজ করে না)

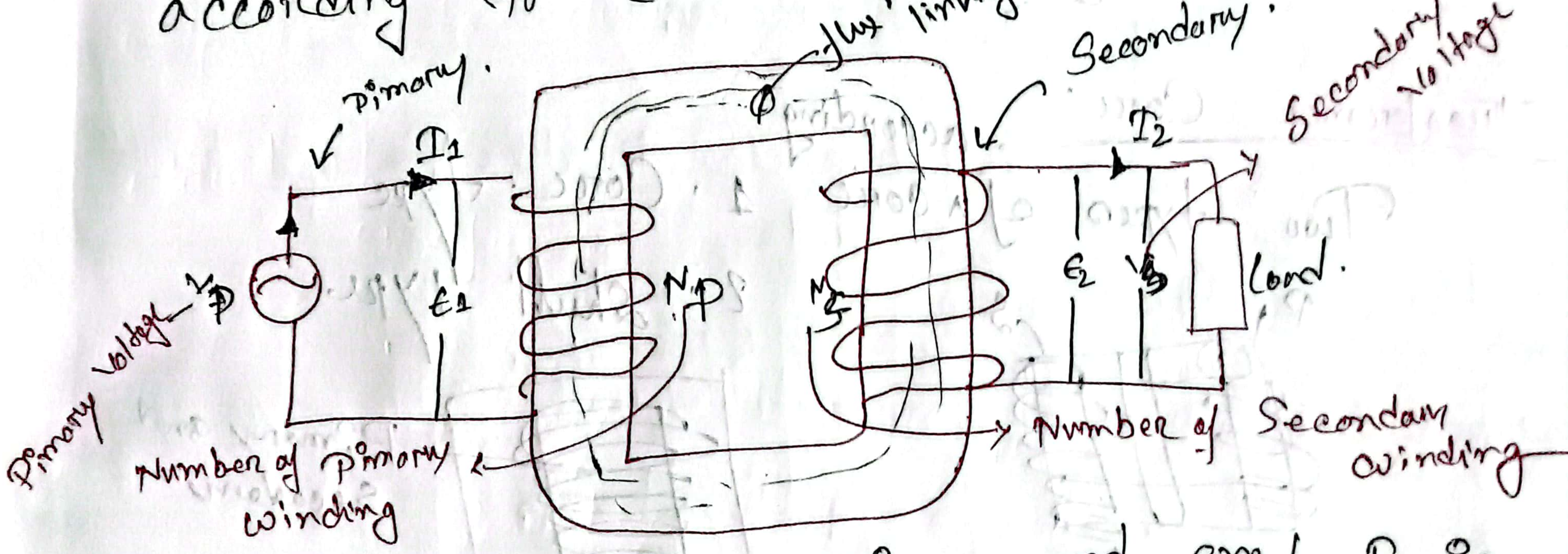
∴ Transformers did not work on dc current, because a changes in current cannot be generated by DC, mean that there was no changing magnetic field to induce a voltage. That's why transformer work on AC current because here eletromagnetic induction are happen.

Working Principle of Transformer

The basic of a transformer is mutual induction between two circuits linked by a common magnetic flux.

It follows faraday's electromagnetic induction.

If one coil of transformer is connected to a source of voltage an flux is set up in the core. most of the flux is linked with other coil according to electromagnetic induction.



when V_p is applied to the primary and e.m.f E_1 is is induced known as primary E.m.f.

$$E_1 = -N_1 \frac{d\phi}{dt}$$

The E.M.f E_2 is termed as secondary E.m.f.

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

Transformer type:

- Step up transformer

if $N_S > N_P$

then $E_S > E_P$ ← Secondary ও হলে Step up

or $V_S > V_P$

- Step Down

if $N_S < N_P$ ← Primary ও হলে Step down

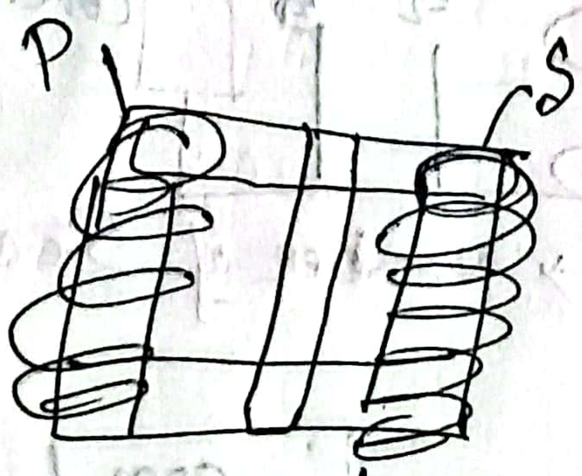
then $E_S < E_P$

or $V_S < V_P$

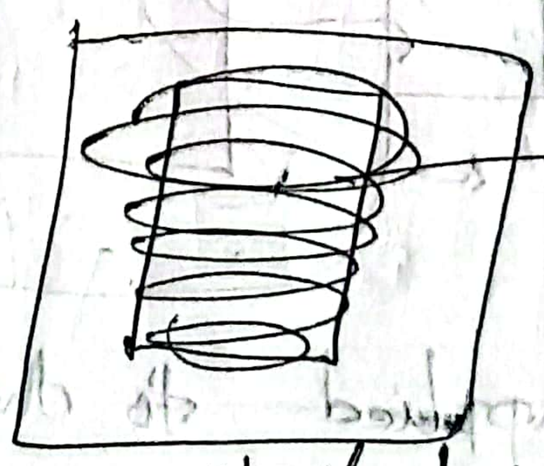
Transformer Core

Two types of core according 1. Core type

2. Shell type



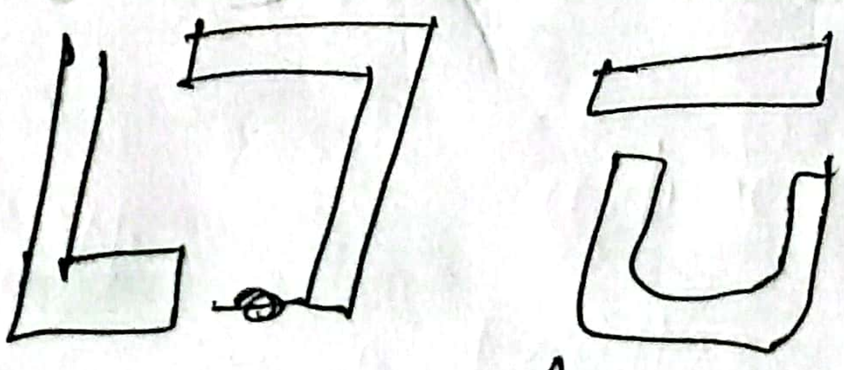
Core type



Primary and Secondary

Shell type

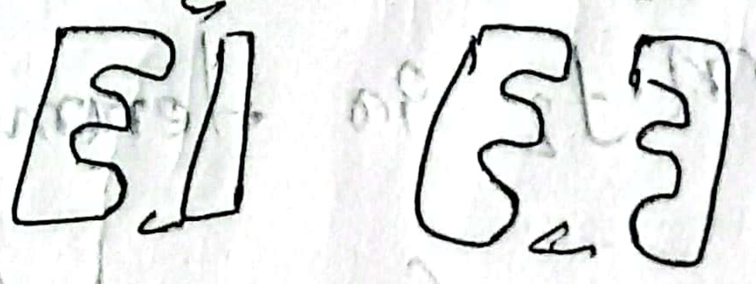
magnetic core in made, U, L shaps



for reducing leakage flux.

voltage winding one after one.

it's made E and I strips



it's surrounds a considerable part of winding.

Losses of Practical Transformer.

- Copper loss → depends on the current
- Core loss / Iron loss → depends on the voltage of transformer
- leakage loss.

Copper Losses: The resistive heating losses in primary and secondary winding in the transformer.

This loss is proportional to the square of the current in the windings.

To determine the copper losses short circuit test is performed.

Total copper losses are $= I_1^2 R_1 + I_2^2 R_2$.

Iron loss: Core loss also called The power loses that palace in its iron core are known as the iron loss.

- Alternating flux set up ~~accoutred~~ এর জন্য তৈরি হয়।
- open circuit test করলে determin করা যায়

Iron losses.

- Eddy current
- hysteresis current

Eddy Current loss: Became of time variation of flux in megnatic material, current is induced in the megnatic material flo called eddy current losses.

[Core এর মধ্যে ছোট voltage induced হয় Megnatic flux এর কারণে উহাকে eddy current loss].

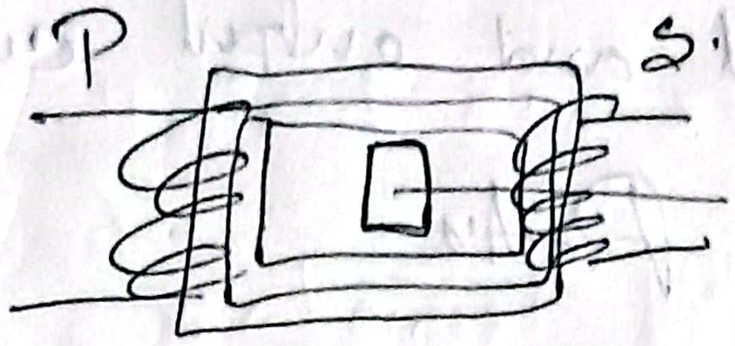
They are proportional (সমানুপাতিক) to the square of the voltage.

Hysterusis Losses: It is ~~associated~~ connected with rearrangement of magnatic domins.

- This power is disappear (বিলীন) in the form of heat is hysterusis.
- To reduce loss we need to select such type of material which has small hysterusis area.

- The eddy current and hysteresis current losses are both occours in the core of the transformer.
- We can reduce eddy ~~and~~ current losses making the core by med thin sheets together and reduce the hysteresis loss that the less area of the hysteresis loop

Leakage Flux: The fluxes which escape the core and pass through only one transformer winding are leakage fluxes.



leakage current (ফ্লাক্স flow করে না leage).

- These escaped fluxes produce a self coiling in primary and secondary coils.

The Ideal Transformer:

- An ideal transformer is a loss-less device that has.
  - No winding resistance
  - No leakage flux
  - No iron losses in the core.

- Why transformer Rating in KVA (Volt ampere)?

⇒ We know copper losses depends on current, core, iron losses are depends on the voltage. Also we don't know the power factor or nature of load. So we don't know the power factor. That's why transformer rating given in KVA not KW.

Turn Ratio: The relation between.

⇒ input voltage and output voltage.

⇒ input current and output current.

(1) are called Turn Ratio.

Transformation Ratio ⇒ $\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$.

Turns Ratio ⇒ $a = \frac{N_P}{N_S}$

Power in ideal Transformer:

Power input at primary

$$P_{in} \Rightarrow V_P I_P \cos\theta_P$$

Power output from Secondary.

$$P_{out} \Rightarrow V_S I_S \cos\theta_S.$$

Apply turns ratio $a = \frac{N_P}{N_S}$

$$V_S = V_P/a \quad I_S = a I_P.$$

$$P_{out} = \frac{V_P}{a}(a I_P)\cos\theta.$$

$$P_{out} = V_P I_P \cos\theta = P_{in}$$

Impedance Transformation.

Primary voltage $V_P = aV_S$.

" current $I_P = \frac{I_S}{a}$. a and k same mean

the apparent impedance of primary is

$$Z_L' = \frac{V_P}{I_P} = \frac{aV_S}{I_S/a} = a^2 \frac{V_S}{I_S}$$

$$Z_L' = \cancel{a^2 Z_L} \cdot a^2 Z_L$$

a^2 and k^2 same mean

Shifting impedance by transformation Ratio.

$$\frac{V_2}{V_1} = E_2/E_1 = \frac{N_2}{N_1} = K.$$

for primary Equivalent of the sec induced voltage $E_2' = \frac{E_2}{K}$

Similarly $V_2' = V_2/K$.

Secnonry current $I_2' = KI_2$

for transforming sec impedance to primary K^2 used

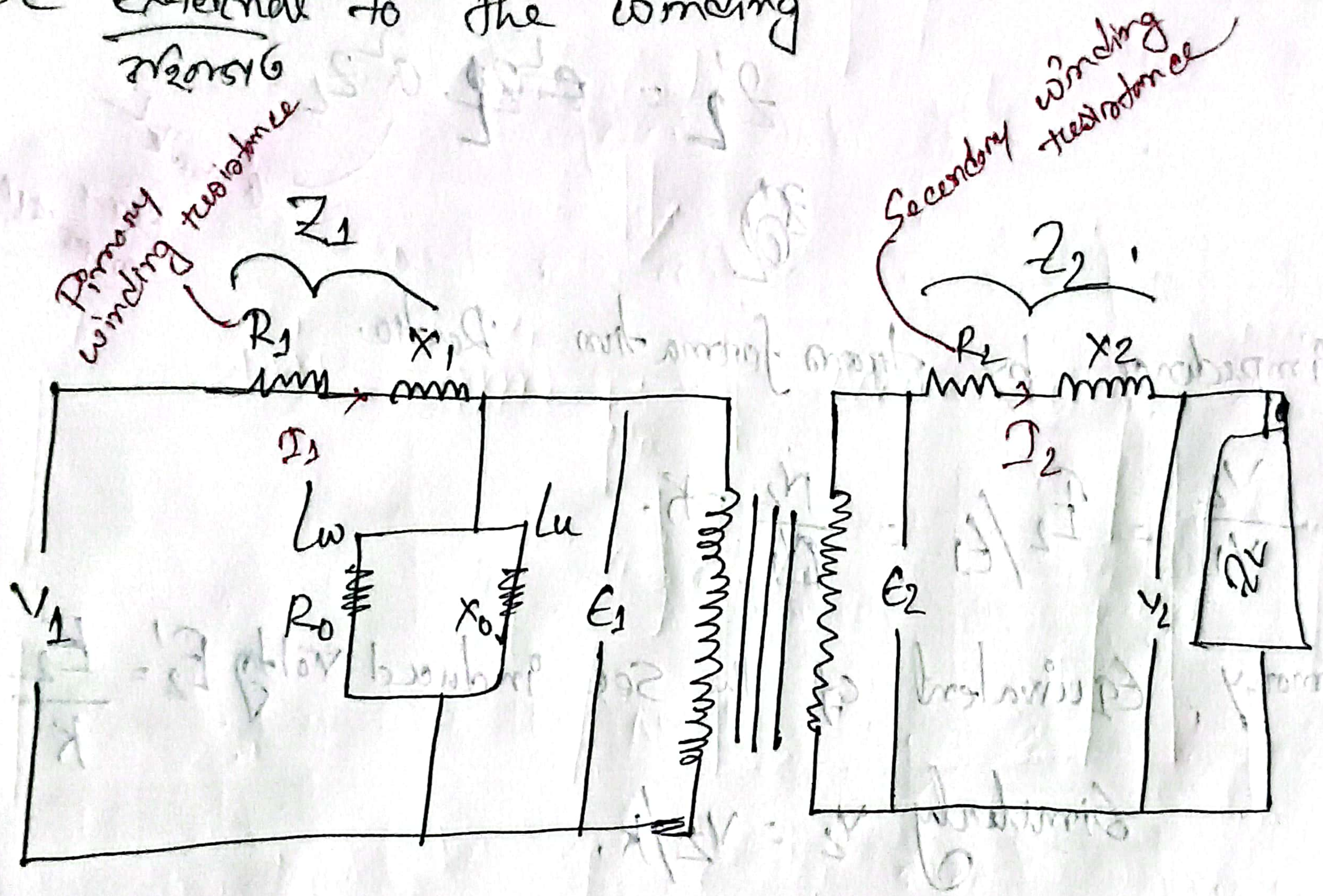
$R_2' = R_2/K^2$

$X_2' = X_2/K^2$

$Z_2' = Z_2/K^2$

Equivalent transformer Circuit for

- Equivalent circuit transformer is basically an equivalent circuit in which the resistance and leakage reactance of the transformer are imagined to be external to the winding



R_1 = Primary winding (Cupper loss)

R_2 = Secondary " (")

X_1 = Leakage

X_2 = "

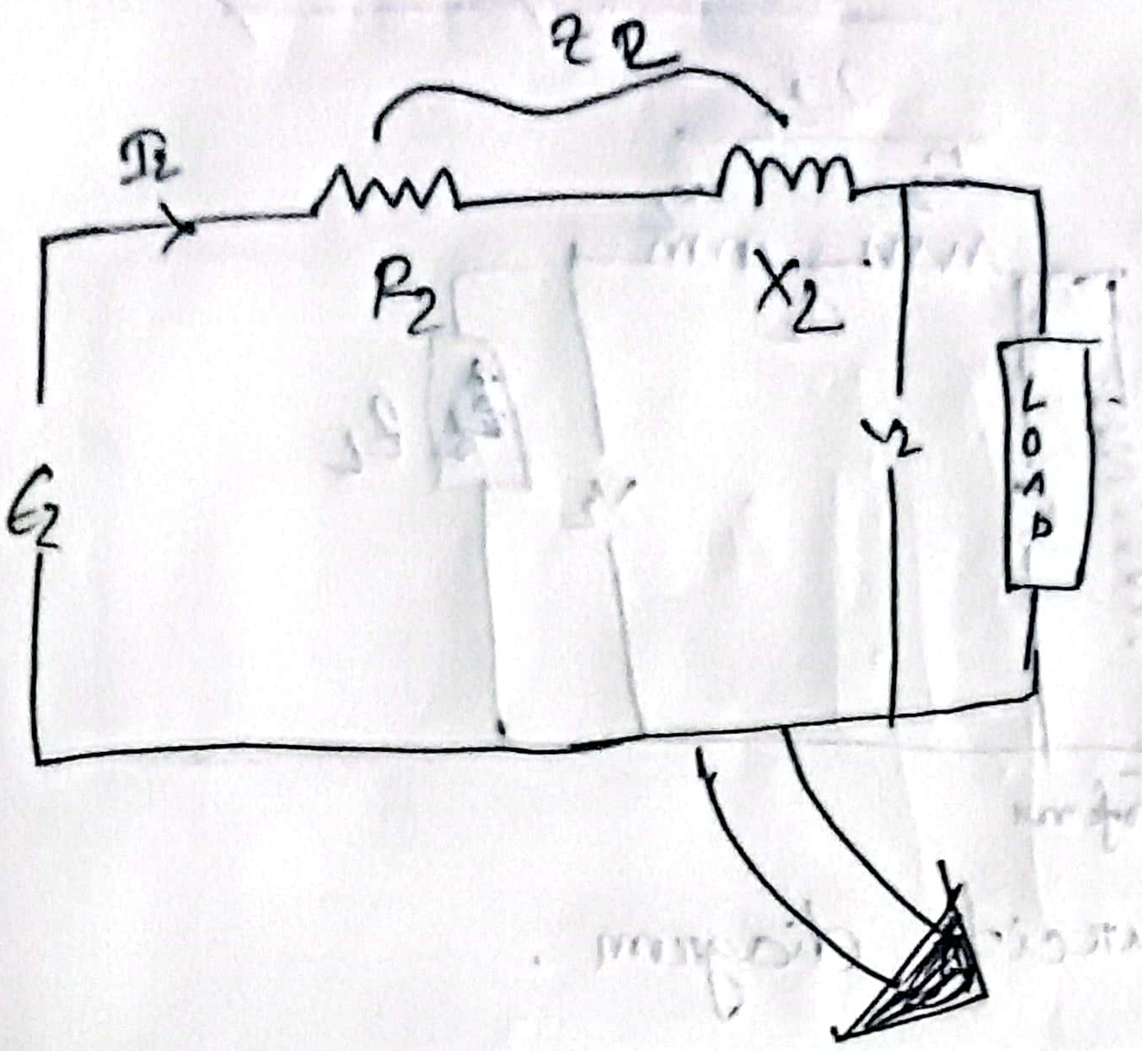
X_0 = Inductor

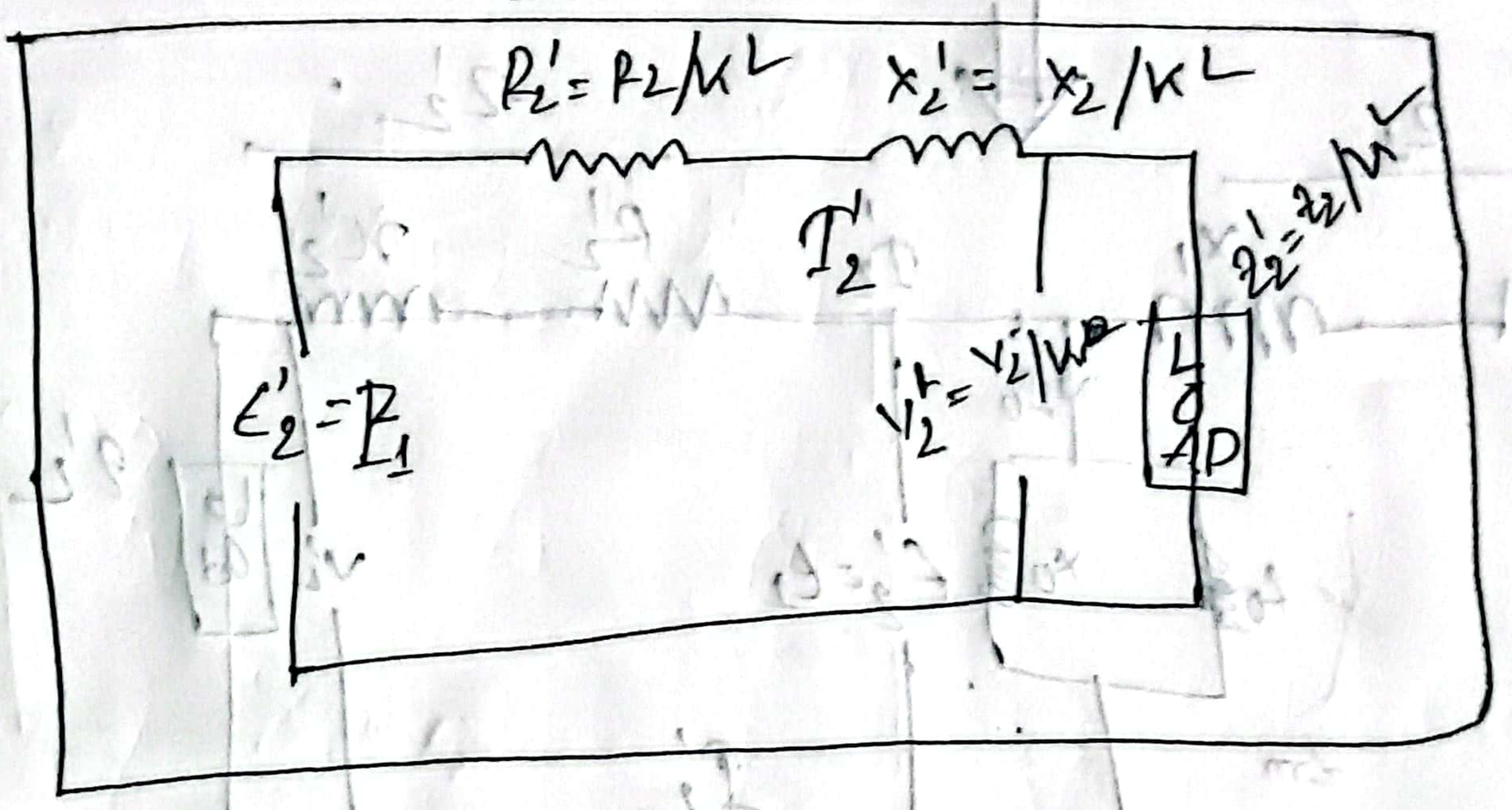
R_0 = iron loss (Eddy and hysteresis)

L_u = Magnetizing component

L_w = working component

Secondary Impedance referred to Primary.





$R_2' = R_2/K^2$

$X_2' = X_2/K^2$

$Z_2' = Z_2/K^2$

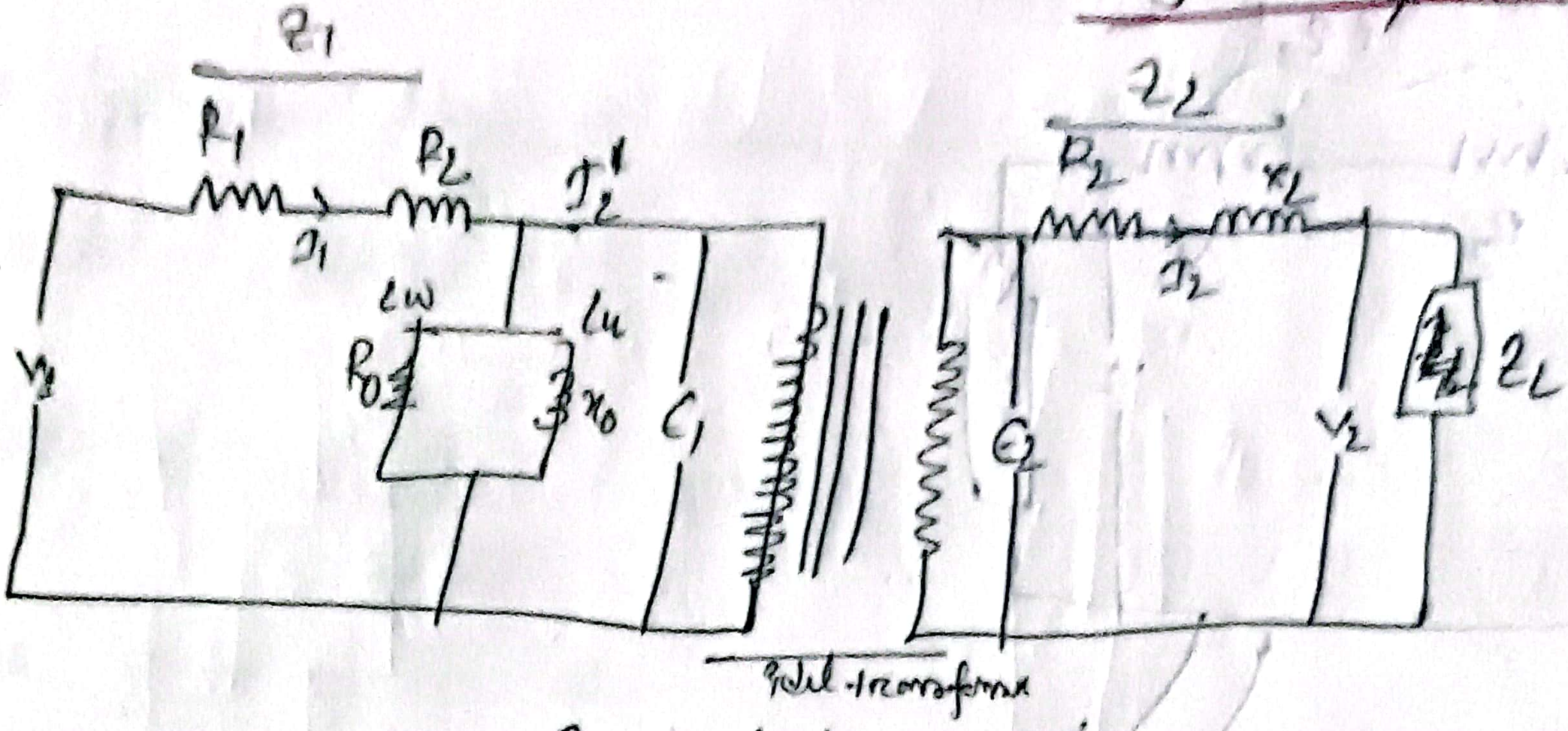
Shortcut:

Primary ⇒ Secondary → K^2 দ্বারা গুণ

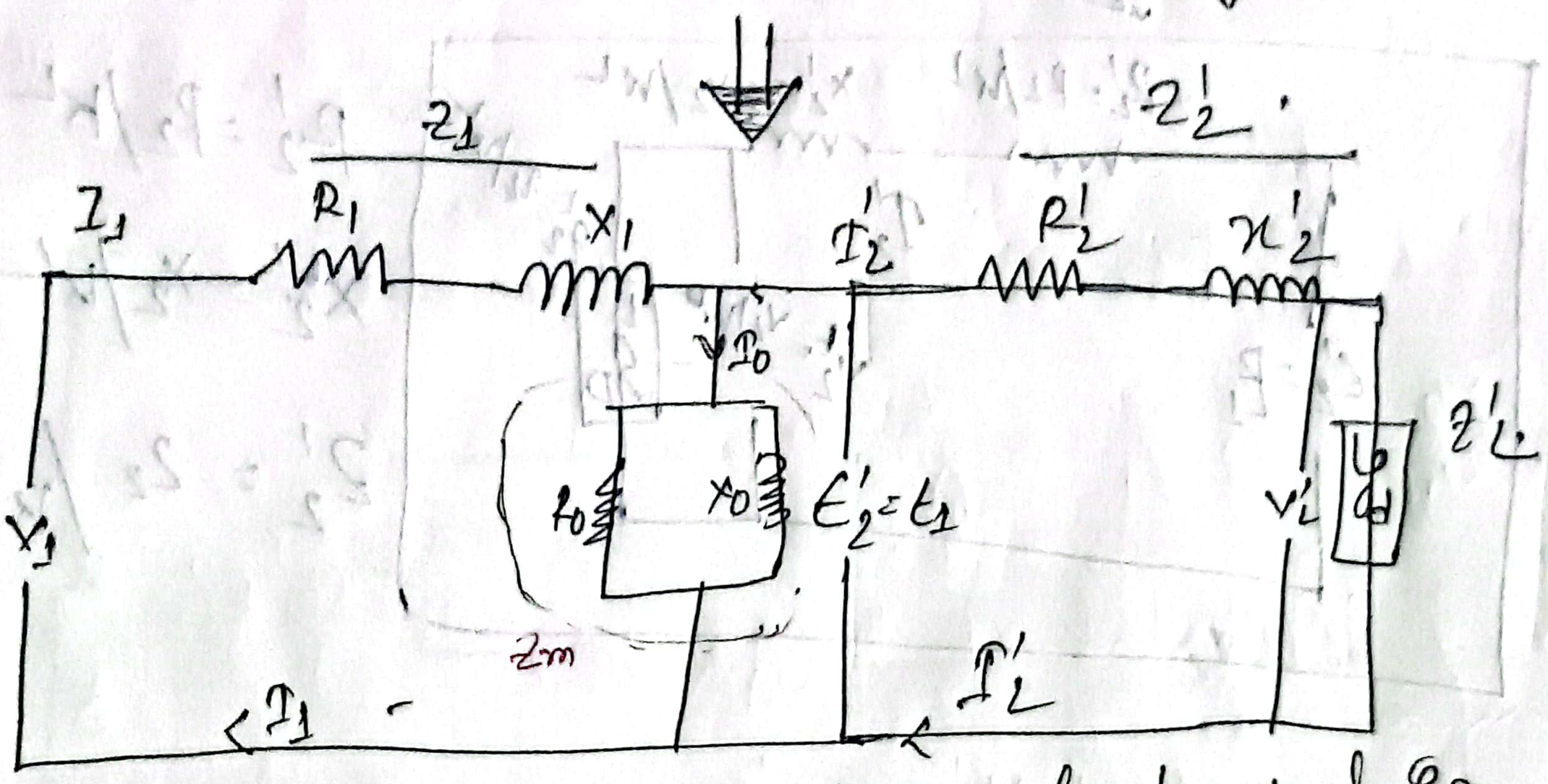
Secondary ⇒ Primary → $\frac{1}{K^2}$ দ্বারা গুণ

Equivalent Circuit

– Referred to Primary.



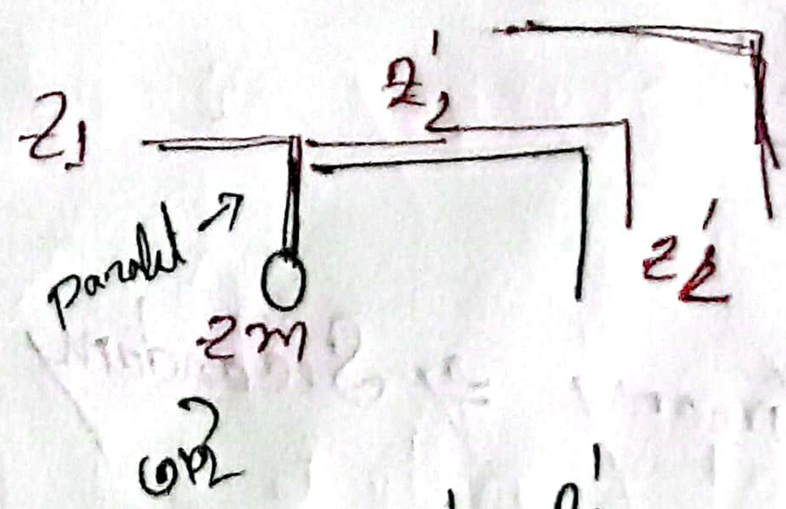
Equivalent circuit diagram.



total impedance between the input terminal is.

$$Z = Z_1 + Z_m \parallel (Z_2' + Z_L')$$

$$= Z_1 + \frac{Z_m(Z_2' + Z_L')}{Z_m + (Z_2' + Z_L')}$$



$Z_m \parallel Z_2' + Z_L'$

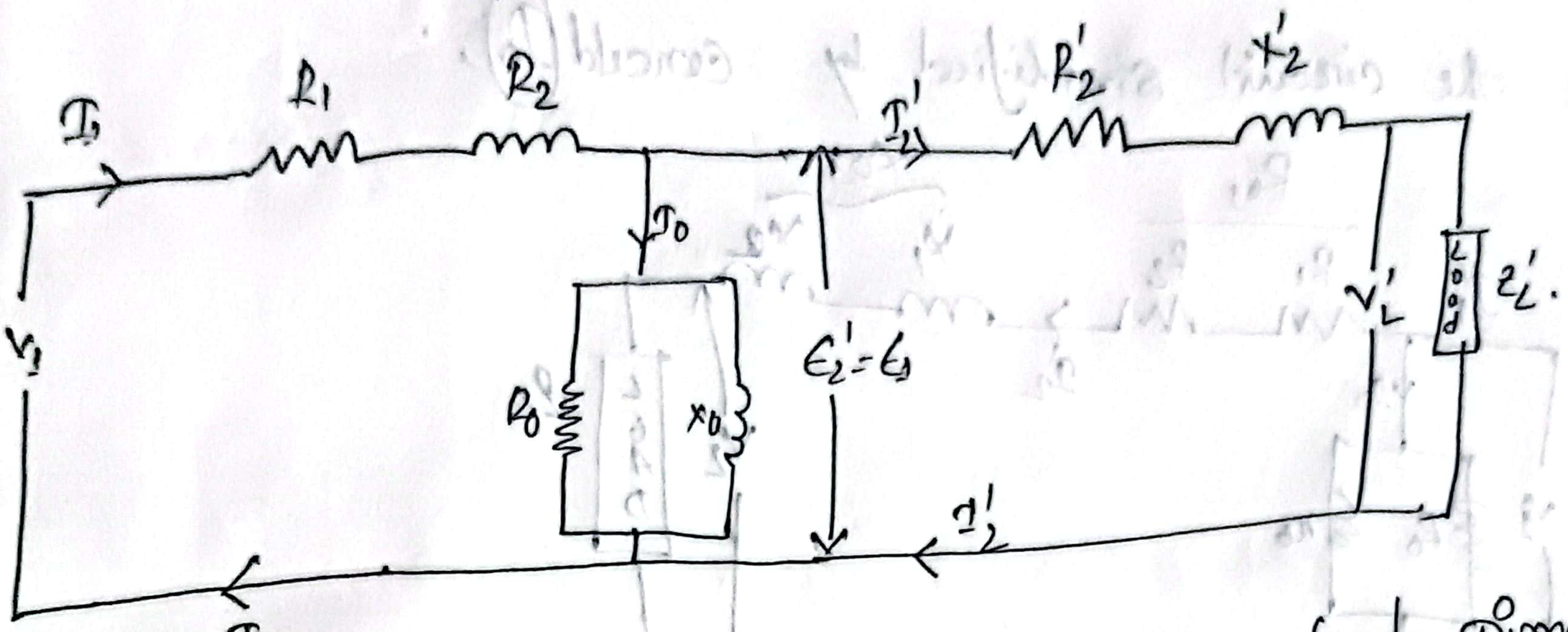
parallel current

$A \parallel B = \frac{AB}{A+B}$

$$V_1 = I_1 \cdot Z_1$$

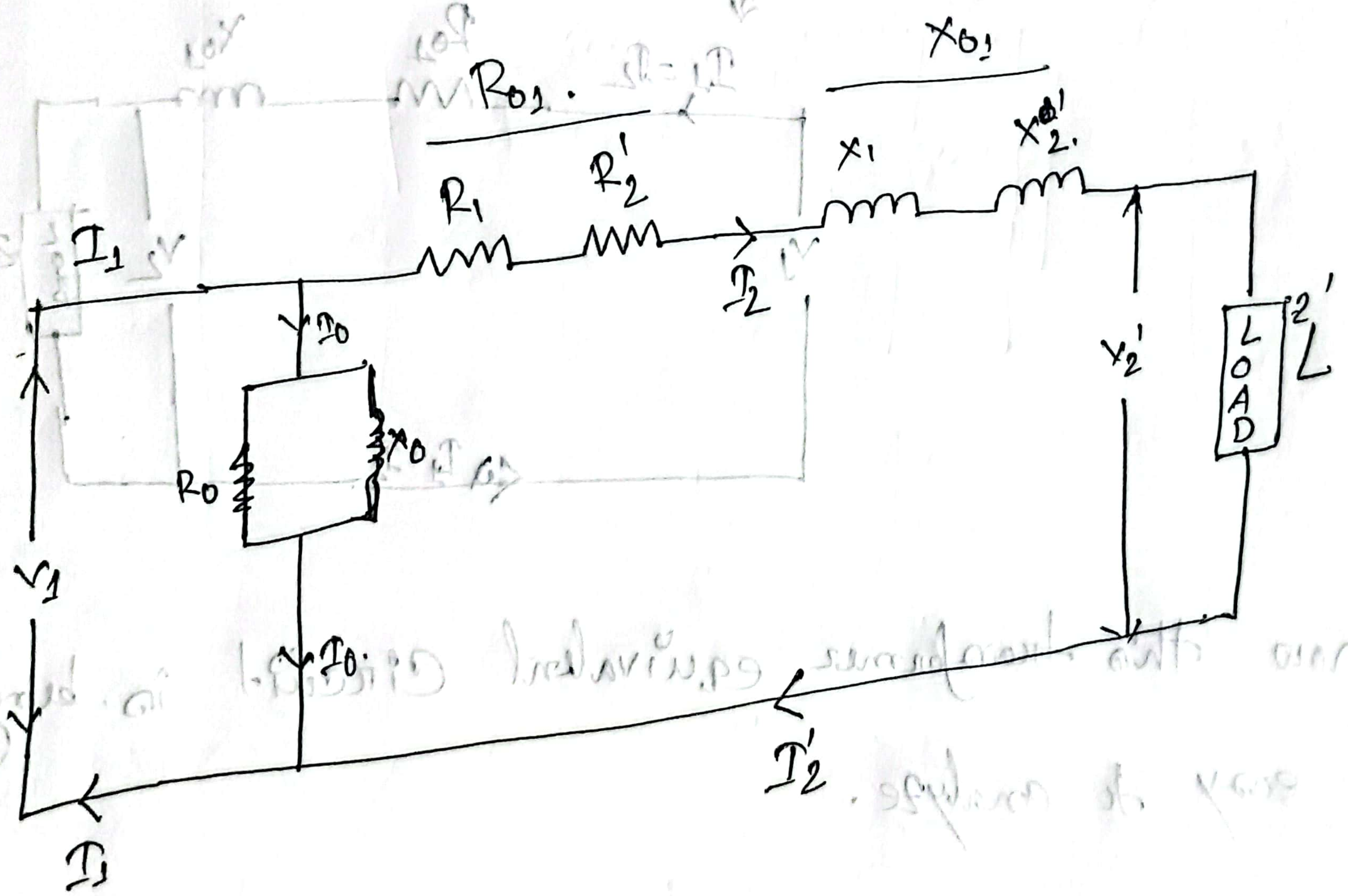
$$= I_1 \left[Z_1 + \frac{Z_m(Z_2' + Z_L')}{Z_m(Z_2' + Z_L')} \right.$$

Exact Equivalent Circuit:



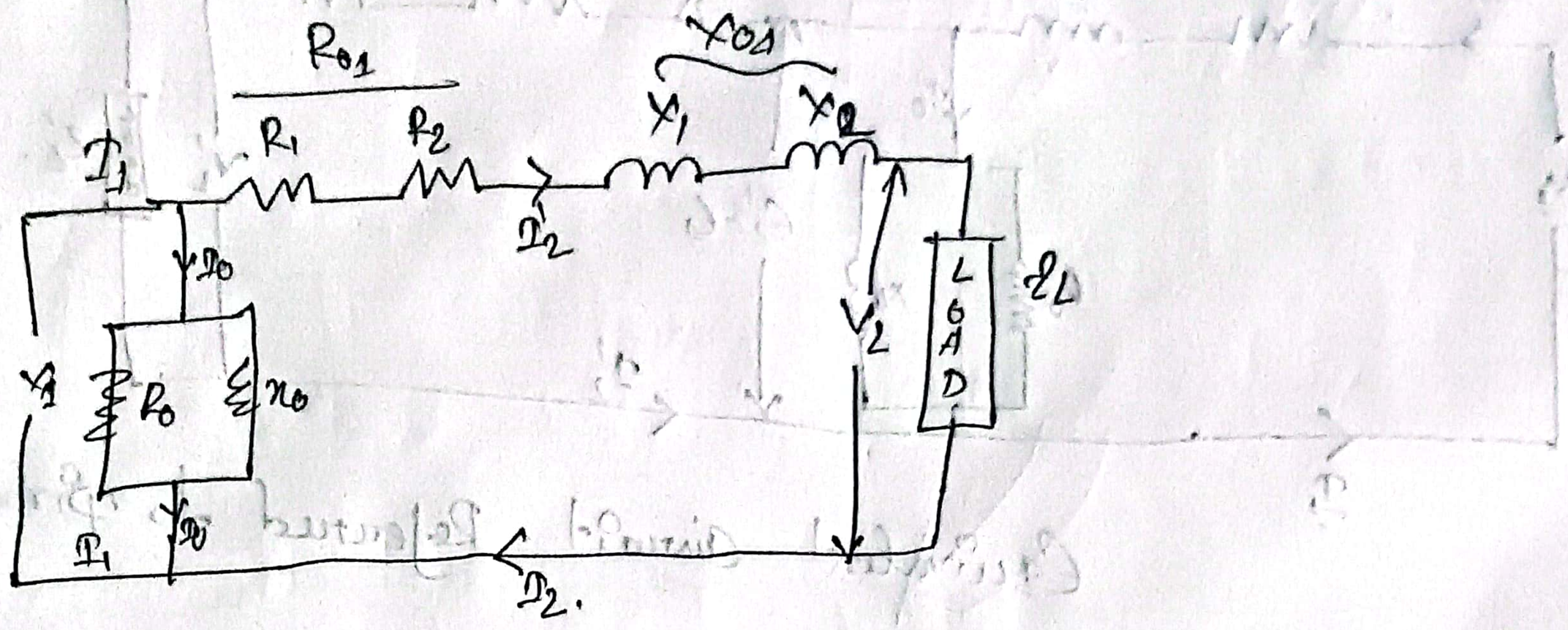
Equivalent circuit - Referred to primary

$\Downarrow$

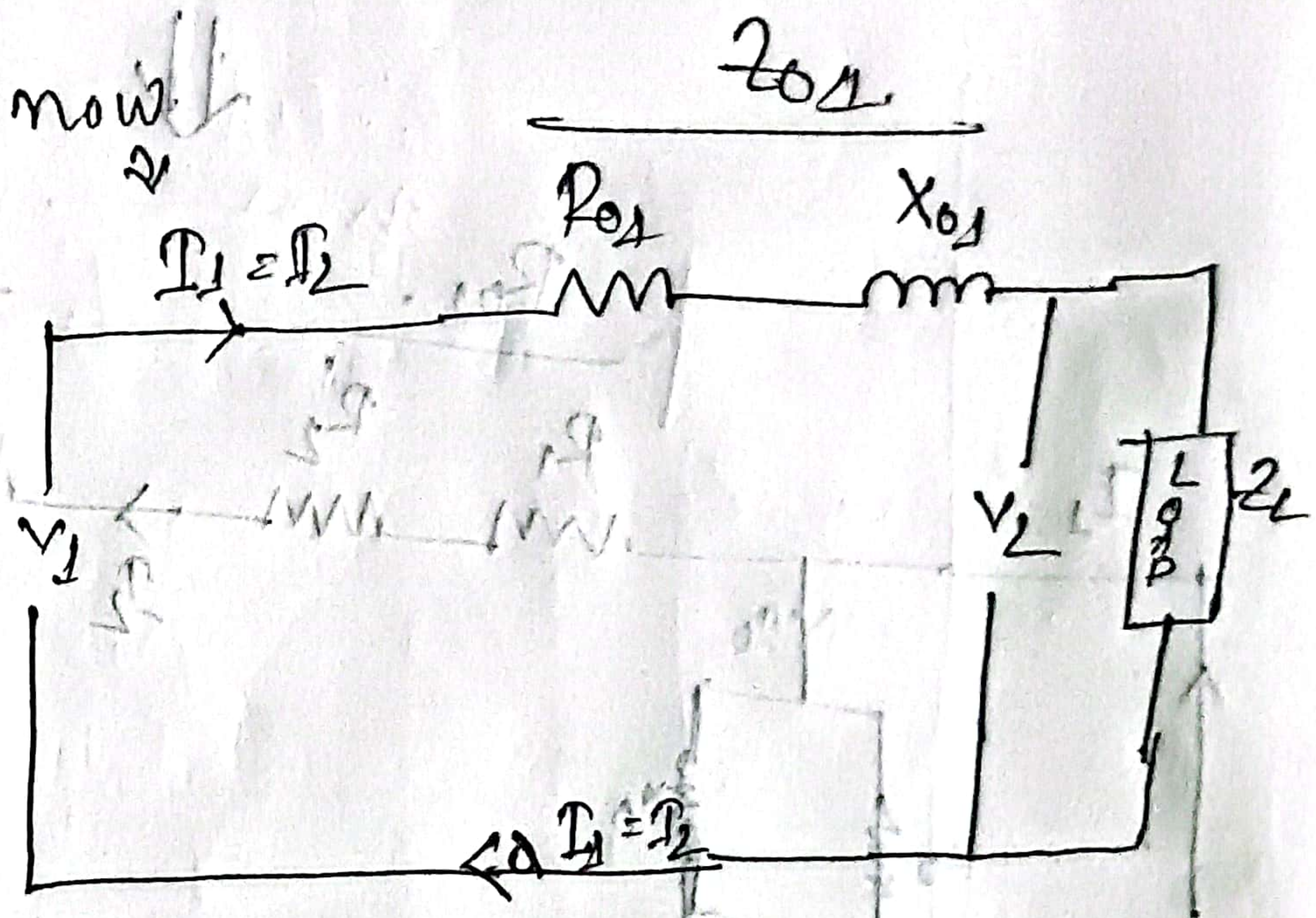


Approximate Equivalent Circuit

Now the circuit simplified by cancel I_0.



now



now this transformer equivalent circuit is being so easy to analyze.

Open Circuit test

why transformer tests is needed.

- The performance of a transformer can be calculated on the basis of its equivalent circuit which contains 4 main parameters.
- These parameters can be easily determined by two steps

⇒ open circuit test / no load test
⇒ Short circuit test / impedance test

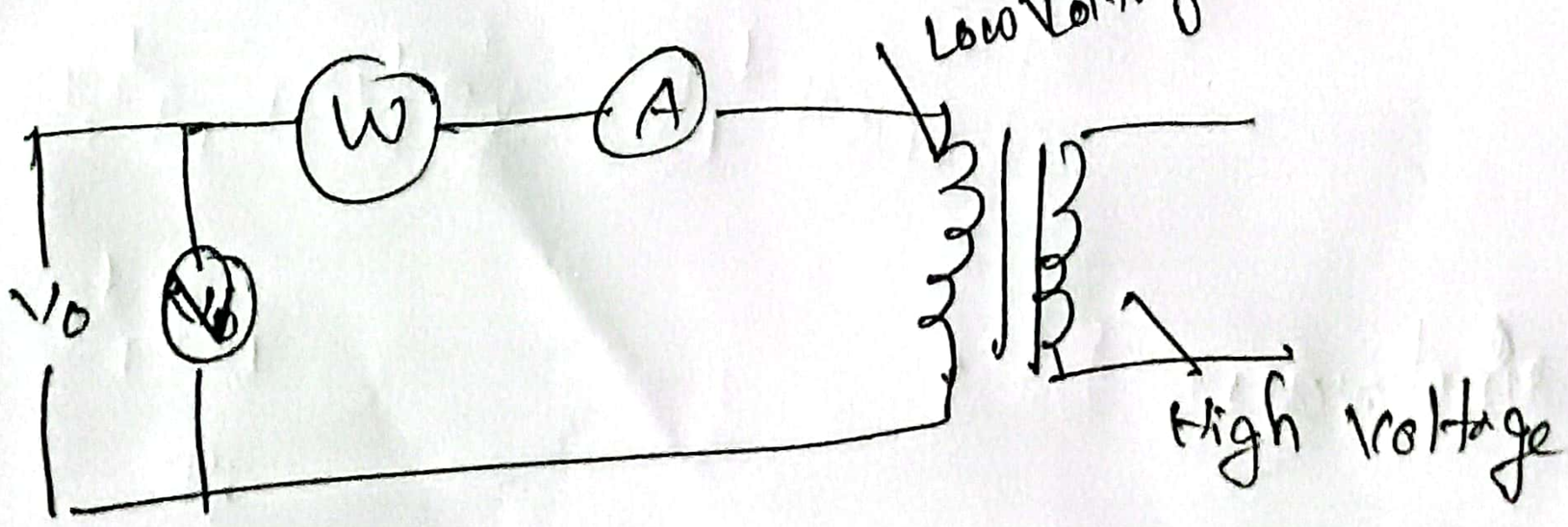
Open circuit test

- Core losses determined are
- open circuit in low voltage.
- wattmeter ⇒ power মাপে
- Amp meter ⇒ Current মাপে (Io)
- Volt meter ⇒ Voltage মাপে

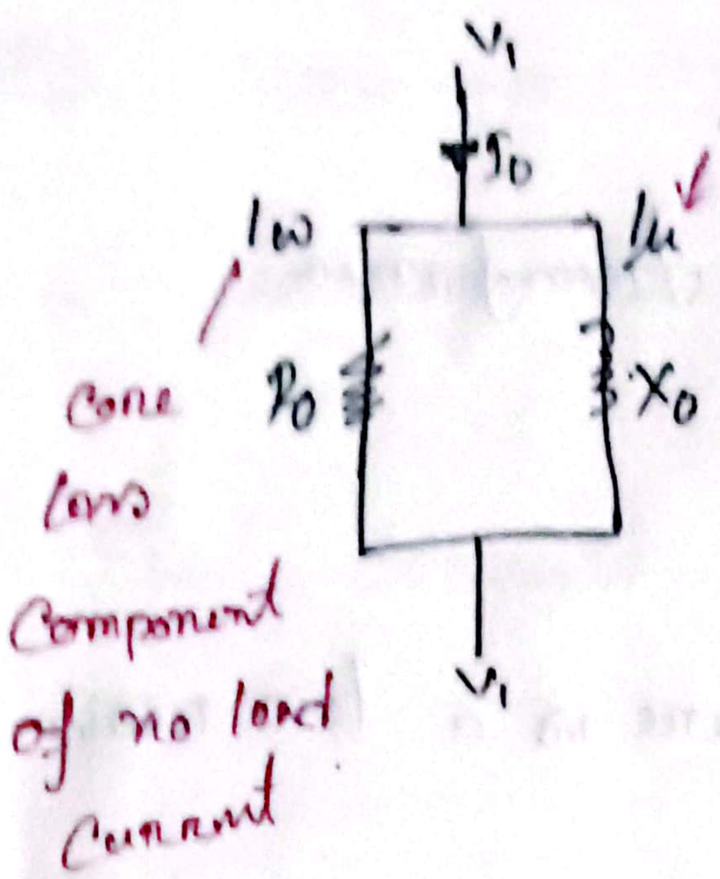
Iron losses measures করে

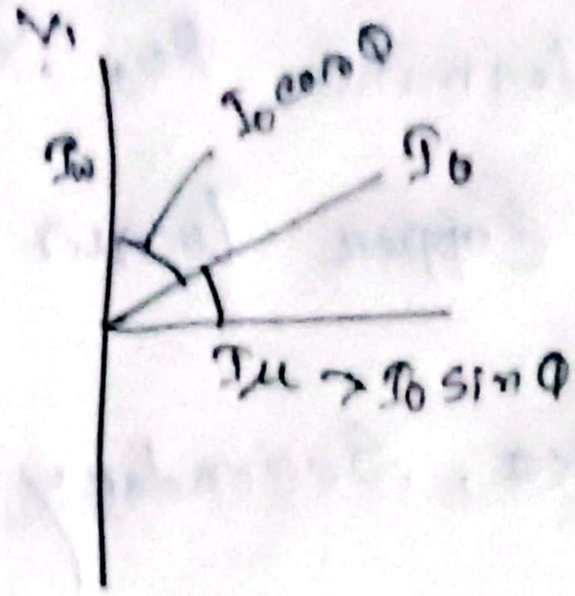
low voltage

- open circuit এক্ষেত্রে open থাকে



(*)





here $I_\mu = I_0 \sin\theta$

$I_w = I_0 \cos\theta$

$X_0 = \frac{V_1}{I_\mu}$

$R_0 = \frac{V_1}{I_w}$

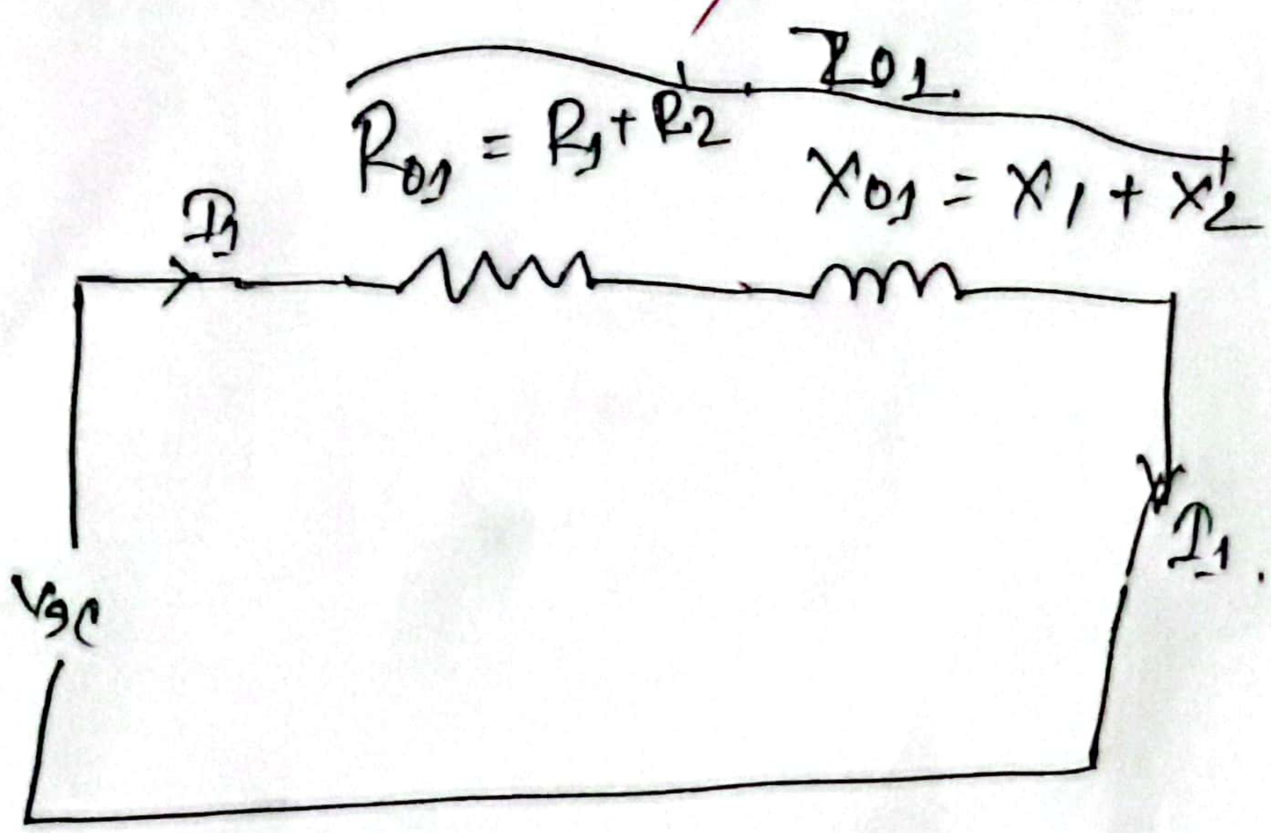
$P = V_1 I_0 \cos\theta$

$Z_0 = \sqrt{R_0^2 + X_0^2}$

Short Circuit Test.

- Conducted to determine R_{01}, X_{01}.
- To full load copper losses of the transformer
- Primary তে হবে, Secondary হবে
- Short circuit will occur where there is a low resistance.. [low voltage হয়)

- Full load Cu loss P_c = wattmeter reading = W_s.
- Voltage = voltmeter reading = V_{sc}
- Full load primary current = Ammeter reading = I_1.



$$P_c = I_1^2 R_1 + I_1^2 R_2' = I_1^2 R_{01}.$$

$$P_c = I_1^2 R_{01}.$$

$$R_{01} = \frac{P_c}{I_1^2}.$$ → total resistance referred to primary.

- Total impedance referred to primary $Z_{01} = \frac{V_{sc}}{I_1}$

" leakage reactance " " $X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$.

Sort Circuit P.f \ Power factor $P = VI\cos\theta$

$$\cos\theta = \frac{P}{VI}$$

—x—

Math open test and Sort Circuit test

Transformer Math C213067

① 5 KVA 200/1000 V, 50Hz, Single-phase transformer gave the following test results.

O.C test (L.V side): 200V, 1.2A, 90W

S.C test (H.V side): 50V, 5A, 110W.

a. Calculate the parameters of the equivalent circuit referred to the L.V. side

b. Calculate the parameters of the equivalent circuit referred to the H.V side

Ans A Given

$V = 200V$

$I = 1.2A$

$P = 90W$

we know

$P = VI\cos\phi$

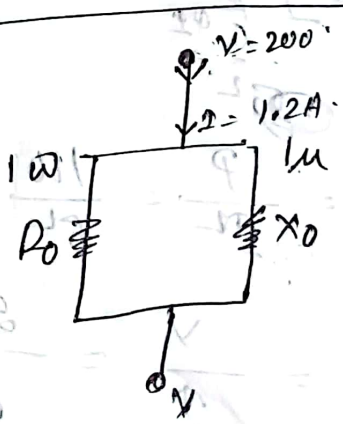
$\cos\phi = \frac{P}{VI}$

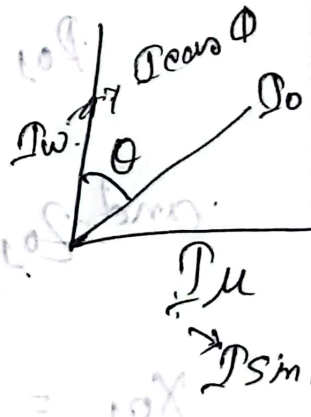
$\phi = \cos^{-1}\left(\frac{P}{VI}\right)$

$= \cos^{-1}\frac{90}{(200\times1.2)}$

$= 67.98$

O.C circuit (L.V side)





now

$I_w = I\cos\phi$

$= 1.2\cos 67.98$

$= 0.45A$

$I_\mu = I\sin\theta$

$= 1.2 \cdot \sin 67.98$

$= 1.11A$

Now $R_0 = \frac{V}{I_W}$ $\qquad X_0 = \frac{V}{I_\mu}$

$= \frac{200}{0.45}$ $\qquad = \frac{200}{1.11}$

$= 444.44\,\Omega$ $\qquad = 180.180\,\Omega$

Ans B

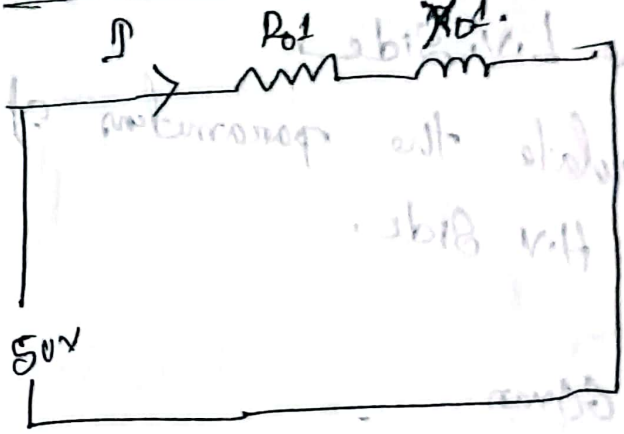
Given:

$V = 50V$

$I = 5A$

$P = 110W$

Short circuit (H.V side)



we know that

$P = I^2 R_{01}$

$R_{01} = \frac{P}{I^2} = \frac{110}{5^2} = 4.4\,\Omega$

and $Z_{01} = \frac{V}{I} = \frac{50}{5} = 10\,\Omega$.

$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$

$= \sqrt{10^2 - (4.4)^2}$

$= 8.98\,\Omega$.

Math CE03067

(2) A 100-KVA, 2000/440-V transformer has $R_1 = 5\,\Omega$, $R_2 = 0.08\,\Omega$.

The values of reactances $X_1 = 6\,\Omega$, $X_2 = 0.05\,\Omega$.

A. Calculate equivalent Impedance referred to primary.

B. Calculate equivalent impedance referred to secondary.

(A) here $K = \frac{V_2}{V_1} = \frac{440}{2000} = 0.22$.

$R_1 = 5\,\Omega$, $R_2 = 0.08\,\Omega$, $X_1 = 6\,\Omega$, $X_2 = 0.05\,\Omega$.

So, $R_{01} = R_1 + R_2'$

$= R_1 + \frac{R_2}{K^2}$

$= 5 + \frac{0.08}{(0.22)^2} = 6.65\,\Omega$.

$X_{01} = X_1 + X_2'$

$= X_1 + \frac{X_2}{K^2}$

$= 6 + \frac{0.05}{(0.02)^2}$

$= 7.03\,\Omega$.

impedance of Primary Side $Z_{01} = \sqrt{R_{01}^2 + X_{01}^2}$

$= \sqrt{(6.65)^2 + (7.03)^2}$

$= 9.68\ \Omega$.

Ans B

$K = 0.22$, $R_1 = 5\ \Omega$, $R_2 = 0.08\ \Omega$, $X_1 = 6\ \Omega$, $X_2 = 0.065\ \Omega$

Now

$R_{02} = R_1' + R_2$

$= R_1 \times K^2 + R_2$

$= \cancel{0.08}\ 5 \times (0.22)^2 + 0.08 = 0.322\ \Omega$.

$X_{02} = X_1' + X_2$

$= X_1 \times K^2 + X_2$

$= 6 \times (0.22)^2 + 0.065 = 0.2954\ \Omega$.

Impedance on Secondary Side $Z_{02} = \sqrt{R_{02}^2 + X_{02}^2}$

$= \sqrt{(0.322)^2 + (0.2954)^2}$

$= 0.44\ \Omega$.

③ A 50-KVA 4400/220 V transformer has $R_1 = 3.45\,\Omega$. $R_2 = 0.009\,\Omega$. The values of reactances are $X_1 = 5.2\,\Omega$ and $X_2 = 0.015\,\Omega$. Calculate for the transformer.

(i) equivalent resistance as referred to primary.

Ans

$$R_{01} = R_1 + R_2'$$

$$= R_1 + \frac{R_2}{K^2}$$

$$= 3.45 + \frac{0.009}{(0.05)^2}$$

$$= 7.05\,\Omega$$

$$K = \frac{220}{4400} = 0.05$$

$R_1 = 3.45$

$R_2 = 0.009$

$X_1 = 5.2$

$X_2 = 0.015$

(ii) Equivalent resistance as referred to secondary.

$$R_{02} = R_1' + R_2$$

$$= R_1 \times K^2 + R_2$$

$$= 3.45 \times (0.05)^2 + 0.009$$

$$= 0.176\,\Omega.$$

(iii) equivalent ~~resistance~~ reactance both primary and Secondary

$$X_{01} = X_1 + \frac{X_2}{K^2} = 5.2 + \frac{0.015}{(0.05)^2} = 11.2\ \Omega.$$

$$X_{02} = X_2 + X_1 \cdot K^2 = 0.015 + 5.2 \times (0.05)^2 = 0.028\ \Omega$$

(v) Equivalent impedance as referred to both primary and secondary.

find value in (3) (4).

impedance as primary $Z_{01} = \sqrt{R_{01}^2 + X_{01}^2}$

$$= \sqrt{(7.05)^2 + (11.2)^2}$$

$$= 13.23\ \Omega$$

impedance as secondary $Z_{02} = \sqrt{R_{02}^2 + X_{02}^2}$

$$= \sqrt{(0.176)^2 + (0.028)^2}$$

$$= 0.03311\ \Omega.$$

(vi) Total Cu loss first using individual resistance of the two winding and secondly, using equivalent resistance as referred to each side.

Ans 5

Cu loss using individual resistance of two winding

$$Cu\ loss = I_1^2 R_1 + I_2^2 \cdot R_2$$

$$= (11.36)^2 \cdot 3.45 + (227.27)^2 \cdot 0.009$$

$$= 910\ W.$$

$$I_1 = \frac{50K}{4400} = 11.36$$

$$I_2 = \frac{50K}{220} = 227.27$$

$$R_{01} = 7.05$$

$$R_{02} = 0.0176$$

Cu loss using equivalent resistance as referred to each side:

$$Cu\ loss = I_1^2 R_{01}$$

$$= (11.36)^2 \cdot 7.05$$

$$= 910\ W.$$

$$Cu\ loss = I_2^2 R_{02}$$

$$= (227.27)^2 \times 0.0176$$

$$= 910\ W.$$