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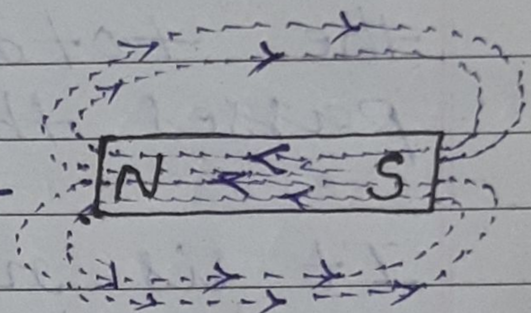
* magnetic circuit :— It is a closed path formed by magnetic material through with the magnetic flux can be transferred is known as magnetic flux.

OR

magnetic line of force originate from North-pole & terminate to the South-pole in out side the magnet, and inside the magnet south-pole to north-pole



- magnetic fields of line makes always a closed loop.

* Magnetic flux :— It is the magnetic line of forces originating from the unit north-pole of a magnet. It is denoted by ϕ. It's unit is webers (wb).

1 wb = 10^8 maxwell (line of force)

1 maxwell = 10^{-8} weber.

* It is analogous to current in electric circuit.

{Analogous → same behaviour but different products element}

OR

Magnetic flux is define as the number of magnetic field line passing through a given surface. It provides the measurment of the total magnetic field that passes through a given surface.

It is represented by ϕ (pie). Its unit is weber (wb).

$$\phi = BA\cos\theta$$

where,

B = Magnetic field density.

A = Given area.

θ = Angle between surface and magnetic flux.

Flux Density :— It is the amount of flux per unit surface area of any magnetic material. It is denoted by 'B'

$$B = \frac{\phi}{A}$$

unit :- $\frac{weber}{m^2}$ or tesla

* Magnetic lines of force :—

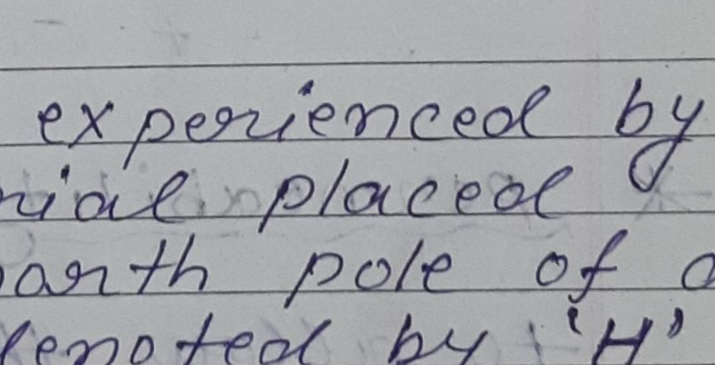
The magnetic lines of force are imaginery lines to represented magnetic field.

* Magnetic field :— The region sarrounding the magnet in which a piece of iron would experience a force is called magnetic field.

* Magnetizing force or magnetic field intensity :—

It is the force experienced by a magnetic material placed near the unit north pole of a magnet. It is denoted by 'H'

$$H = \frac{NI}{l}$$



where,

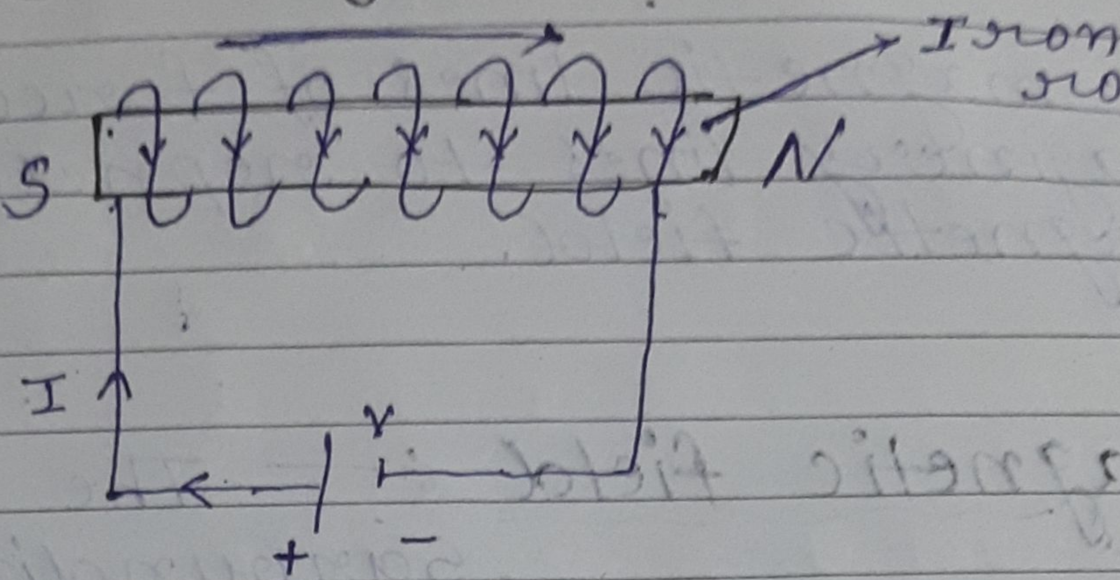
N = No. of conductor turns

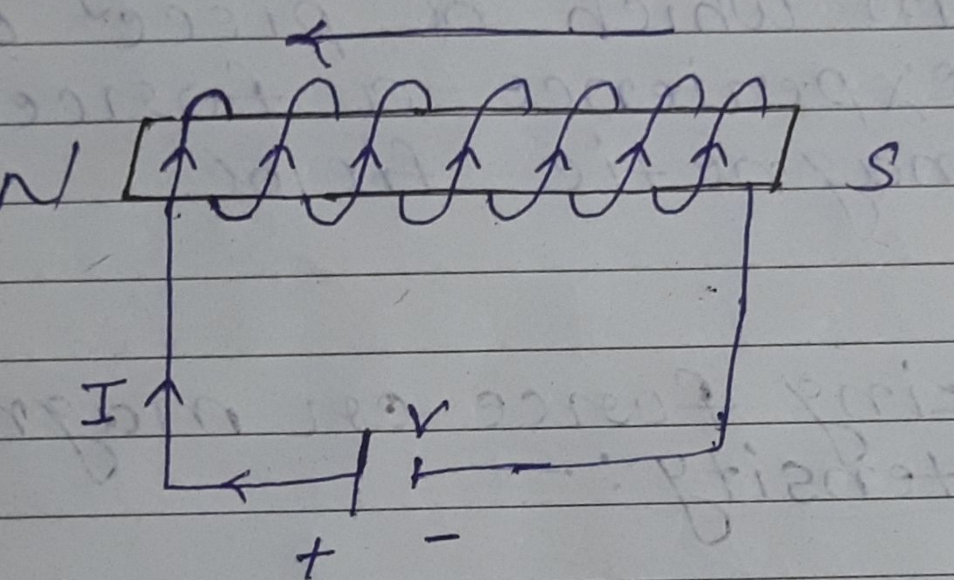
I = supply current

l = length of conductor.

* Unit :- Ampere x turns (AT/m)

* Electro Magnet :-

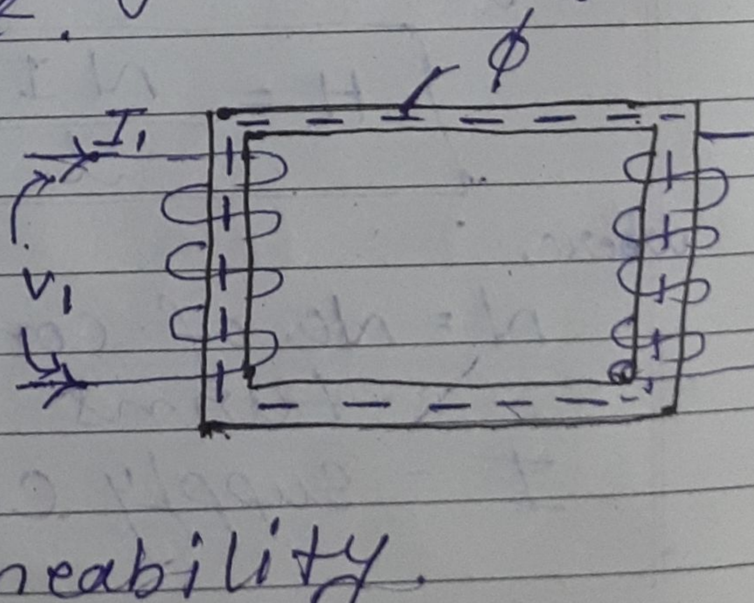




* permeability :-

It is ability of a magnetic material to allow the passage of magnetic flux through it.

It is denoted by 'μ'



$$\mu = \mu_0 \cdot \mu_r$$

μ_0 = Absolute permeability.
$(4\pi \times 10^{-7})$ unit :→ Henry

$$e = -N\frac{d\phi}{dt}$$

μ_r = Relative permeability of medium

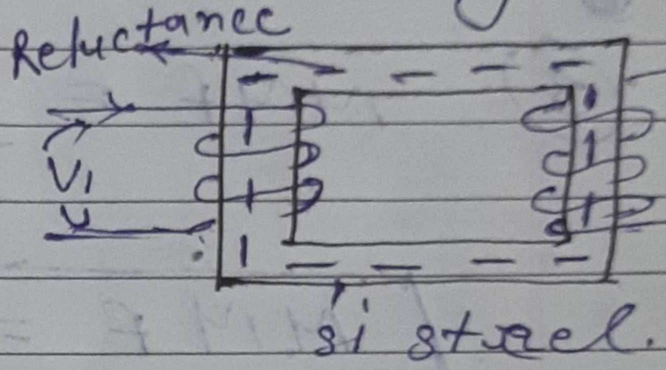
$\mu_r = 1$ {only for air or vaccume}

* It is unit less quantities.

* <u>Reluctance</u> :— It is the opposition offered to the transfer of magnetic flux through a magnetic material. It is denoted by 'S'

$$S = \frac{1}{\mu} \cdot \frac{l}{A}$$

$S \propto l$, $S \propto \frac{1}{A}$



$$S = \frac{l}{A \mu_0 \cdot \mu_r}$$ → unit :→ $\frac{AT}{weber}$

* MMF (Magneto-motive-force) :—

It is the driving force required for the transfer of Magnetic material

$$MMf = \phi S$$ ∵ $S = \frac{l}{A \mu_0 \mu_r}$

$\therefore MMf = \frac{\phi l}{A \mu_0 \mu_r} = \frac{B \cdot l}{\mu_0 \mu_r}$

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$$\therefore \boxed{MMF = \frac{B l}{\mu_0 \mu_r}} \quad \text{--- (1)}$$

$\because B \propto H$

$B = \mu H$ or $B = \mu_0 \mu_r H$

or $H = \dfrac{B}{\mu_0 \mu_r}$

(2) $\boxed{MMF = H \cdot l}$ → unit :- (AT)

we know that $H = \dfrac{NI}{l}$

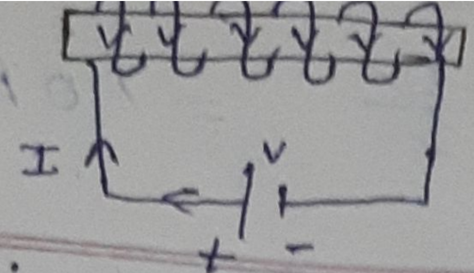
(3) $MMF = \dfrac{N \cdot I}{\cancel{l}} \times \cancel{l}$

$\boxed{MMF = N \cdot I}$ unit :- (AT).

OR

* MMF (Magneto Motive force) :-

MMF similar to the way that emf drives a current of electrical charge in electric circuits. MMF drives magnetics flux through the magnetic circuit.



- MMF is analogic (similar) of emf

- It is represented by "F"

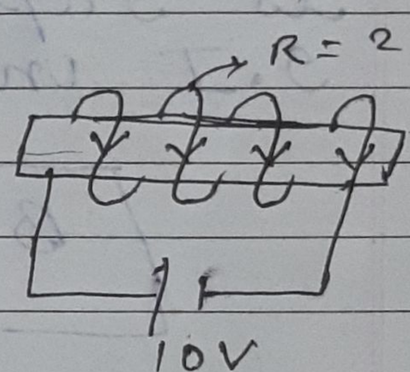
$$\boxed{MMF = N \cdot I} \quad \text{unit} \rightarrow (AT)$$

where,

N → Number of turns
I → current flowing the turns.

Numricals.

Q:-



given,
$R = 2\,\Omega$, $N = 4$
$V = 10V$, $MMF = ?$

$$I = \frac{V}{R} = \frac{10}{2} = 5A$$

$$MMF = N \cdot I = 4 \times 5 = 20\ (AT)$$

Ans.

Q:- If in a coil connected with a 20 V DC source and resistance of the coil is 2 Ω then what will be the MMF Generated by coil (N = 100)

given, $V = 20V$, $R = 2\,\Omega$, $N = 100$
find MMF = ?

$I = \frac{V}{R} = \frac{20}{2} = 10A$

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$MMF = N \cdot I$
$= 100 \times 10 = 1000 \ AT$
Ans.

* Magnetic field density :-

Magnetic field density is define as the force acting per unit current per unit length on a wire placed at right angle (90°) to the magnetic field. It is a vector quantity. It is represented by 'B'. Its S.I unit is weber/m^2 or Tesla.

$$B = \frac{f}{IL}$$ unit → wb/m^2 or Tesla.

$$f = BIL$$

Q:- If a wire of length 5cm kept in a magnetic field of value 0.5 Tesla at right angle. and current flowing through the wire is 2A then what will be the force acting on the wire.

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→ given, $L = 5\,cm = \frac{5}{100}\,m$

$B = 0.5$ Tesla

$I = 2\,A$

$f = ?$

$f = BIL$

$= \frac{0.5}{10} \times 2 \times \frac{5}{100}$

$f = 0.05\,N$

Ans

* Electro motive force (e.m.f):—

The electro motive force (e.m.f)

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* Potential Difference :-

The potential difference (P.d) between two points in the energy required to move one coulomb of charge from one to the other.

$$\boxed{V = \frac{W}{Q}} \quad \text{unit} = J/C$$

where,

W = energy required to transfer the charge.

Q = charge transfered between the points

V = potential difference.

* absolute premeablity :-

The premeability of all non-magnetic materialls including air is represented by is called Absolute premeability. It is denoted by μ_0. Its unit is H/m.

$$\mu = \mu_0 \mu_r$$

$$\Rightarrow \mu_0 = \frac{\mu}{\mu_r}$$

μ_r = Relative premeability

μ = premeability.

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* Relative magnetic permeability:-

The degree or extent to which magnetic field can permeate a material is called Relative magnetic permeability. Its denoted by μ_r. Its no dimention and unit.

$$\boxed{\mu_r = \frac{\mu}{\mu_0}}$$

OR

Relative magnetic permeability is the ratio of magnetic permeability of the material (μ) to the magnetic permeability of the free space (μ_0)

μ_r < for air or vaccum = 1
for soft iron = 8000

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* **Reluctance :-** The resistance offered by a magnetic circuit to the magnetic flux is known as Reluctance. As in electric circuit the reluctance similarly in the magnetic circuit.

OR

* Reluctance is the ratio of mmf to the flux. Its SI unit is AT/wb. It is represented by 'S'

$$S = \frac{mmf}{flux}$$ unit :- AT/wb

$$S = \frac{N \cdot I}{\phi}$$

$$S = \frac{l}{\mu_0 \mu_r A}$$

where, $\mu_0 \rightarrow$ absolute permeability
$\mu_0 = 4\pi \, 10^{-7}$ H/m

$\mu_r \rightarrow$ relative permeability
$A \rightarrow$ crossectional area of the

l → length of Rode.

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* faraday law of electro magnetic Induction or faraday's law:-

michael faraday prapose the law of electromagnetic induction in the year 1831

faraday law of electromagnetic induction consist of two laws. The first law describes the induction of emf in a conductor and the second law tell as the amount of emf in used.

* faraday's first law of electromagnetic induction:-

whenever a conductor is placed in a varying (change) magnetic field. An electro motive force (e.mf) is in used. If the conductor circuit is closed a current is in used

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* faraday's first law of electro-magnetic induction :-

whenever a conductor is placed in a varying (change) magnetic field. An electromotive force (emf) is indused. If the conductor circuit is closed a current is in used it is called induced current.

* faraday's second law of electro-magnetic induction :-

faraday's second law state that the emf produce due to electromagnetic induction is directly proportional to rate of change of flux with respect to time and No. of turns of the conductor

$$e \propto \frac{N d\phi}{dt}$$

$$e = \frac{N d\phi}{dt}$$ unit = wT/sec

• constant values is 1.

* **Lenz's law :—**

Lenz's law state that the direction of the electric current indused in a conductor by a changing magnetic field such that the magnetic field created by the indused current opposes in the initial magnetic field.

$$e = -N \frac{d\phi}{dt}$$

Negative stand for lenz law

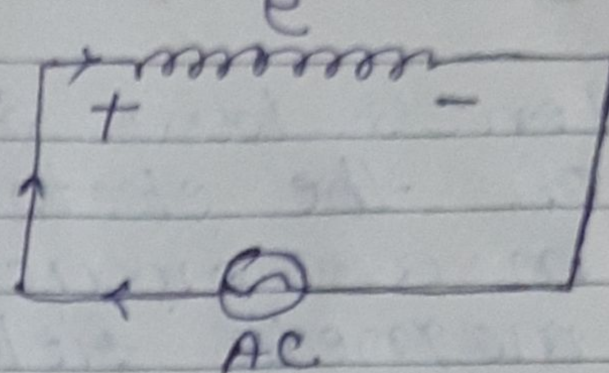
* It is the combination of faraday second law and lenz law.

* **self induction :—**

It is the finominal due to ~~the~~ which an emf induced in a coil as a result of change in current flowing through it

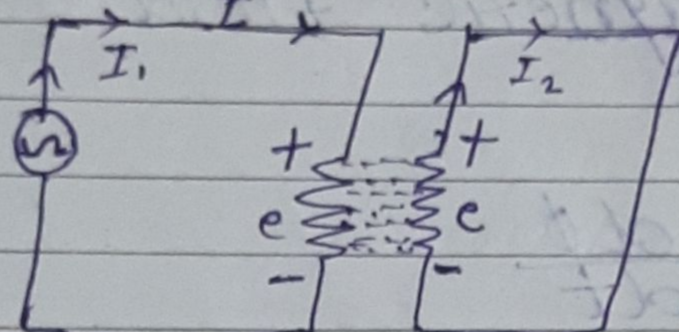
$\boxed{\phi = L \cdot I}$ I = current
L = Inductance of the coil (Handry).

$$e = -N \frac{d\phi}{dt}$$



$$\boxed{e = -N \frac{d(L.I)}{dt}}$$

* Mutual inductor:-



If a coil placed near to the changing carrying coil then flux cut through it as a result an emf in induced.

$$\boxed{e = -M \frac{dI_1}{dt}}$$

m = mutual induction

It's SI unit is Hanery.

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* Absolute permeability (μ_0) :—

permeability is the measure of the ability of the material to allow the formation to of magnetics lines of force magnetic field within.

$$\mu_0 = 4\pi \times 10^{-2} \quad H/M$$

* (μ_r) Relative permeability :—

It is the ratio of permeability of the material to the absolute permeability.

Dimension less and unit less this ability.

* Reactance :—

The resistance offered by the capacitar or inductor is known as Reactance. It depends on frequency.

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* inductive Reactance :-

The reactance offered by the inductor is known as inductive Reactance. It represented by X_L

$$X_L = \omega L \qquad X_L = 2\pi f L$$

where

$\omega = 2\pi f$

f = frequency (50 Hz)

L = inductance (H).

* capacitive Reactance :-

The reactance offered by the capacitor is known as capacitive reactance.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

where,

$\omega = 2\pi f$

f = frequency

C = capacitance. (F).

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* current :- The flow of electric charge is known as electric current.

$$I = \frac{dQ}{dt}$$ S.I unit → Ampere

where
Q = charge
t = time.

* power factor (p.f):-

The ~~cosine~~ cos sign angle between voltage and current is known as power factor.

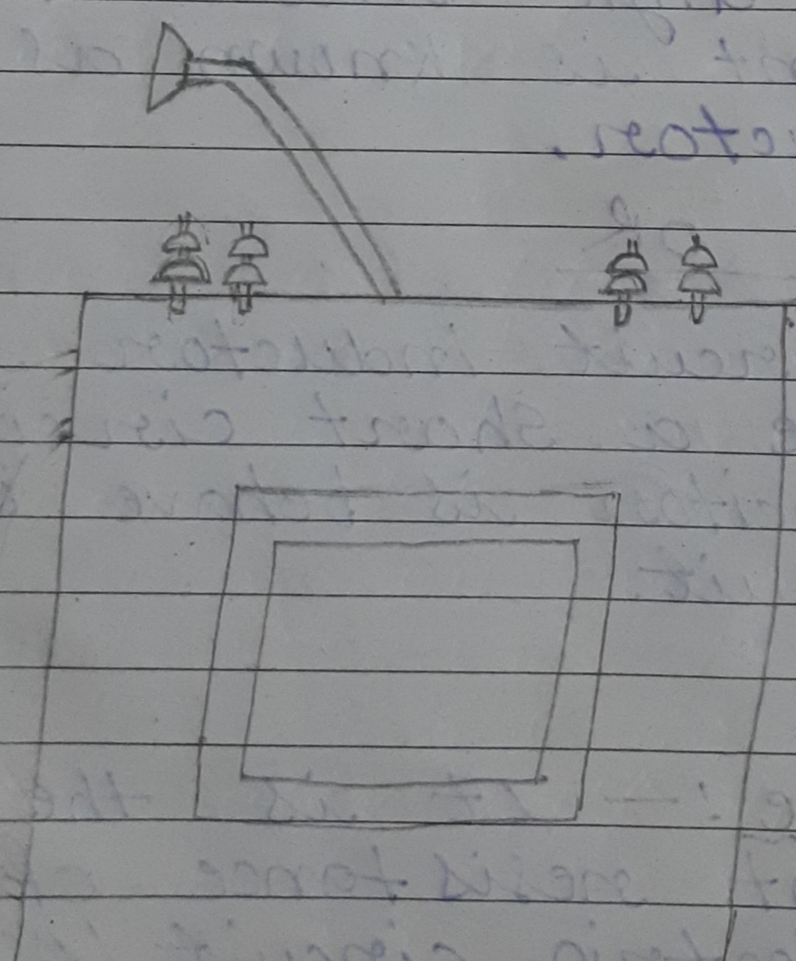
OR

In DC circuit inductor is behave like a short circuit and capacitor is behave like a open circuit.

* (Z) Impedance :- It is the equivalent resistance offered by an electric circuit (AC circuit) is known as Impedance. It is represented by 'Z'

$$Z = \sqrt{R^2 + X_L^2}$$

Transformer :- Transformer transfered the electrical energy from one electric circuit to another electric circuit without changing the frequency and power. **OR** :- Transformer is an electro magnetic energy conversion static device it is commonly used in electrical power system and distribution system.



* **primary side** :— That side of Transformer in which source or input or excitation is applied is known as primary side

* **secondry side** :— That side of transformer in which load is connected.

Construction of Transformer :—

A Transformer is mainly consist of primary winding, secondry winding and core with the increase in the size or capacity of the transformer it also needs other part such as suitable tank, breather, conser-vator, exploin vent, bucholz relay and busing.

* **core** :— Generilly it is made up leminated silicon steel it provide law reluctance path and minimize eddy current loss.

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* **windings** :- The coils forming the primary and secondry winding at transformer would is the well insulated copper (conductor) in the form of wire

* **Transformer tank** :-

Transformer tank protect the transformer from mois ture and other external distribution It is made up of metalic material.

* **conservator tank** :- The main function of conservator tank is to provide extra space to accomabodete the transformer oil during oil expension. It is a selinatrical tank maintained on the top of the transformer. It generally half field transformer oil.

or

The main function of conservator tank to provide extra space is to expend the transformer oil during oil. expension due to

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heating.

Breather :- The main function of breather is to prevent ~~moisture~~ ~~to~~ (protect) moisture to entre the transformer during the breathing cycle of transformer it contain the silicagell that observe the moisture from the air and prevent transformer oil.

Buchholz relay :- The main function of buchholz relay is to protect the transformer from different internal fault It detectes the accurance of fault and generate the alarm circuit. It is present the main tank and conservation tank.

cooling tube :- The main function of cooling tube is to transformer heat from the transformer coil and core to the environment. The heated transformer oil circulates through the cooling tubes, where the heat radiater out.

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* **Top charge :-** The main function of top charge is to regulate the transformer output voltage by altering the number of turn in one winding and there by changing the turn ratio of transformer

* **Explosion vent :-** The main function of explosion vent is to provide protection againt accessering presure build up in the transformer during heavy internal fault.

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Classification of substances according to μ_r :-

① **Non magnetic substances :-** ($\mu_r = 1$)

eg:- Air, cotton, glass, wood, plastic, mica, rubber etc.

(ii) **Magnetic substances :-**

ⓐ Diamagnetic ($\mu_r < 1$)

eg:- Antimony, Bismuth, copper, qurtz, water, etc

ⓑ paramagnetic ($\mu_r > 1$)

eg:- Aluminium, chromium, manganese, lithium, platinum, etc.

ⓒ ferromagnetic ($\mu_r >> 1$)

eg:- Iron, cobalt, Nickel and their alloys.

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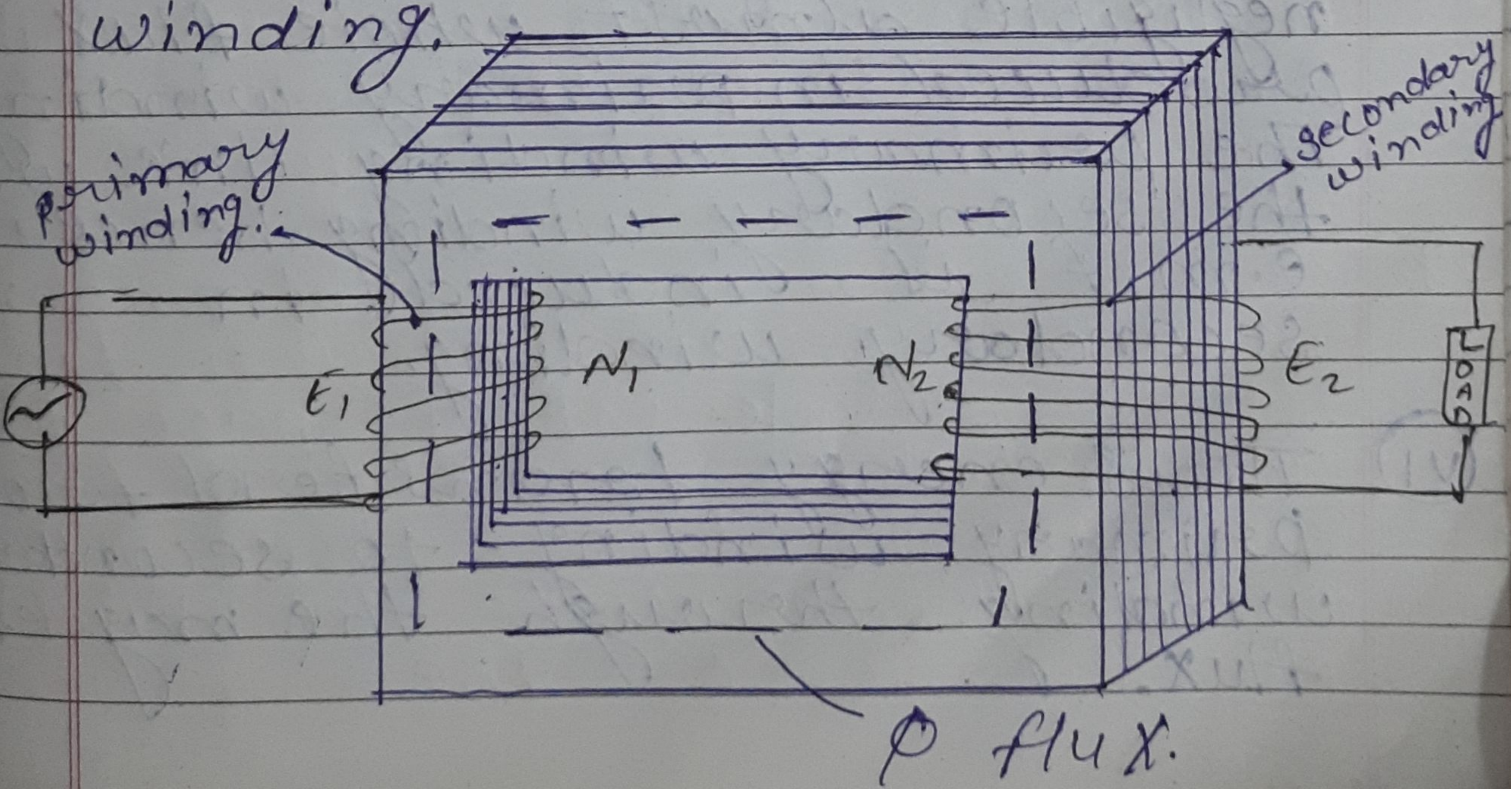
* working principle of transformer :-

(i) The transformer is static piece of device by means of which an electric power transfered from one circuit to another circuit with change in frequency.

(ii) A transformer operates on the principal of mutual inductance between two inductively couplet coils. The winding in which electrical energy is fed is called primary winding and the other form energy is drown out is called secondary winding.



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(iii) The primary winding has N_1 number of turn, while the secondary winding has N_2 number of turns. The basis transformer and its symbol is show. (1.1)

(iv) when an aternating voltage V_1 is applied to primary an alternating current I_1 flow in it prioducing alternating flux in the core. According to faradays low of electromagnetic induction on e.m.f is induced in the primary winding.

(v) Assume leakage flux to be negligible almost whole flux produced in primary winding. The primary winding link with the secondary winding hence, e.m.f is induced in secondary winding.

(vi) Thus energy transferd from primary winding to secondary winding through the magnetic flux.

* Derive e.m.f equation, and explain tranfarmation ratio.

→

let the flux of any instant

$$\phi = \phi_m \sin \omega t \quad \text{--- (i)}$$

where,

ϕ_m = maximum flux.

Now,

assume Number of turns of the winding is N

∴ from faraday's law

$$e = \frac{-N\, d\phi}{dt}$$

$$e = -N \frac{d(\phi_m \sin \omega t)}{dt}$$

$$e = -N \phi_m \frac{d(\sin \omega t)}{dt}$$

$$e = -N \phi_m \frac{d \sin \omega t}{\sin \omega t} \times \frac{d \omega t}{dt}$$

$$e = -N \phi_m \cos \omega t \cdot \omega$$

$$\boxed{e = -N \phi_m \omega \cos \omega t}$$

$e = N \phi_m \omega (-\cos \omega t)$

$e = N \phi_m \omega [\sin(\omega t - \pi/2)$

$e = N \phi_m \omega \sin(\omega t - \pi/2)$

Let,

$e_m = N \phi_m \cdot \omega$

$e_{rms} = \frac{e_m}{\sqrt{2}}$

$e_{rms} = \frac{N \phi_m \omega}{\sqrt{2}}$

$e_{rms} = \frac{\omega}{\sqrt{2}} N \phi_m$

$e_{rms} = \frac{2\pi f}{\sqrt{2}} N \phi_m$ $[\omega = 2\pi f]$

$e_{rms} = \frac{2\pi}{\sqrt{2}} N \phi_m f$

$$\boxed{e_{rms} = 4.44 \phi_m f N} \quad \text{— (11)}$$

where,

ϕ_m = maximum flux

f = frequency

N = Number of turns.

for primary winding number of turns is N_1

$$e_{rms} = 4.44\ \phi_m\ f N_1 \quad \text{--- (III)}$$

for secondary winding number of turn is N_2

$$e_{2rms} = 4.44\ \phi_m\ f N_2 \quad \text{--- (IV)}$$

Now, devided eqn (III) and (IV)

$e_{1rms} = E_1$, $e_{2rms} = E_2$

then

$$\frac{E_1}{E_2} = \frac{4.44\ \phi_m\ f N_1}{4.44\ \phi_m\ f N_2}$$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \text{or,} \quad \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

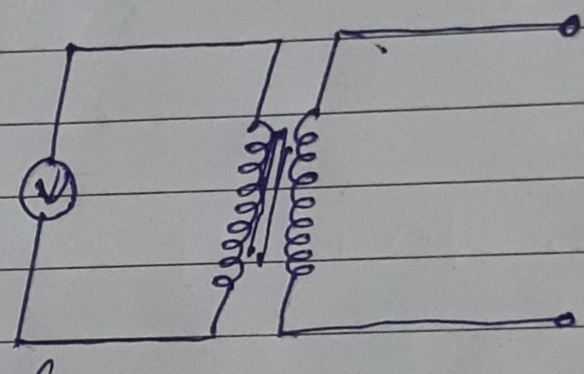
Transformation ratio.

Losses of ~~transformer~~

* Transformer on no-load:-

A transformer is said to be on no load when the secondary winding is open circuited the secondary current is zero. when an alternating voltage is applied to the primary a small current (I_o) flowes in the primary the current I_o is called the no load current of transformer.

I_0 = no load current



$I_0 \rightarrow$ 2 to 5 % of rated current.

- It is made up of two components of I_u and I_w.

The components I_u is called the magnetizing component. It magnetize the core. In other words It sets up a flux in the core and their for I_u is in phase with ϕm.

The current I_μ is also called reactive. wattless components of no load. current.

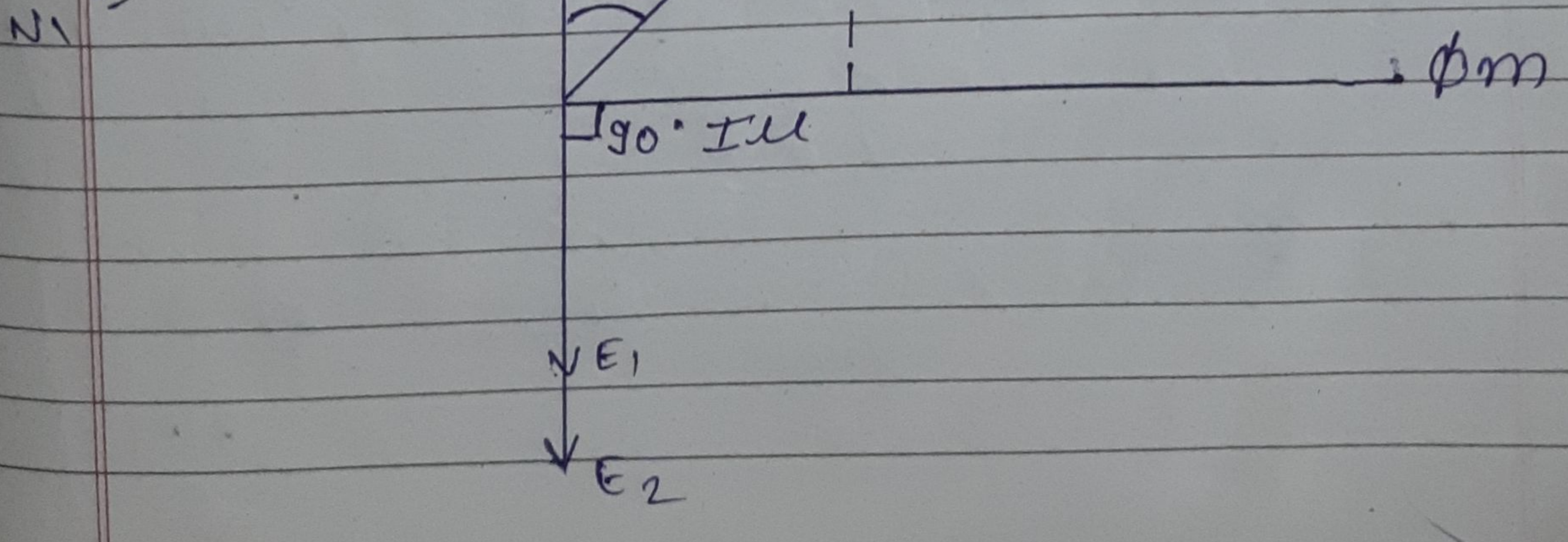
The component I_w supplies is the hysteresis and eddy current losses. In the core. The current I_w is called the active components or wattfull components of no load current. It is in phase with applied voltage V_1

The no load current is 2 to 5% of rated or full load current of the transformer.

* phasor diagram of transformer at no load:-

$\phi = \phi_m \sin \omega t$

$E_1 = E_m \sin(\omega t - \frac{\pi}{2})$



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$I_\mu = I_0 \sin\phi_0$

$I_w = I_0 \cos\phi_0$

$I_0 = \sqrt{I_\mu^2 + I_w^2}$

power factor at n/o load =

$\cos\phi_0 = \frac{I_\mu}{I_0}$

core loss = $V_1 I_0 \cos\phi_0$

$= V_1 I_\mu$ (watt).

Ideal transformer :-

An Ideal transformer is an imaginary transformer which has the following properties:-

(i) Its primary and secondary winding resistance are negligible (zero)

(ii) Its leakage flux and leakage inductance are zero therefore the entire flux confined to the both winding

(iii) There are no losses due to resistance, hysteresis and eddy current loss therefore the efficiency of Ideal transformer 100%

$$\text{efficiency } (\eta)\ \% = \frac{\text{output}}{\text{input}} \times 100$$

Input = output + losses.
= output + P_i + P_{cu}

output := input − losses
= ~~input~~

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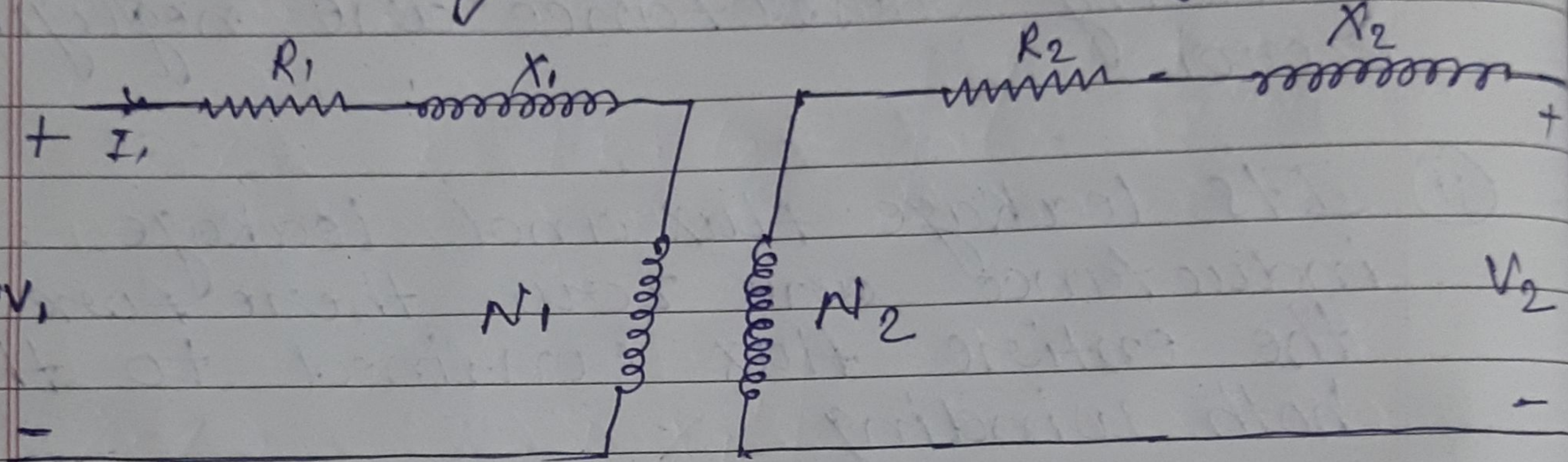
winding resistance :-

An ideal transformer is suppose to no resistance. But in actual transformer (practical transformer) there is always some resistance of primary and secondary winding



where

R_1 = Resistance of primary winding

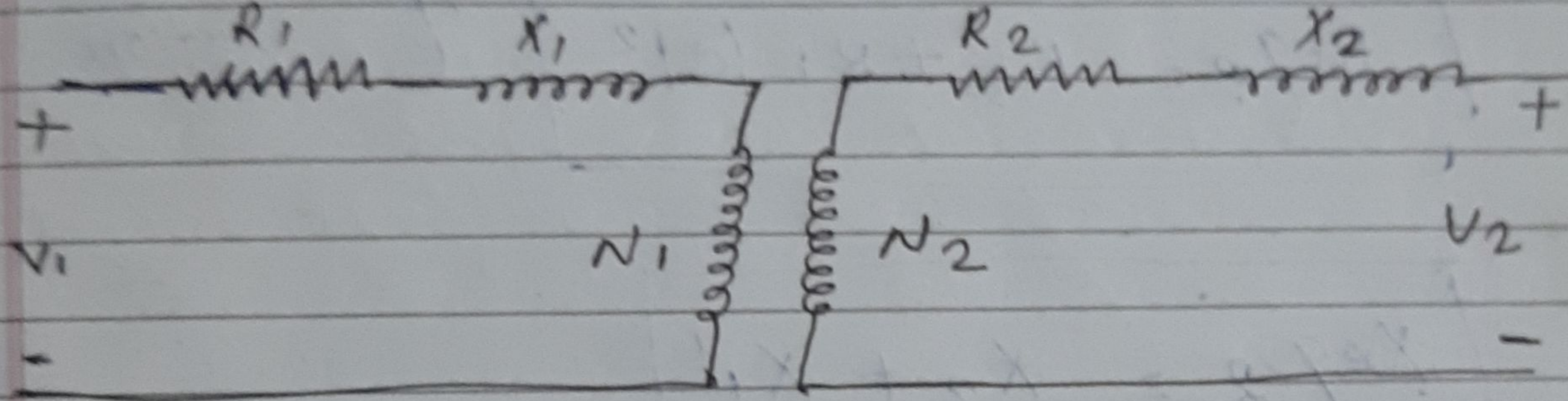
R_2 = Resistance of secondary winding

X_1 = Reactance of primary winding

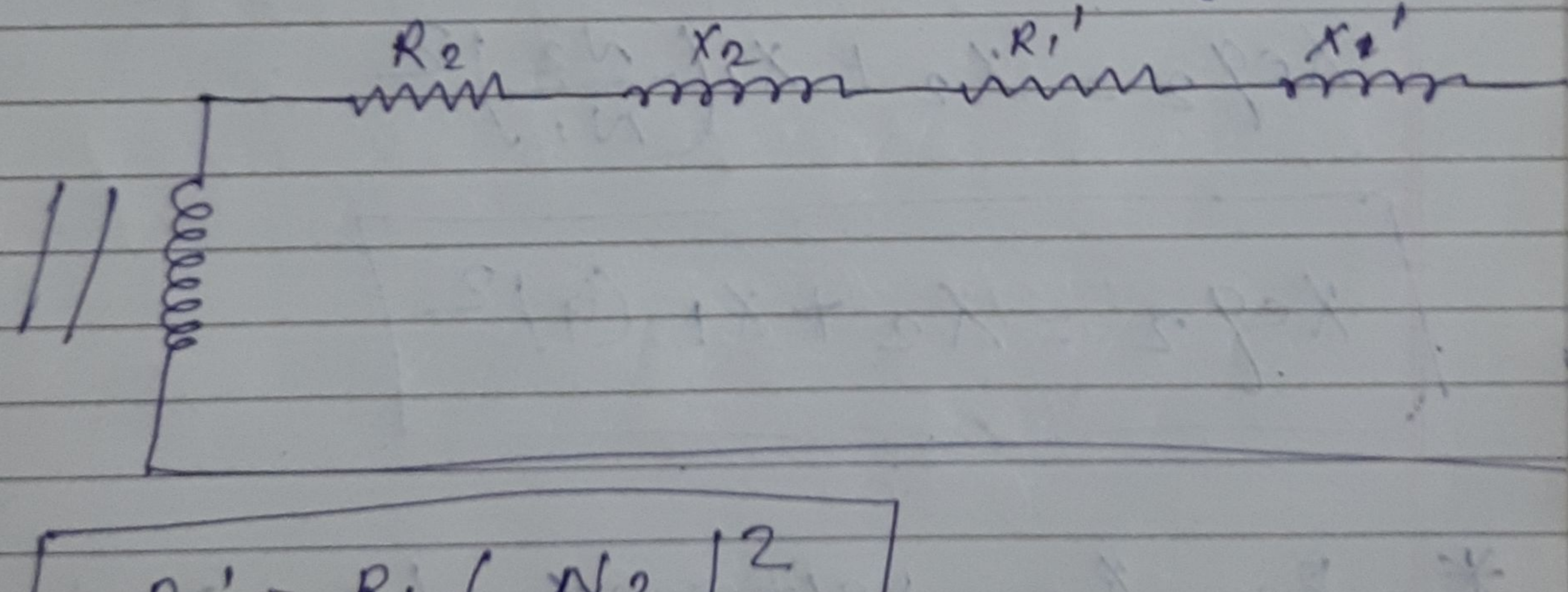
X_2 = Reactance of secondary winding.

Refferd values of Resistance and reactance of transformer:-

$R_1' \to R_1$ reffered to secondary side
$R_2' \to R_2$ reffered to primary side
$X_1' \to X_1$ reffered to secondary side
$X_2' \to X_2$ reffered to primary side



R_1, X_1 reffered to secondary side



$$R_1' = R_1 \left(\frac{N_2}{N_1}\right)^2$$

$$X_1' = X_1\left(\frac{N_2}{N_1}\right)^2$$

$$Req_2 = R_2 + R_1'$$

$$= R_2 + R_1\left(\frac{N_2}{N_1}\right)^2$$

$$Req_2 = R_2 + R_1 (a)^2$$

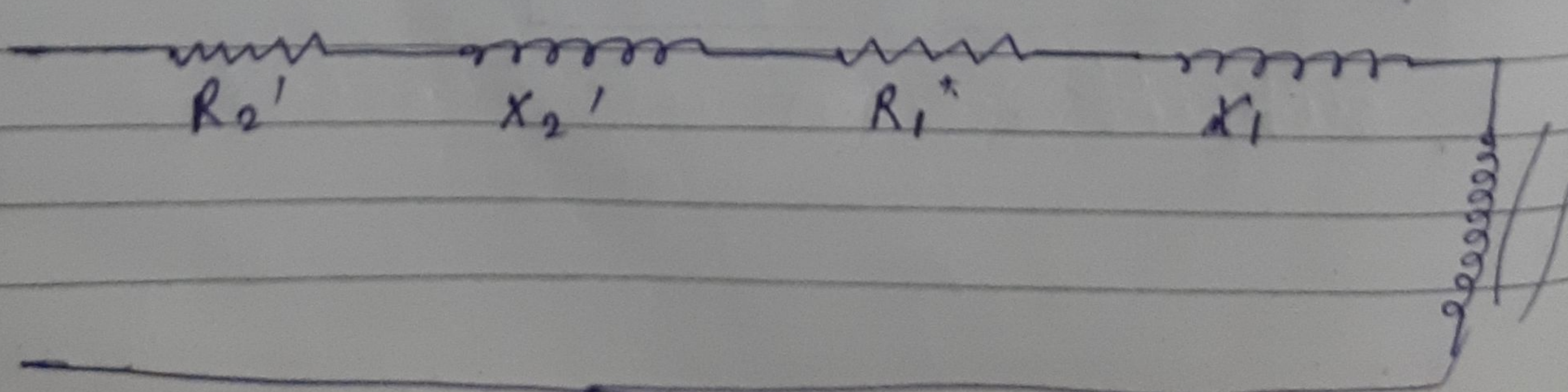
[a = transfar mation ratio]

$$Xeq_2 = X_2 + X_1'$$

$$Xeq_2 = X_2 + X_1\left(\frac{N_2}{N_1}\right)^2$$

$$Xeq_2 = X_2 + X_1 (a)^2$$

* R_2, X_2 Reffered to primary side



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$$R_2' = R_2\left(\frac{N_1}{N_2}\right)^2$$

$$Zeq_2 = \sqrt{Rs_2^2 + Xs_2^2}$$

$$X_2' = X_2\left(\frac{N_1}{N_2}\right)^2$$

$$Req_1 = R_1 + R_2'$$

$$Req_1 = R_1 + R_2\left(\frac{N_1}{N_2}\right)^2$$

$$Req_1 = R_1 + R_2\left(\frac{1}{a^2}\right)$$

$$Xeq_1 = X_1 + X_2'$$

$$= X_1 + X_2\left(\frac{N_1}{N_2}\right)^2$$

$$Xeq_1 = X_1 + X_2\left(\frac{1}{a^2}\right)$$

$$Zeq_1 = \sqrt{Rp_1^2 + Xp_1^2}$$

Impedence

{Numericals}

Q:- A 200 KVA single phase transformer with the voltage ratio of 6350/600V has the following winding resistance and reactance

$R_1 = 1.56\,\Omega$ $R_2 = 0.016\,\Omega$

$X_1 = 4.67\,\Omega$, $X_2 = 0.048\,\Omega$

Calculate the resistance and reactance of the transformer reffered to high voltage winding.

given →

$V_1 = 6350V$ $V_2 = 600V$

$R_1 = 1.56\,\Omega$ $R_2 = 0.016\,\Omega$

$X_1 = 4.67\,\Omega$ $X_2 = 0.48\,\Omega$

$R_2' = R_2 \left(\frac{N_1}{N_2}\right)^2$ $\left[\frac{N_1}{N_2} = \frac{V_1}{V_2}\right]$

$= \frac{0.016}{1000}\left(\frac{635}{60}\right)^2$

$\frac{16 \ldots 5}{\ldots 00}$

$\frac{16}{1000} \times \frac{403225}{3600}$

$\frac{6451.600}{3600000}$ 1.79

156
86
936
468
5616

$Re' = R_1 + R_2'$

$= 1.56 + 1.79$

$= 3.35\,\Omega$

$R_1' = R_1\left(\frac{N_2}{N_1}\right)^2$

$\frac{1.56}{100}\left(\frac{60\cancel{0}}{635\cancel{0}}\right)^2$

$\frac{156}{1\cancel{00}} \times \frac{360\cancel{00}}{403225}$

$\frac{5616}{403225}$

$X_2' = X_2\left(\frac{N_1}{N_2}\right)^2$

$\frac{0.048}{1000} \times \left(\frac{635\cancel{0}}{60\cancel{0}}\right)^2$

$\frac{48}{1000} \times \frac{403225}{3600}$

$\frac{193548\cancel{00}}{36000\cancel{00}} = 5.37$

$Xe_1 = X_1 + X_2'$

$= 4.67 + 5.37$

$= 10.04.$

Losses of transformer:-

(I) copper loss or winding loss

(II) Iron loss or core loss → Hysteresis loss
→ eddy current loss

(III) stay loss or flux loss

(IV) Dielectric loss.

(I) Copper loss or winding loss or Resistive loss or variable loss

Resistive loss is the power loss in a transformer caused due to the ohmic Resistance of copper wire used to make the winding the power is dissipated in the form of heat due to the electric current in the conductors of transformer primary & secondary winding these losses are also called copper loss or ohmic loss.

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(ii) Iron loss or core loss:-

core of the transformer is the one that links both like primary and secondary winding by magnetic induction the losses that occurs in the magnetic core are called core loss in transformer

* There are two main types of iron loss

(i) Hysteressis loss
(ii) eddy current loss.

(i) Hysteresis losses:-

Hysteresis loss in a transformer occurs due to magnetization saturation in the core of the transformer. magnetic materials in the core will eventually become magnetically saturated when they placed in a strong magnetic field such as the magnetic field generated by an AC current

OR

Hysteresis loss is caused by the magnetization and demagnetization of the core as current flows in the forward and reverse directions. As the magnetizing force (current) and magnetic flux increase.

* **Stray losses :-** stray losses refer to the heat losses that occurs in all transformer components except for the copper winding.

* **Dielectric losses :-**

The power loss occurs in insulating materials like oil, solid insulation of the transformer etc is known as dielectric loss.

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losses of transformer

$$P_i = P_h + P_e$$

P_i → Iron loss
P_h → Hesteresis loss
P_e → eddy current loss

$$P_h = K_h f B_m^x$$

$$P_e = K_e f^2 B^2 m$$

* K_h → porportioniality constant which depends upon the volume and quality of the core materials.

* K_e → parportionality constant which depends upon the volume and quality of the core materials, thickness of the lemination

B_m → maximum flux density
f → frequency
x → load fraction.

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$P_n \propto f$

$P_n = af$ —— (i)

$P_e \propto f^2$

$P_e = bf^2$ —— (ii)

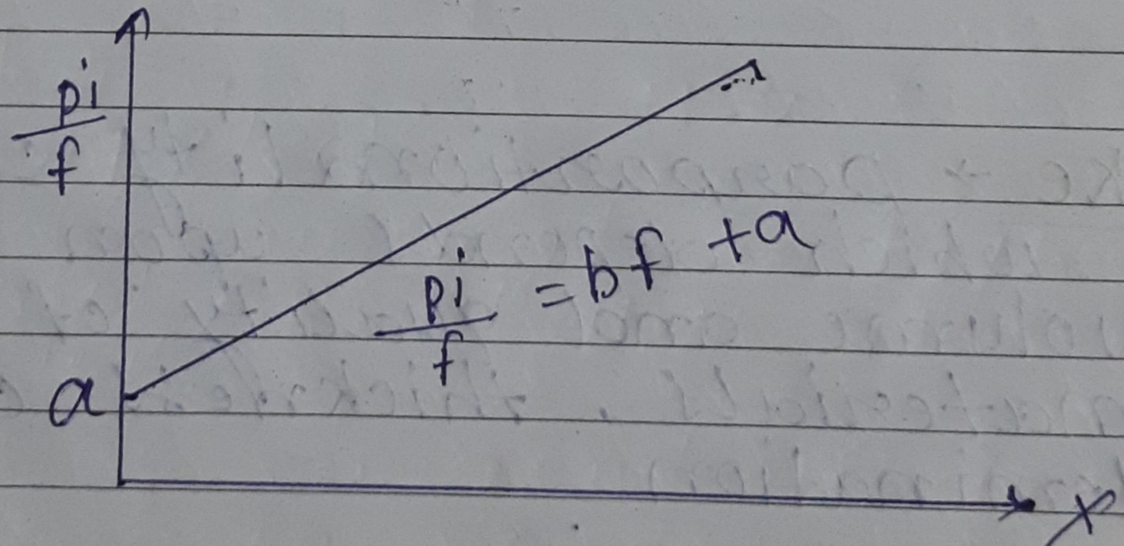
$P_i = P_n + P_e$

$P_i = af + bf^2$ (from (i) & (ii))

$P_i = f(a + bf)$

$$\frac{P_i}{f} = a + bf$$

$$\boxed{\frac{P_i}{f} = bf + a}$$



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* Total copper loss of transformer
= primary winding copper loss
+ secondary winding copper loss

$$P_c = I_1^2 R_1 + I_2^2 R_2$$

* No-load losses :-

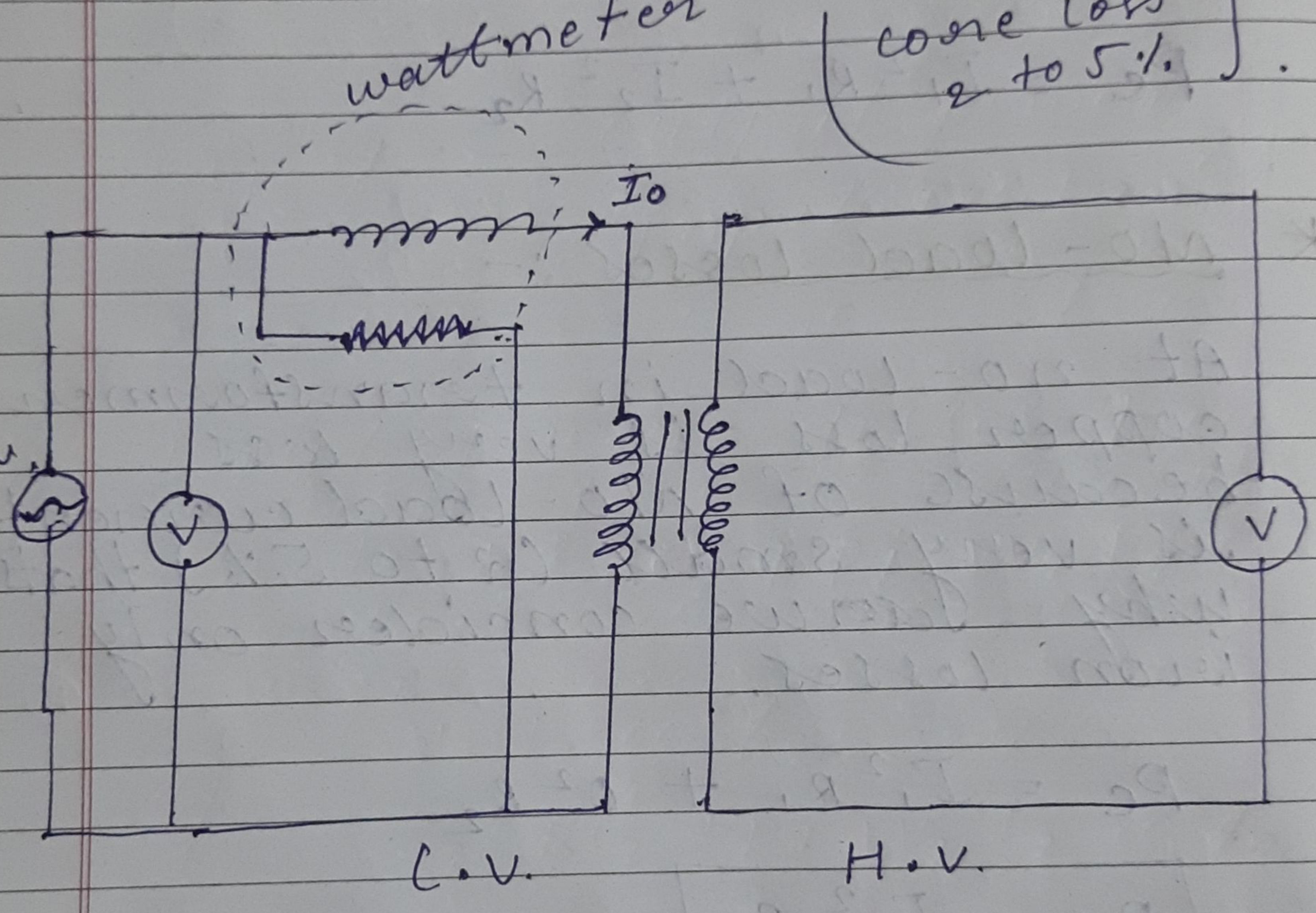
At no-load in transformer copper loss is very less because of No-load current is very small (2 to 5%) thats why we concider only iron losses.

$$P_c = I_1^2 R_1 + 0^2 R_2$$

$$\boxed{P_c = I_1^2 R_1}$$

* open circuit test :-

open circuit test are perform to determine the circuit constants, efficiency and regulation the transformer. These test gives more accurate results then these obtained by taking measurement on fully loaded condition transformer



- L.V. side current is high as compareason to H.V. side
- H.V. side current is low as compareason to L.V. side

$P_i = P_{iron}$

$$P_{iron} = V_1 I_0 \cos\phi_0$$

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$$P = VI \cos \phi_0$$

* Ammeter reading = No Load current (I_0)

* voltmeter reading = primary rated voltage (V_1)

* watt meter reading = iron or core loss (P_i)

* **Efficiency** :- It is the ratio of output power to the input power of transformer is known as efficiency of the transformer.

$$\eta\% = \frac{\text{output power}}{\text{input power}} \times 100$$

input power = losses + output power

$$= I_2^2 Re_2 + pi + V_2 I_2 \cos\phi_2$$

$$\eta = \frac{V_2 I_2 \cos\phi_2}{I_2^2 Re_2 + pi + V_2 I_2 \cos\phi_2}$$

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + pi + I_2^2 Re_2}$$

* condition for maximum efficiency :-

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + p_i + I_2^2 Re_2}$$

$$\boxed{\eta = \frac{V_2 \cos\phi_2}{V_2 \cos\phi_2 + \frac{p_i}{I_2} + I_2 Re_2}}$$

for minimum value

$$\frac{d\left(V_2 \cos\phi_2 + \frac{p_i}{I_2} + I_2 Re_2\right)}{dI_2} = 0$$

$$= 0 + p_i\left(\frac{-1}{I_2^2}\right) + Re_2 = 0$$

$$p_i\left(\frac{-1}{I_2^2}\right) + Re_2 = 0$$

$$\frac{-p_i}{I_2^2} + Re_2 = 0$$

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$$\frac{\not{P_i}}{I_2^2} = \not{R_{e2}}$$

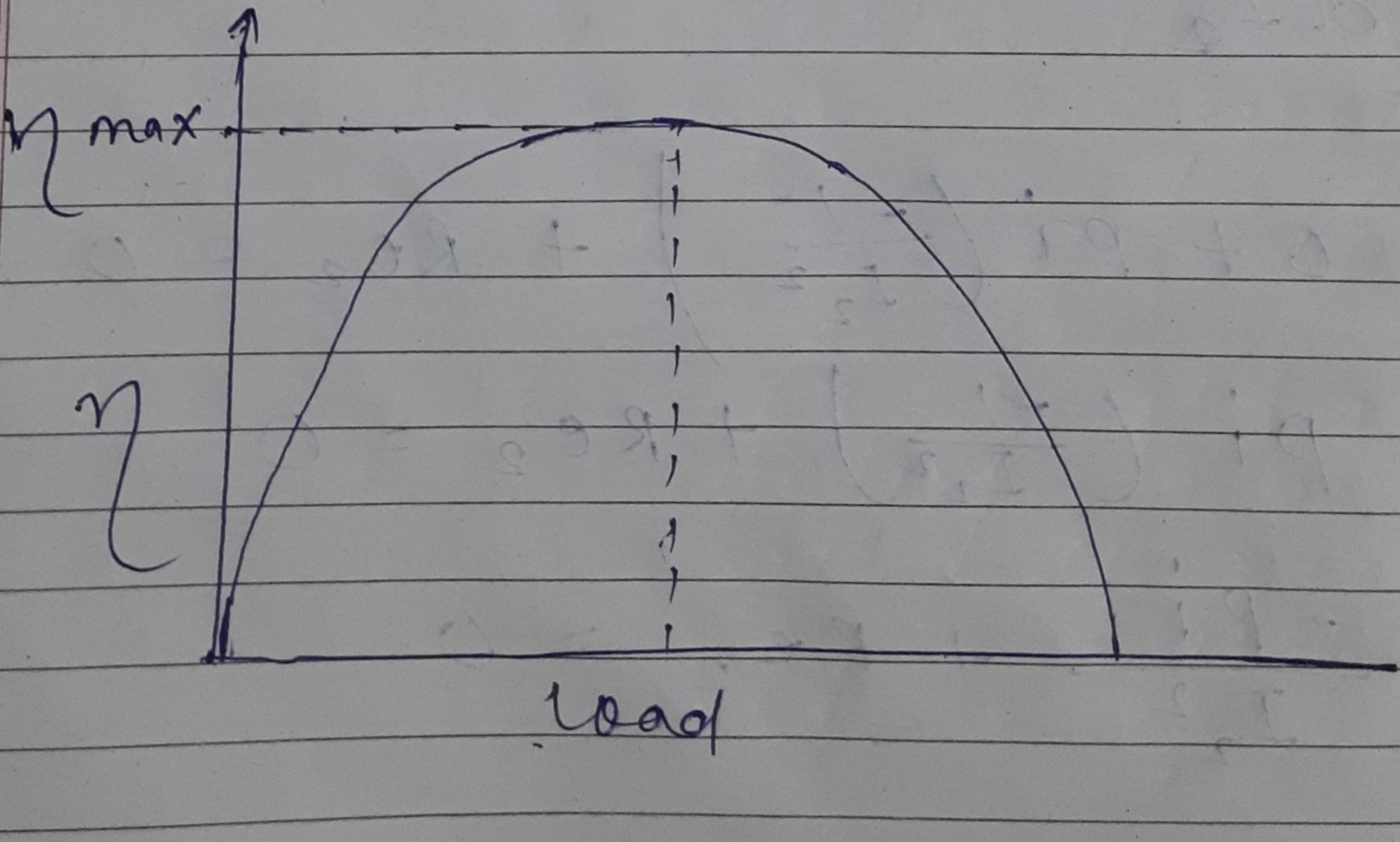
$$\boxed{P_i = R_{e2} I_2^2}$$

where

$P_i \Rightarrow$ iron loss (constant)

$I_2^2 R_{e2} \Rightarrow$ core loss (variable)

variable loss is equal to constant loss of the transformer then transformer work on maximum efficiency.



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* **All day efficiency :-**

It is the ratio of output power over 24 hours to the input power over the 24 hours.

$$\text{all day '}\eta\text{'} = \frac{\text{output power over 24 hours}}{\text{input power over 24 hours}}$$

Q:- A 25 KVA, 2000/200V Transformer with iron and full load copper loss of 350 w and 400 w is load full at 0.85 p.f calculate the η of the transformer at this power factor

→

$V_1 = 2000\,V$, $V_2 = 200\,V$

$P_i = 350\,W$, $P_{cu} = 400\,W$

$\cos\phi_2 = 0.85$ $\quad V_2 I_2 = 25 \times 10^3$

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$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_{e2}}$$

$$= \frac{25 \times 10^3 \times 0.85}{25 \times 10^3 \times 0.85 + 350 \times 400}$$

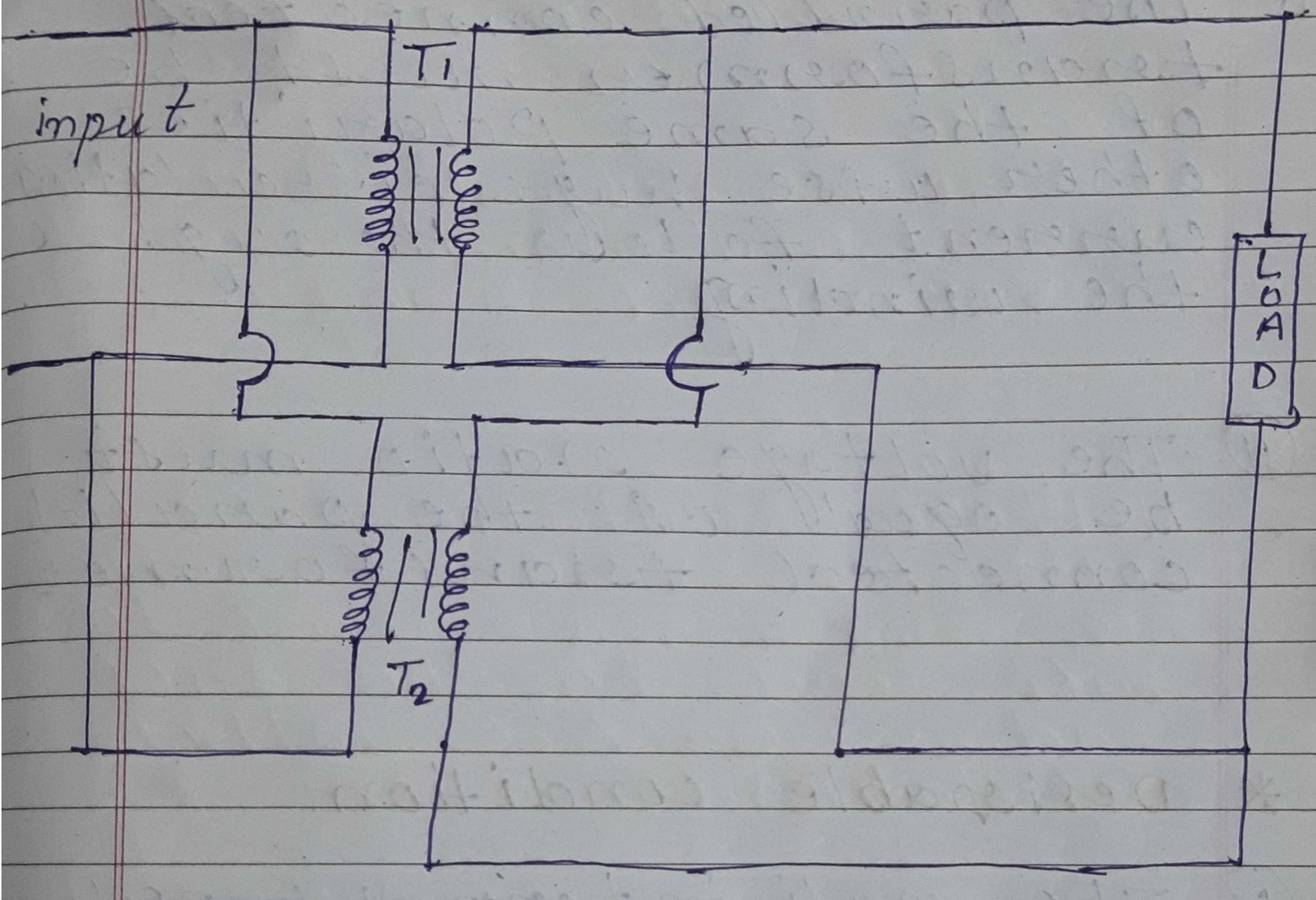
$$= \frac{21250}{22000}$$

$$\eta = 0.965$$

$$\eta \% = \frac{0.965}{100} \times 100$$

96.5 % Ans

* parallel operation of single phase transformer



when two or more transformer connected with same input (common) input (source) and their output are connected with same load then it is called parallel operation of single phase transformer.

* condition for parallel operation :-

(1) The parallel connected transformer must be of the same polarities other wise huge circulating current follow through the winding.

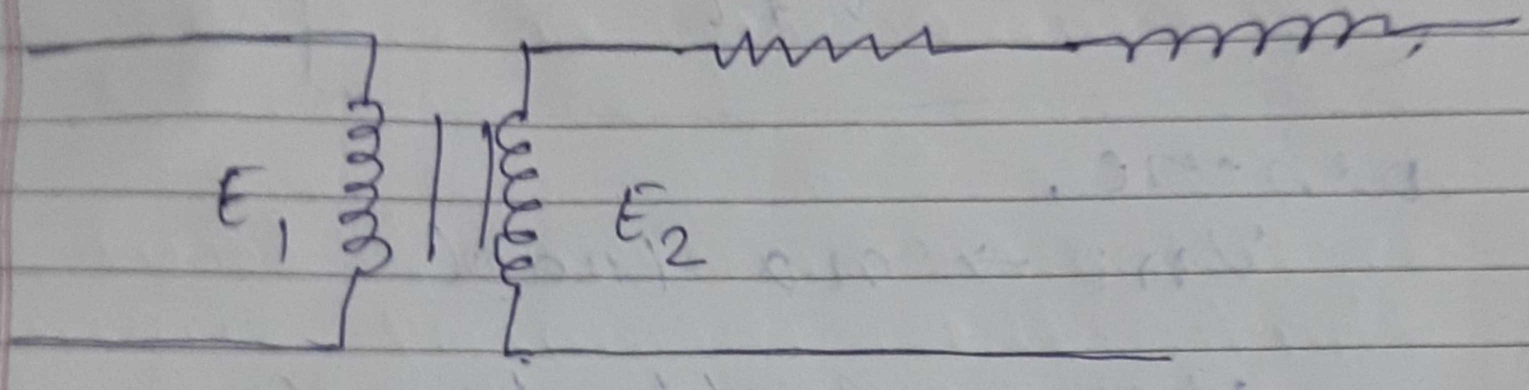
(11) The voltage ratio must be equal of the parallel connected transformer

* Desirable condition.

(1) The ~~rati~~ internal impedance of the parallel connected transformer should be equal

(11) The ratio of Resistance to the inductive reactance of the parallel connected transformer should be same (equal).

* Voltage regulation :-



Actually the transformer is designed to operate at constant voltage But due to voltage drop by internal impedance of the transformer the output voltage of the transformer will get less this parameter is known as voltage regulation

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$$V.R = \frac{V_{nl} - V_{fl}}{V_{fl}}$$

where,
V_{nl} → no load
V_{fl} → full load.

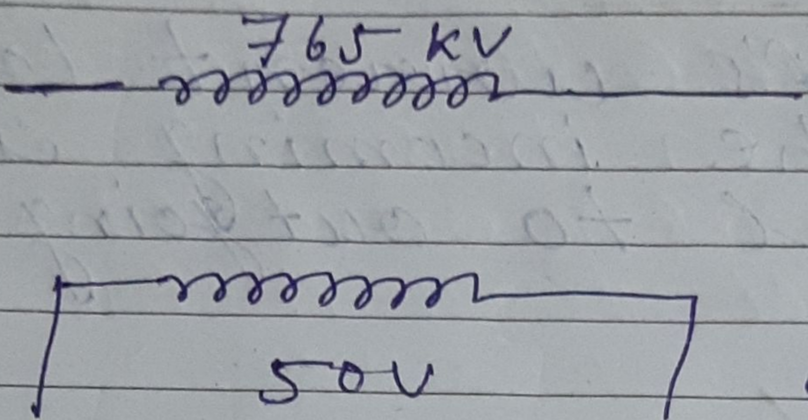
OR

Voltage Regulation is the ratio of voltage refference from no load to full load to the full load is called voltage regulation.

Voltage ↑ → step down
current ↑ → step up

* potential transformer :-

$$V_1 = \left(\frac{N_1}{N_2}\right) V_2$$



step down.

CT (current transformer)

CT connected of sereise circuit

PT (potential transformer)

PT connected of parallel transformer.

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* Ideal transformer

An ideal transformer is an imaginary transformer which the following properties

(I) Its primary and secondary winding ~~is~~ are negligible

(II) Its leakage flux and leakage inductance are zero. The entire flux is confined to the core and links both windings

(III) There are no losses due to resistance, hysteresis and eddy currents. Thus the efficiency is 100%

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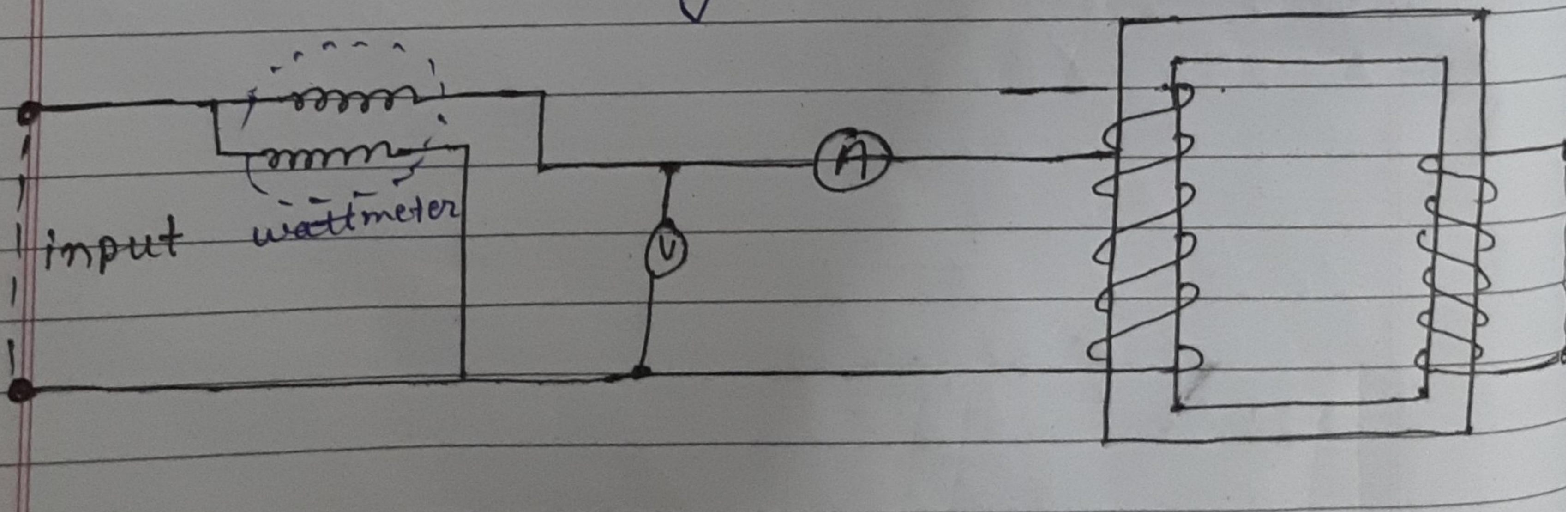
* short circuit test

→ In this test secondary winding is generally short circuited and primary is supplied with a small voltage and increased until full load current is flowing in this windings. This full load current is obtained on small percent of normal voltage.

As the applied voltage will be small percentage of its normal value, hence, the iron loss will be small, so it can be neglected. The wattmeter reading will give the copper losses and ammeter will show primary full load current



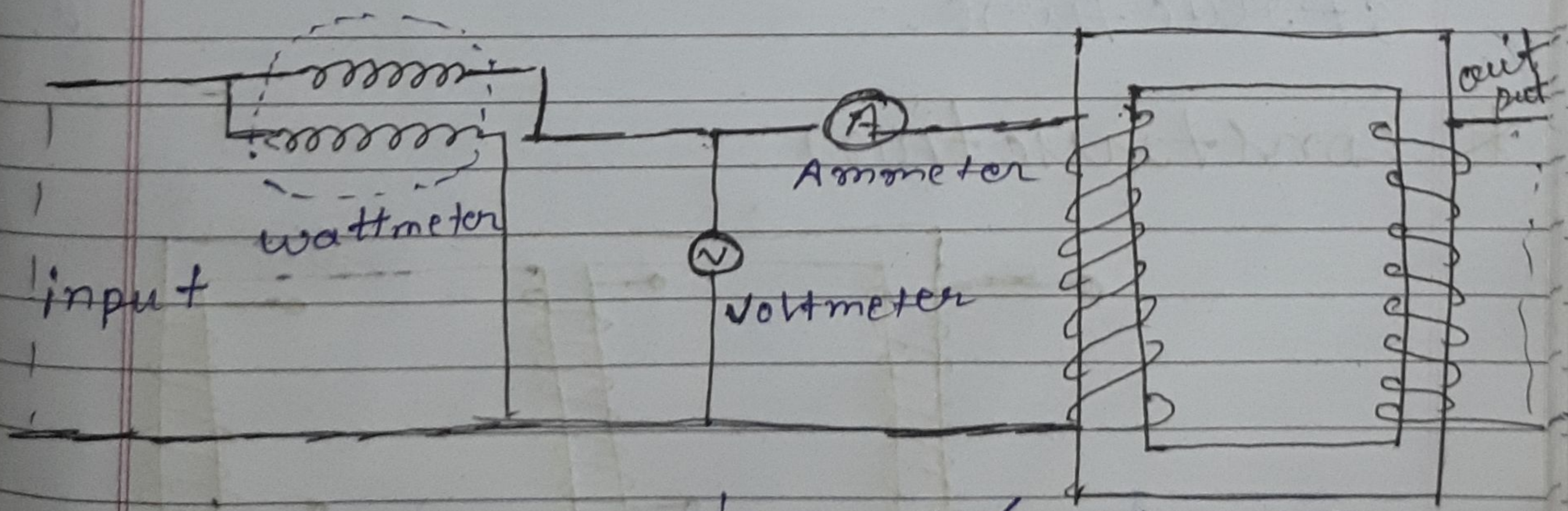
short circuit test

* open circuit test :-

→ This test is used to calculate the iron losses of transformer in the no-load condition. Generally primary being supplied at normal voltage and frequency, and the secondary winding is left open circuit.

A wattmeter, voltmeter and Ammeter is connected to the primary side. Ammeter gives the no-load current and wattmeter show the no-load losses.

In the primary winding no-load current is negligible as compared to iron loss. Hence the wattmeter reading only show the iron losses.



Open circuit test.

Three-phase Transformer

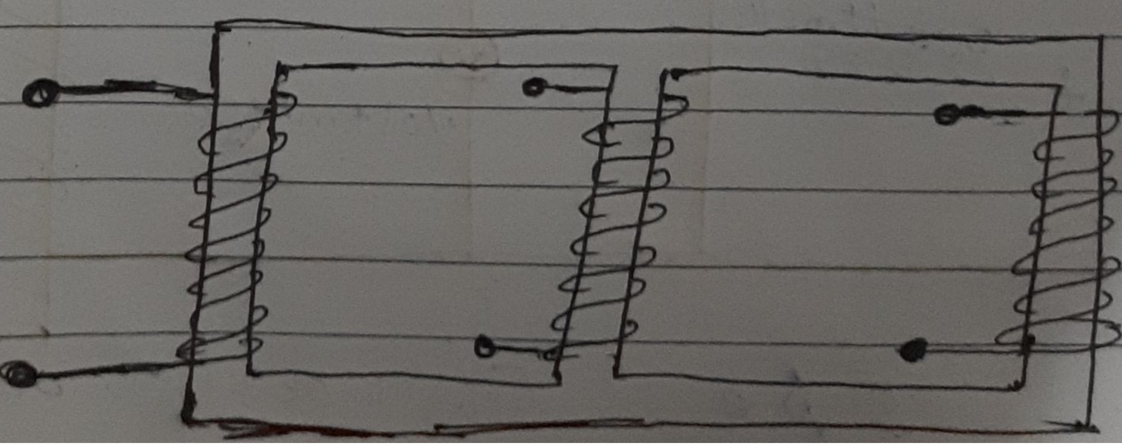
* A three-phase system is used to generate and transmit large amount of power. Three phase transformer are required to step-up or step down voltages in various stage of a power system network.

* Transformer of 3-Φ circuit can be constructed in one of the following ways:-

- The separate single phase transformer are suitably connected for 3-Φ operation such an arrangement called a Three-phase bank of transformer

- A single three-phase transformer in which the cores and windings for all the three phases are combined in a single structure:-

* construction



construction of the magnetic core of a 3-ϕ core type transformer may be understand by considering three single phase core type transformer positioned at 120° each other for simplicity only the primary winding are shown. If balance 3-ϕ sinosoidal voltages are applied to the windings the flux ϕ_a, ϕ_b and ϕ_c also will be sinosoidal and balanced If the three legs carrying this fluxes are merged. The total flux in the merged leg is 0. (zero).