MADE EASY

BPSC AE-2025

GENERAL ENGINEERING HANWRITTEN NOTES

Electrical machine

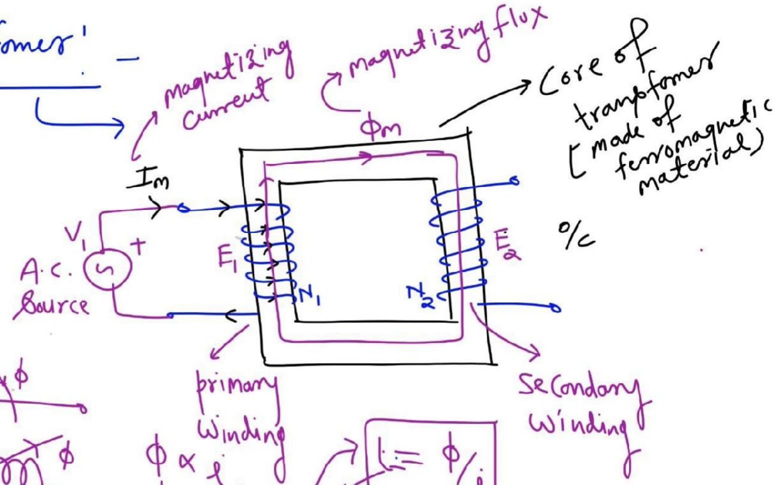
→ ideal transfomer

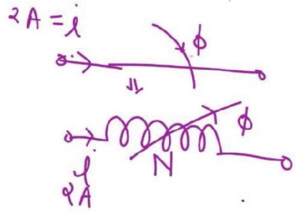
→ Electromechanical energy conversion

→ Dc motor, Dc generator

→ Ac motor, generator

Transfomer: -





$\phi \propto i$

$\phi = Li$

$\boxed{L = \phi/i}$

self inductance

$N\phi \propto i$

$N\phi = Li$

$\boxed{L = \frac{N\phi}{i}}$

Right hand curl Rule → curl → represent direction of current

→ Faraday's law of electromagnetic induction

Thumb :- represent direction of flux.

→ The main task performed by transformer.

> Changing voltage and current levels.

> Maintain constant frequency, power and magnetizing flux.

→ Wound

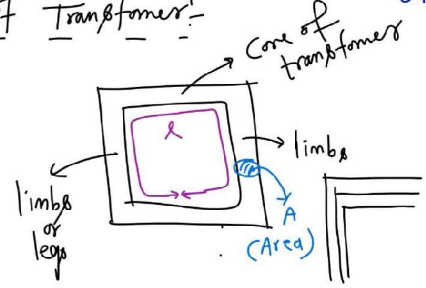
→ Applications of transformer:-

>

generation → Transmission → Distribution.

→ Construction of Transformer:-

>



Core:-

> maximum flux

> minimum magnetizing current

> minimum core loss or iron loss

→ > High permeability and low reluctance

$\mu = \mu_0 \mu_r$ — μ_0: Absolute permeability, μ_r: Relative permeability

For iron $\mu_r \simeq 4000$

$$R_l \text{ (Reluctance)} = \frac{l}{\mu A}$$

$$\text{Flux} = \frac{\text{mmf}}{\text{Reluctance}} = \frac{N \times I}{R_l}$$

→ Si-steel Core
(3%)

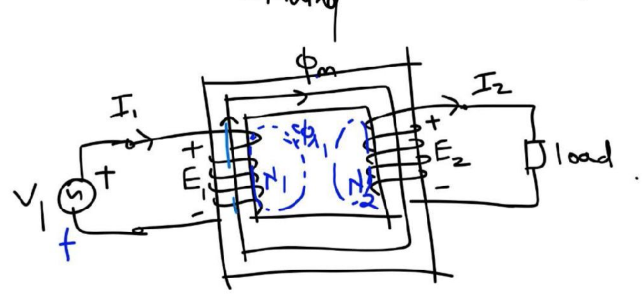
Core loss = Hysteresis loss + eddy current loss

→ C.R.G.O (Si-steel)
(Cold rolled grain oriented Si-steel)

> <u>windings:-</u> Copper wire → $I^2 R$ loss i.e copper loss.

L.V, → low voltage winding

H.V. → High voltage winding.



rms induced emf

$$E_1 = \sqrt{2}\pi f N_1 \phi_m$$
$$E_2 = \sqrt{2}\pi f N_2 \phi_m$$

$$\rightarrow \frac{E_2}{E_1} = \frac{\cancel{\sqrt{2}\pi f} N_2 \cancel{\phi_m}}{\cancel{\sqrt{2}\pi f} N_1 \cancel{\phi_m}} = \frac{N_2}{N_1}$$

$$\therefore \boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}} = k$$

$\downarrow$ Trunratio or Transformation ratio

$$k = \frac{N_2}{N_1} = \frac{1}{3} \qquad k = \frac{N_2}{N_1} = \frac{E_2}{E_1}$$

$N_1 > N_2$, $E_1 > E_2$, $I_1 < I_2$ } step down Transfomer.

$$\Rightarrow \frac{1}{3} = \frac{E_2}{E_1}$$

$$E_2 = \frac{E_1}{3}$$

$N_1 < N_2$, $E_1 < E_2$, $I_1 > I_2$ } step up Transfomer

> Transfomer oil:-

It act as a insulation and as a coolant.

> Types of Xfer

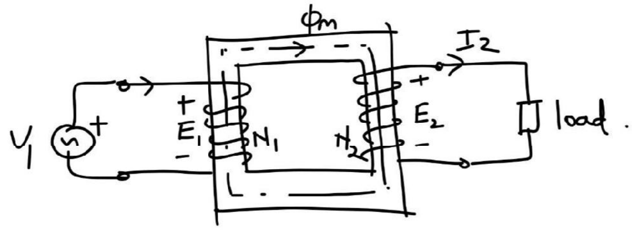
↳ > Core type Xfer → It is suitable for high voltage and high power Application.

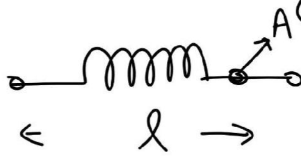
> Shell type Xfer → It is suitable for low voltage and low power application.

→ If Transformation ratio $\frac{N_2}{N_1} = \frac{E_2}{E_1} = k$

$k = 1:1$ → it is called isolation transfomer.

Equivalent circuit of transfomer:



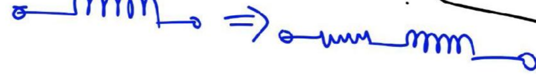


Resistivity

$$R = \frac{\rho l}{A}$$

Resistance, length, Area

$$\boxed{R \propto \frac{l}{A}}$$

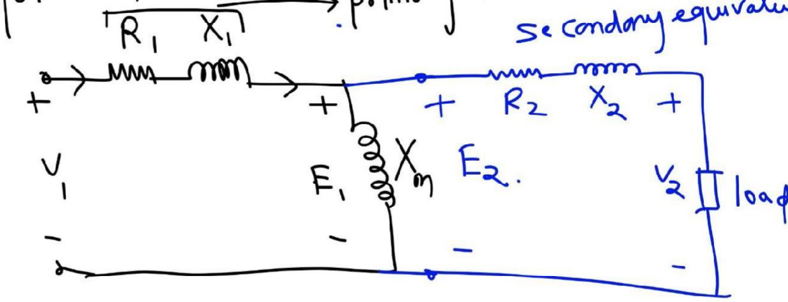


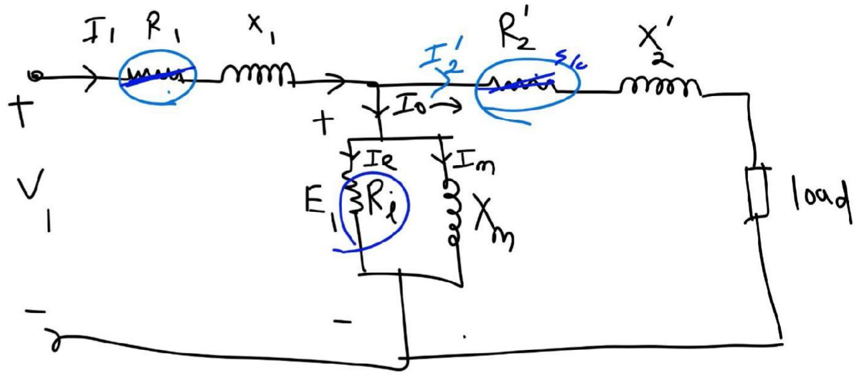
primary equivalent circuit → primary leakage impedance.

R_1 X_1

secondary equivalent

$$X = 2\pi f L$$





Ideal transformer :-

↳ No loss ie
no iron loss and no cu loss.
$R_1 = 0$, $R_2' = 0$

Cu loss $= I^2 \cdot R$
$= I_1^2 R_1$

iron loss $P_i = \dfrac{E_1^2}{R_i}$

For no iron loss $R_i = \infty$ ie open circuit.

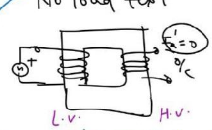
> No leakage flux.

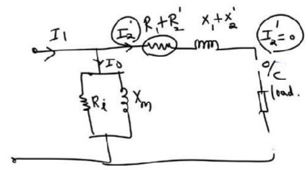
in short circuit
$R = 0$
$V = I \cdot R$
$V = 0$

Test of transformer :-

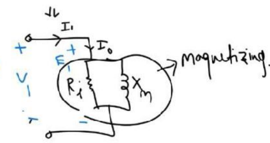
> open circuit test
> short circuit test
> back to back test or sumpner's test

→ open circuit test :-
or
No load test



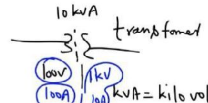


→ is used to determine no load loss ie iron loss or core loss. and circuit parameters.



→ It is performed at rated voltage.

10 kVA transformer



kVA = kilo volt Ampere
MVA = Mega volt Amp

$S = V_1 \cdot I_1$
$= V_2 \cdot I_2$
$S =$
$10 \times 10^3 = 100 \times I_1$

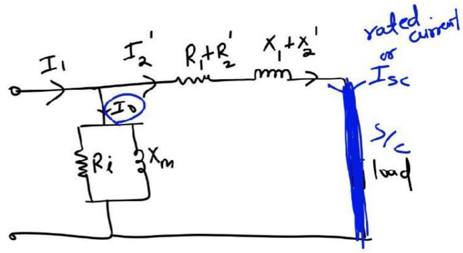
$I_1 = 100 \text{ Amp.}$

$S = V_2 \cdot I_2$
$10 \times \cancel{10^3} = 1 \times \cancel{10^3} \times I_2$
$I_2 = 10A$

>

$\boxed{\begin{array}{l}\text{Volt-Ampere} \\ \text{kVA} \\ \text{MVA}\end{array}}$
Unit of Xfer.

→ Short circuit test of transformer!



in xfer

I_0 → no load current

↳ 4 to 5 % of full load current or rated current.

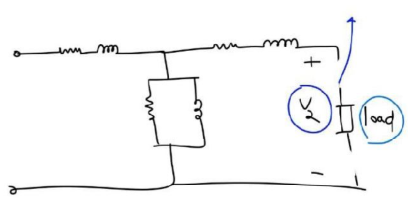
It is used to determine load loss ie Cu loss.

→ It is performed at rated current.

> back to back test or sumpners test!-

↳ It is used to determine temperature rise in the transformer.

Voltage regulation!-



↳ what is the %age rise in terminal voltage from full load to no load. It is called voltage regulation.

practically it is recommended 5 to 7 %.

(voltage regulation) $\boxed{V.R^n = \dfrac{V_{nl} - V_{Fl}}{V_{Fl}}}$

$S = V \cdot I$

$P = VI\cos\phi$

$\downarrow Q = VI\sin\phi\downarrow$ → using power factor improvement voltage regulation can be improved.

True power or Active power or Real power → Power factor = $\cos\phi$

P → watt or kW or MW

Reactive power Q → VAR or kVAR or MVAR

S → VA, or kVA, or MVA

$\cos\phi \uparrow \Rightarrow \phi\downarrow$

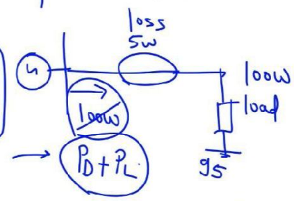
$\sin\phi\downarrow$

$\downarrow Q \propto \Delta|V|\downarrow$

Efficiency of Transformer :-

$$\eta = \frac{\text{power output}}{\text{power input}}$$

Power input = power o/p + losses



$$\eta = \frac{\text{Power o/p}}{\text{Power o/p + losses}}$$

Most of the time power transformer operates on its rated condition.
So efficiency of transformer is maximum at rated load or near around rated load.

Condition for maximum efficiency

η_{max}

Iron loss

$$P_i = \frac{E_1^2}{R_i} = \frac{V_1^2}{R_i}$$

it is voltage dependent loss. So it is constant loss.

→ Copper loss $= I^2 \cdot R$
it is depends on load current
So it is load loss or variable loss.

* Iron loss = Copper loss
or
Constant loss
or
No load loss = variable loss or load loss

* In general efficiency of transformer is around (90 to 95 %).

Q:- For the Construction of the core of the transfomer the material used should have ______ permeability and ______ Reluctance.

(a) High, High
(b) Low, Low
(c) High, Low
(d) Low, High

Reluctance

$$\left\{ R_l = \frac{l}{\mu A} \right\}$$

Q:- A transformer is said to be a step up transformer when.

(a) Voltage transformation ratio is greater than 1
(b) Voltage transformation ratio is zero.
(c) Voltage transformation ratio is less than 1
(d) Voltage transformation ratio is equal to 1.

Transformation ratio

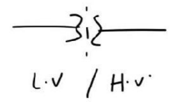
$$K = \frac{N_2}{N_1} = \frac{V_2}{V_1}$$

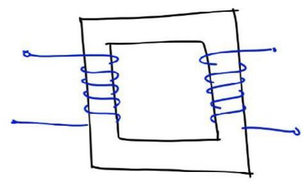
$\rightarrow$ $N_2 > N_1$ $\quad K > 1$ ie $\frac{N_2}{N_1} = \frac{V_2}{V_1} > 1$

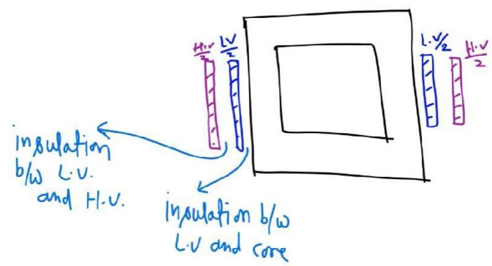
→ Types of transformer

> Core type   Shell type

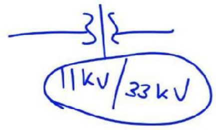
Core type transformer:

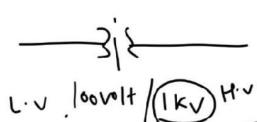






Voltage rating $\uparrow$ ∝ insulation $\uparrow$

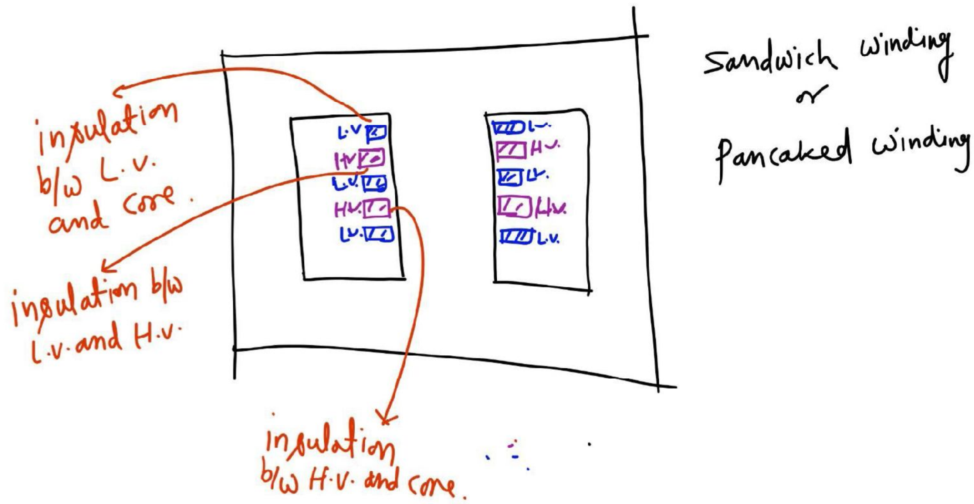




→ In core type transformer
Low voltage winding is kept inside. So as to reduced the cost of insulation.

→ It is suitable for High voltage and high power application.

→ <u>shell type transformer</u>:-



→ It is suitable for low voltage and low power application.

→ <u>Core loss or Iron loss in transformer</u>

$$P_c = \underset{\text{loss}}{\text{Hysteresis}} + \underset{\text{loss.}}{\text{eddy current}}$$

<u>Hysteresis loss P_h</u>:-

$$P_h = \underbrace{k_h}_{\text{Constant}} \underbrace{B_m^{1.6}}_{B_m \rightarrow \text{Peak flux density}} \times f \rightarrow \text{Frequency}$$

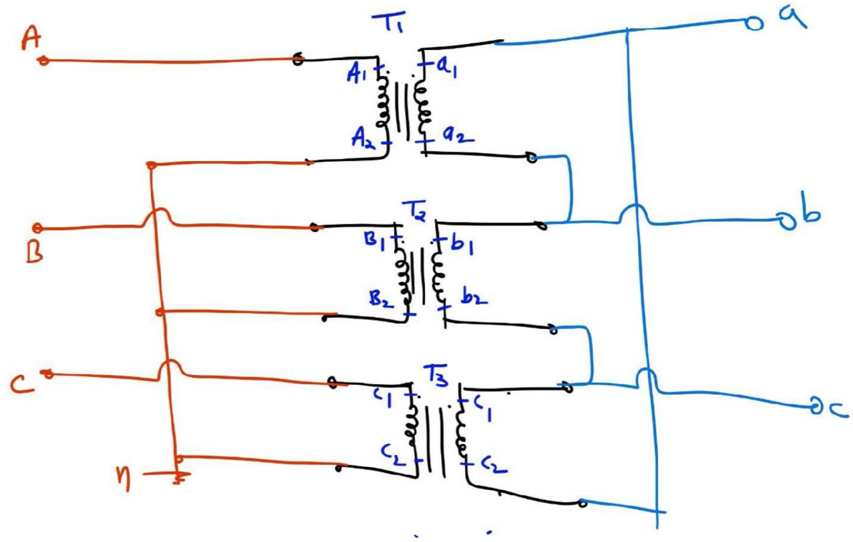
<u>Eddy current loss</u>:

$$P_e = \underbrace{k_e}_{\text{Constant}} B_m^2 f^2$$

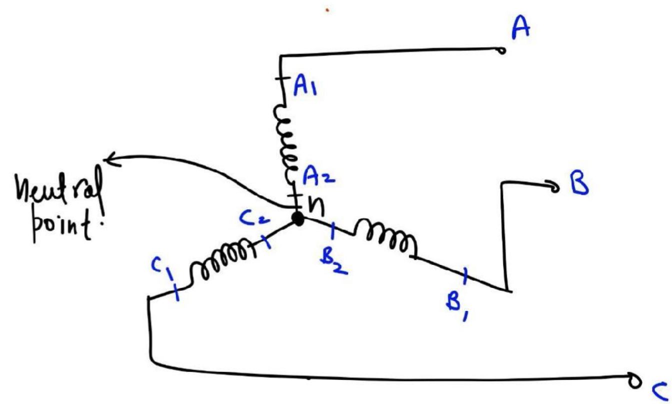
B_m = Peak flux density
f = Frequency.

Three phase transformer :-

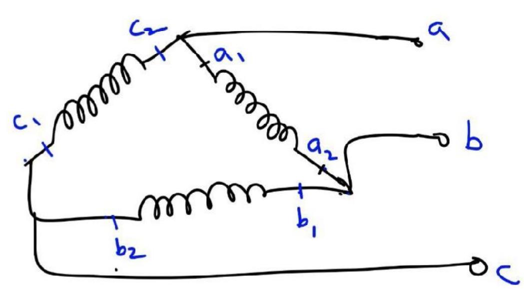
↳ 3 → 1 ϕ unit.



→ Star winding.



Delta winding.



→ 3ϕ transformer Connections :-

- 0° Connection and 180° Connection ⟷ Y-Y transformer (star-star transformer)
- 0° Connection and 180° Connection ⟷ Δ-Δ transformer (Delta-Delta transformer)
- ±30° Connection ⟷ Y-Δ transformer (star-Delta ")
- ±30° Connection ⟷ Δ-Y transformer (Delta-star ")
- 0° Connection and 180° Connection ⟷ Δ-zigzag Y (Delta-zigzag Y)
- ±30° Connection ⟷ Y-zigzag Y (star-zigzag Y)

→ operative parallel operation

Transformer-1	Transformer-2
Y-Y	Y-Y, ΔΔ, Δ zigzag Y
Δ-Δ	Δ-Δ, Y-Y, Δ zigzag Y.
Δ Y	Δ-Y, Y-Δ, Y-zigzag Y
Y-Δ	Y-Δ, ΔY, Y zigzag Y.

→ Δ-Δ transformer :-

10kVA

LV: 100V, 100A (H.C → Δ)

H.V.: 1kV, 10A (L.C. → Y with neutral ground)

$$S = V_1 I_1 = V_2 I_2$$

$$10\times10^3 = 100 \times I_1$$

$$I_1 = 100A$$

$$10\times10^3 = 1\times10^3 \times I_2$$

$$I_2 = 10A$$

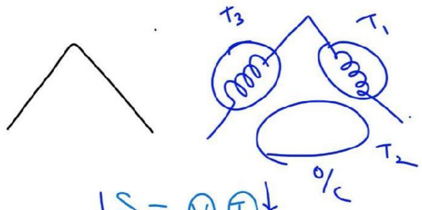
Y (grounded) → star with neutral ground

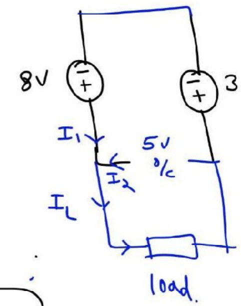
Y → star with neutral unground.

→ In star connected winding if neutral is grounded cost of insulation get reduced, so star connected winding is used for high voltage or low current application).

→ Delta (Δ) Connected winding is used for low voltage or high current application.

→ The additional advantage of Δ-Δ transformer is that it can be operated as an open delta if one of the 3φ unit fail to supply.



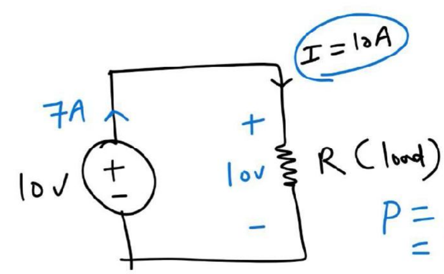


$S = V I$

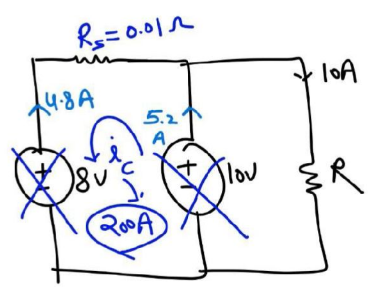
$$\boxed{S_{\text{open-}\Delta \text{ or V connection}} = 58\% \text{ of } S_{\Delta-\Delta}}$$

> parrallel operation of transformer

DC source



$P = V \cdot I$
$= 10 \times 10 = 100$ watt.



Circulating Current: $i_c = \frac{10-8}{R_s} = \frac{10-8}{.01}$

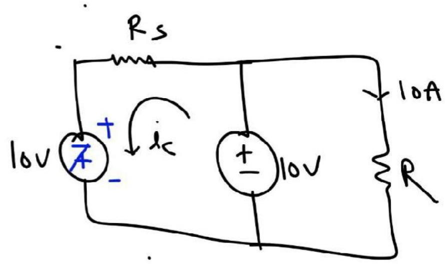
$i_c = \frac{2}{.01} = 200A$

Condition for parallel operation

$i_c = \frac{10-10}{R_s} = 0$

> magnitude of voltage should be same

> polarity should be same.



$i_c = \frac{10-(-10)}{R_s}$

Q:- Which of the following three phase transformer combination can be successfully run in parallel.

(a) star-star and Delta-star

(b) Delta-Delta and Delta-star

✓(c) Delta-star and Delta-star

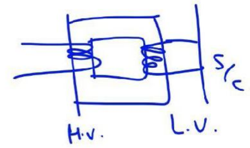
(d) Star-delta and Delta-Delta

$Y - Y$

$\Delta - Y$

Q:- which is to short circuited on performing short circuit test on a transformer.

(a) Low voltage side ✓
(b) primary side
(c) High voltage side
(d) secondary side.



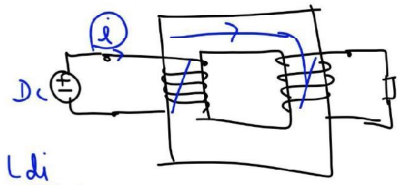
Q:- what happens if a dc supply is applied to a transformer's primary.

$\frac{V_2}{V_1} = k$

$V_2 = k \cdot V_1$

For dc inductor behave as a short circuit

burn out



$V_L = L\frac{di}{dt}$

$V_L = 0$

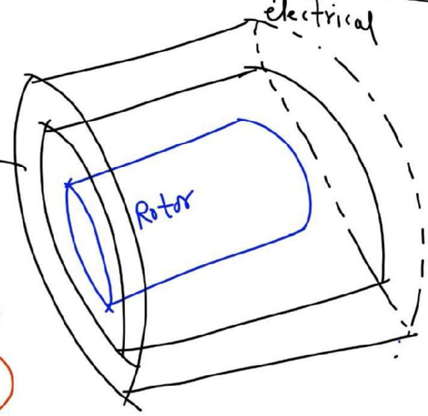
DC machine → Hard magnetic material (ie wider B-H loop)

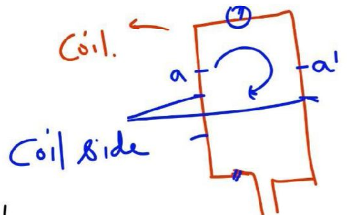
[tungsten steel]

input mechanical → gen^r → output electrical

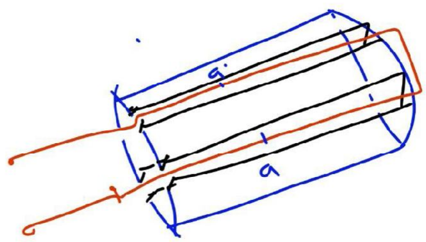
input electrical → Motor → output Mechanical

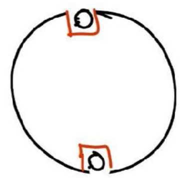
exact view of rotor and stator are cylindrical

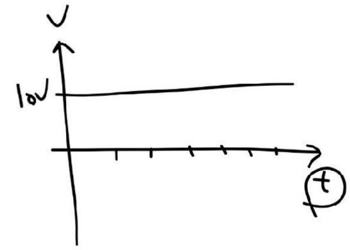




↳ one single turn coil have two coil side.





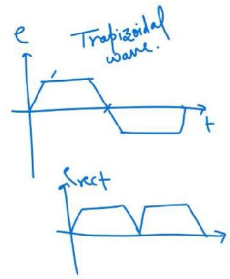


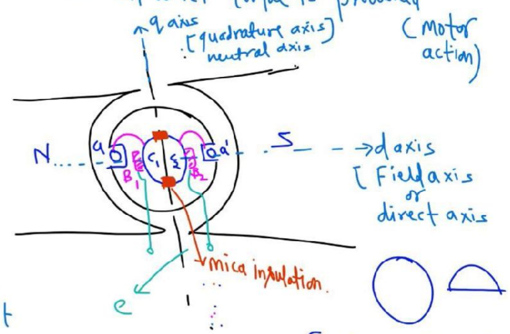
→ In dc M/c:

stator → Field winding
Rotor → Armature winding

Field winding:- To produce main flux or to establish main field.

Armature winding:- → In which induced emf → (generator Action.)
→ on which torque is produced (Motor action)





C_1 C_2 → Commutator segment
↳ (semi circular shape)

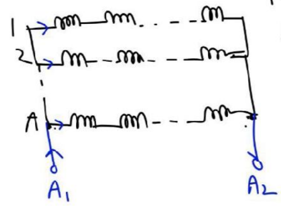
Carbon brushes B_1, B_2 (stationary)

Induced emf in DC M/c :-

$$\boxed{E = \frac{P \phi Z N}{60\,A}}$$

P = number of Poles
ϕ = Avg flux.
Z = number of Conductors
N = speed in rpm (revolution per minute)
A = number of parallel path.

Armature winding pattern



For
Wave winding → (High voltage low current application.)

no. of parallel path
$A = 2$

For Lap winding :- $A = P$
→ (High current low voltage application)

Types of DC M/c

- > separately excited dc machine
- > self excited dc machine → shunt, series, Compound.

Excitation :- To flow the current in the field winding to establish or produce the working flux.