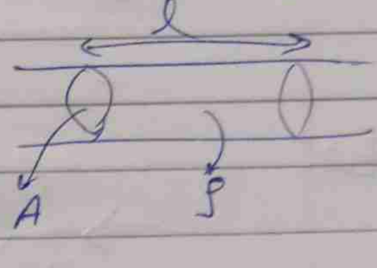
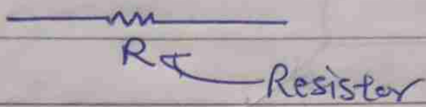
Basic Laws :-

Resistance :- The property or ability of physical material to resist the flow of current.

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



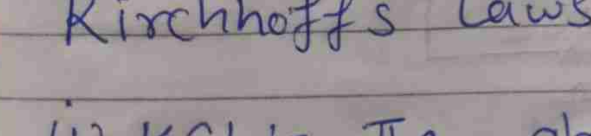


Ohm's Law (Georg Simon Ohm)

$$V \propto i$$
$$V = Ri$$

$R \longrightarrow$ Range $\Rightarrow [0, \infty)$

Short circuit

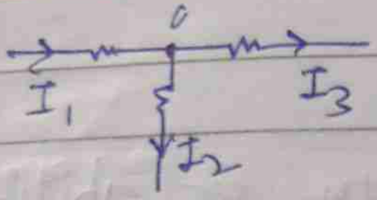


because current always flow high terminal to low terminal.

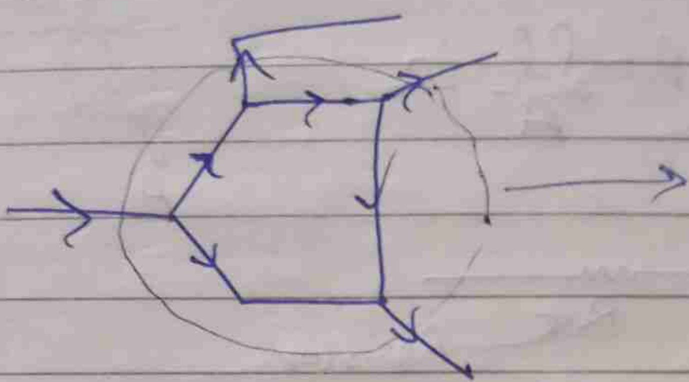
(Gustav Robert)

Kirchhoff's Laws :- (Law of Con. charge)

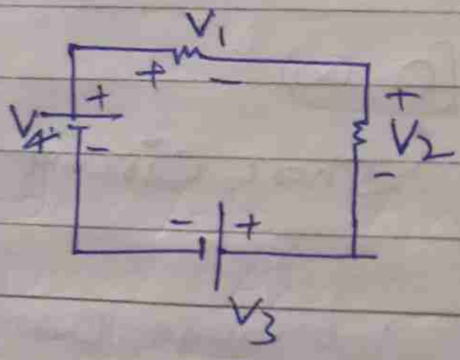
(1) KCL :- The algebraic sum of current at a junction or closed boundry is zero.

Ex: 

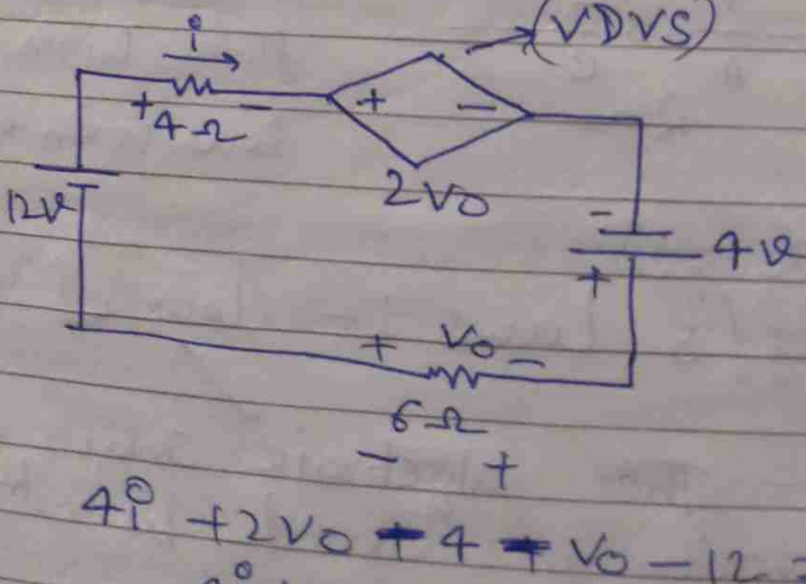
at 0, $I_1 - I_2 - I_3 = 0$

Ex: 

(2) <u>KVL</u>:- (Based on Law of Conservation Energy)
The algebraic sum of voltage in a loop or closed path of a circuit is zero.

Ex: 

$V_1 + V_2 + V_3 - V_4$

Q: 

Determine v_o & i in the circuit shown below.

Soln

$4i + 2v_o + 4 + v_o - 12 = 0$
$4i + v_o - 16 = 0$

$V_0 = -6i$

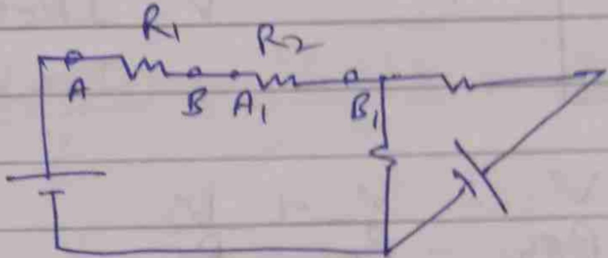
$\cancel{i = 1.6A}$

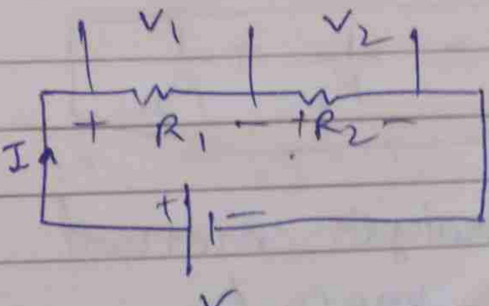
$\cancel{V_0 = 9.6V}$

$i = -8A$

$V_0 = 48V$

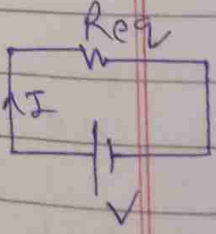
Element in series/voltage division in series Elemenes.





$V_1 = IR_1$

$V_2 = IR_2$



$V = IR_{eq}$

$$V = V_1 + V_2$$

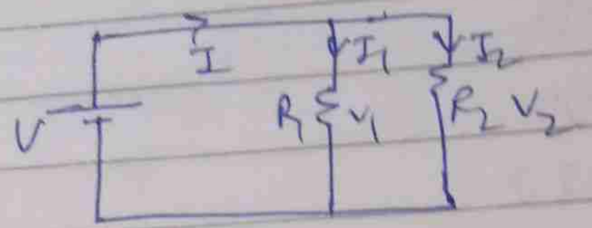
$$IR_{eq} = IR_1 + IR_2$$

$$\boxed{R_{eq} = R_1 + R_2}$$

$$V_1 = \left(\frac{V}{R_1+R_2}\right) R_1$$

$$V_2 = \left(\frac{V}{R_1+R_2}\right) R_2$$

Parallal

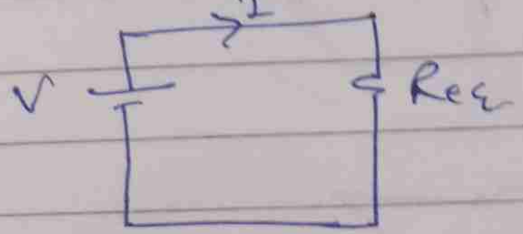


$V = V_1 = V_2$

$V_1 = I_1 R_1$

$V_2 = I_2 R_2$

$I = I_1 + I_2$



$V = I R_{eq}$

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2}$$

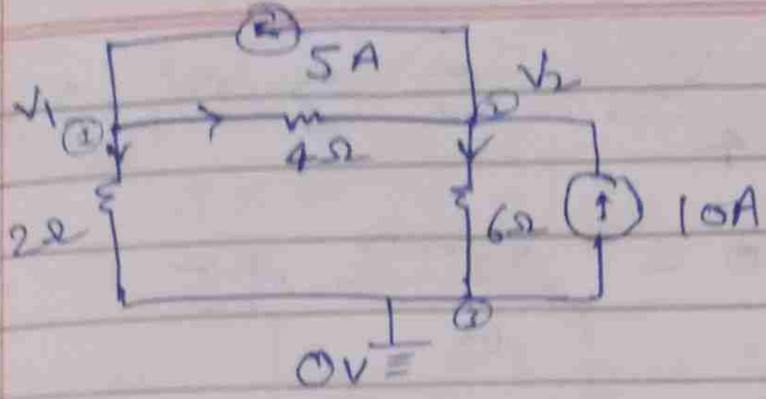
$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}}$$

Node Volt Analysis method

Nodal Analysis method

1. Idintify the number of nodes in a circuit.
2. Out of n nodes mark one node as node as reference node.
3. Assume Voltages for remaining (n-1) nodes
4. Apply KCL at all non reference node.
5. Solve the Eq. obtained by (4)

Q



~~let $(V_2 > 0 > V_1)$~~

we apply KCl at Node 1

let $(V_2 > V_1 > 0)$

$$2\left(\frac{V_1 - 0}{2}\right) + \frac{V_1 - V_2}{4} = 5 \times 4$$

$$\frac{V_2 - V_1}{4} + 10 = \frac{V_2 - 0}{6} + 5$$

$$2V_1 + V_2 - V_1 = 20$$

$$V_1 + V_2 = 20 \quad \text{--- (1)}$$

$$3V_2 - 3V_1 + 120 = 2V_2 + 60$$

$$60 = 3V_1 - V_2 \quad \text{--- (2)}$$

$$80 = 4V_1$$

$$\boxed{V_1 = 20}$$

$$V_2 = 0$$

Node(1) $\frac{V_1-0}{2}+\frac{V_1-V_2}{4}=5 \Rightarrow 3V_1-V_2=20$ —(1)

Node(2) $\frac{V_1-V_2}{4}+10=\frac{V_2-0}{6}+5$

$3V_1-3V_2+120=2V_2+60 \Rightarrow 5V_2-3V_1=60$ —(2)

$\boxed{V_2=20}$

$\boxed{V_1=\frac{40}{3}}$

Cramers Rule:-

$a_{11}x_1+a_{12}x_2+ \cdots a_{1n}x_n=b_1$

$a_{21}x_1+a_{22}x_2+ \cdots a_{2n}x_n=b_2$

$\vdots$

$a_{n1}x_1+a_{n2}x_2+ \cdots a_{nn}x_n=b_n$

$x_1=\frac{\Delta_1}{\Delta},\ x_2=\frac{\Delta_2}{\Delta} \cdots x_n=\frac{\Delta_n}{\Delta}$

$$\Delta=\begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & & a_{nn} \end{vmatrix}$$

$$3V_1 - V_2 = 20$$

$$5V_2 - 3V_1 = 60$$

$$\Delta = \begin{vmatrix} 3 & -1 \\ -3 & 5 \end{vmatrix} \qquad \Delta_1 = \begin{vmatrix} 20 & -1 \\ 60 & 5 \end{vmatrix} = 160$$

$$\Delta = +12$$

$$\Delta_2 = \begin{vmatrix} 3 & 20 \\ -3 & 60 \end{vmatrix} = 240$$

Q

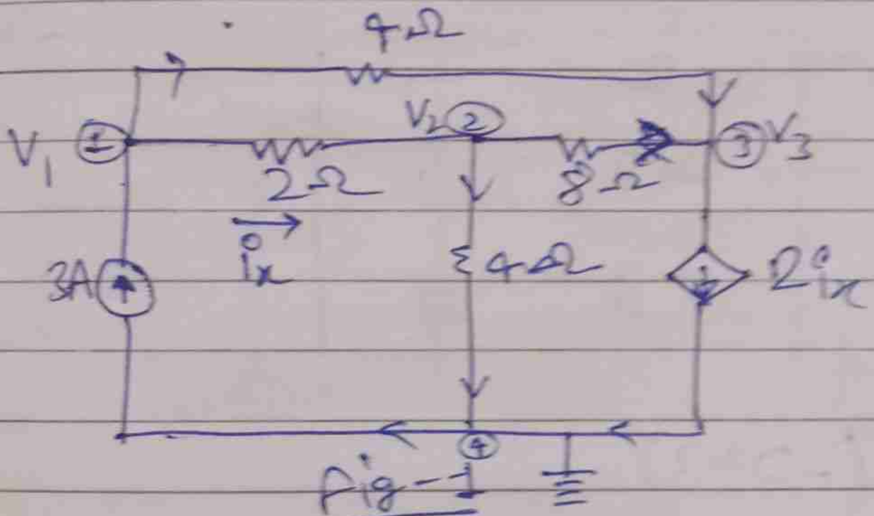


Fig-1

By Apply KCL at all node

at node ①
$$\frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{4} = 3$$

$$2V_1 - 2V_2 + V_1 - V_3 = 12$$

$$3V_1 - 2V_2 - V_3 = 12 \quad -①$$

③
$$\frac{V_1 - V_3}{4} + \frac{V_2 - V_3}{8} = 2\left(\frac{V_1 - V_2}{2}\right)$$

$$2V_1 - 3V_2 + V_3 = 0$$

②
$$\frac{V_2 - V_3}{8} + \frac{V_2}{4} + \frac{V_2 - V_1}{2} = 0$$

$$4V_1 - 7V_2 + V_3 = 0$$

$$A = \begin{vmatrix} 3 & -2 & -1 \\ 4 & -7 & 1 \\ 2 & -3 & 1 \end{vmatrix}$$

$$3(-7+3) + 2(4-2) - 1(-12+14)$$

$$-12 + 4 := -2$$

$$A = -10$$

$$A_1 = \begin{vmatrix} 12 & -2 & -1 \\ 0 & -7 & 1 \\ 0 & -3 & 1 \end{vmatrix}$$

$$= 12(-7+3)$$

$$= -48$$

$$A_2 = \begin{vmatrix} 3 & 12 & -1 \\ 4 & 0 & 1 \\ 2 & 0 & 1 \end{vmatrix}$$

$$= 12(4-2)$$

$$= 24$$

$$A_3 = \begin{vmatrix} 3 & -2 & 12 \\ 4 & -7 & 0 \\ 2 & -3 & 0 \end{vmatrix} = 12(-12+14)$$

$$= 24$$

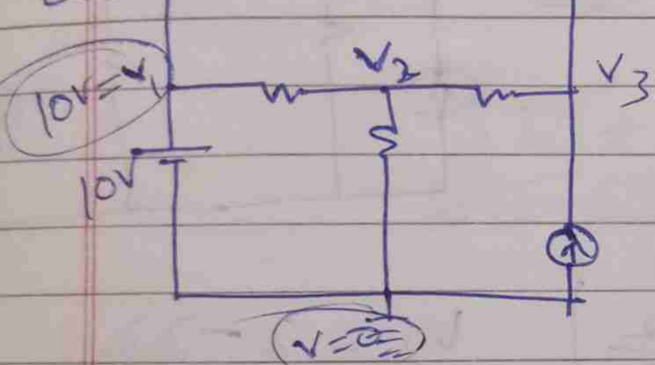
$V_1 = 4.8 \quad V_2 = -2.4 \quad V_3 = -2.4$

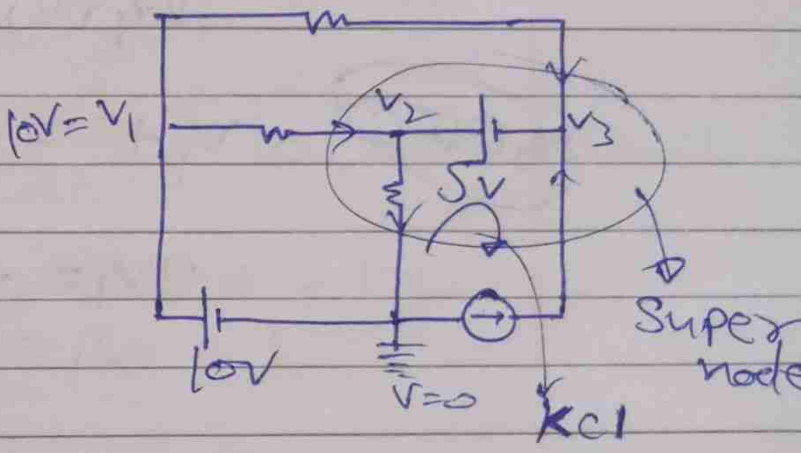
Special Cases:-

(1) Voltage Source connected b/w a reference and non-reference node.

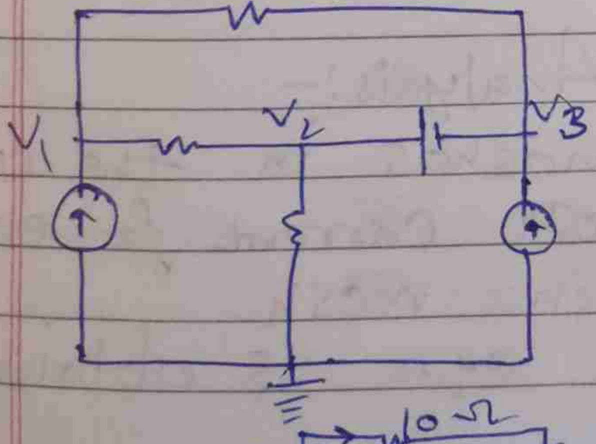
(2) when we have voltage source b/w two non reference node

Ex(1)

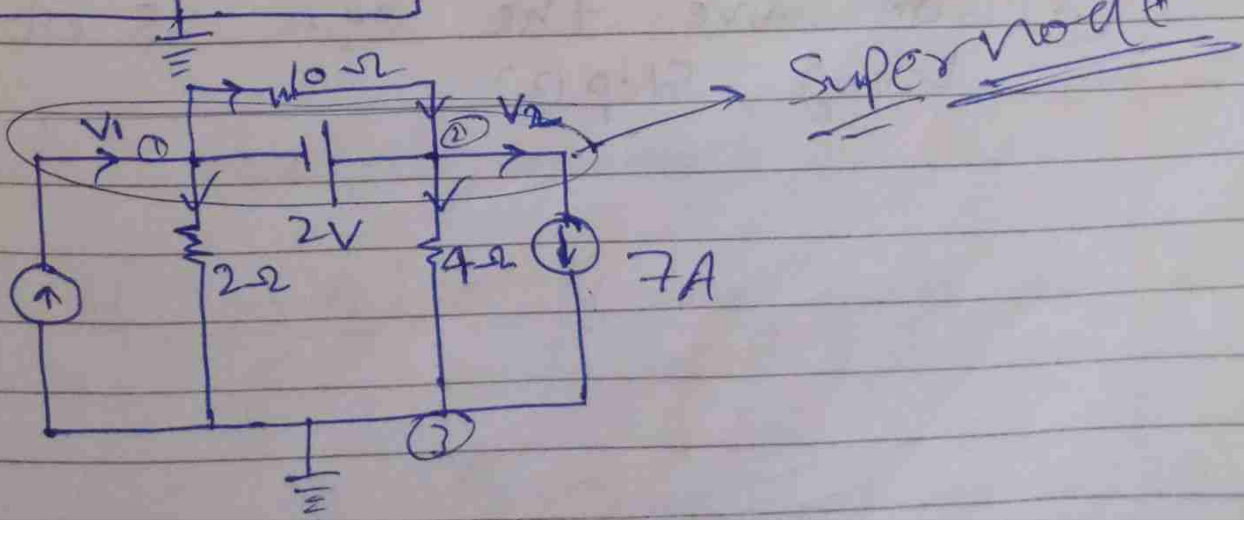




$V_2 - 5 - V_3 = 0$



Q

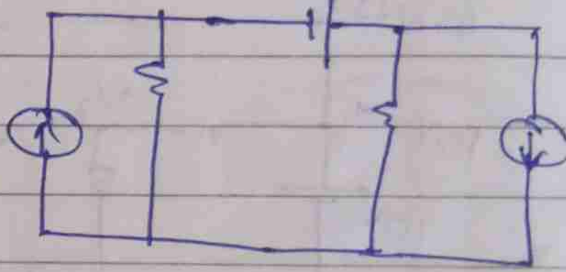


By applying kcl at Super node we get

$$2+\cancel{\frac{V_2-V_1}{10}} = \frac{V_1}{2}+\frac{V_2}{4}+7+\cancel{\frac{V_2-V_1}{10}}$$

(यदि voltage sorce के Parallel में Resistance हो तो उसे हटा देंगे उसका कोई मतलब नही होगा)

$$2V_1+V_2=-20$$



or ① ② ③ $\quad V_1+2=V_2$

$$3V_1=-22$$

$$V_1=\frac{-22}{3} \quad \Big| \quad V_2=2-\frac{22}{3}$$

$$V_2=\frac{-16}{3}$$

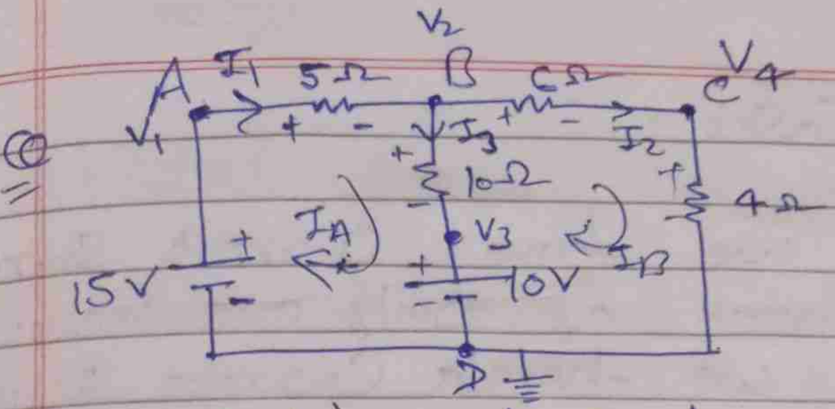
Mesh Current Analysis:-

(1) Identify the meshes in the circuit and assign mesh current for each mesh

(2). Apply KVL ~~in~~ each mesh

(3) ~~Sol~~ Solve the eq. as obtain ~~by~~ using Step (2)

$I_A \circlearrowright$ $\uparrow I_B$



$V_1 = 15V$
$V_3 = 10V$
$V_2 = ?$
$V_4 = ?$

Applying KVL in mesh ABDA we get

(let $I_A > I_B$)

$$5I_A + 10(I_A - I_B) + 10 - 15 = 0$$
$$15I_A - 10I_B - 5 = 0$$
$$3I_A - 2I_B = 1 \quad - (1)$$

$$6I_B + 4I_B - 10 - 10(I_A - I_B) = 0$$
$$\cancel{16 I_B = 6 I_A}$$
$$20I_B - 10I_A = 10$$
$$2I_B - I_A = 1$$
$$2I_A = 2$$
$$I_A = 1$$
$$I_B = 1$$

$$I_1 = I_A = 1$$
$$I_B = I_2 = 1$$
$$I_3 = I_A - I_B = 0$$

Nodal Analysis method

$$2\left(\frac{15 - V_2}{\cancel{5}}\right) = \frac{V_2 - 10}{\cancel{10}} + \frac{V_2}{\cancel{10}}$$

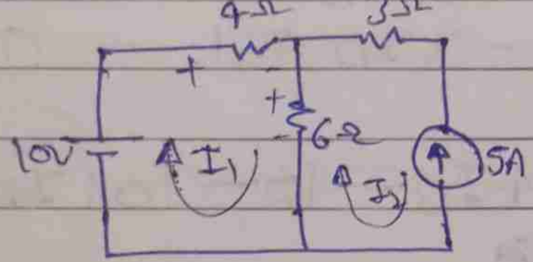
$$30 - 2V_2 = 2V_2 - 10$$
$$40 = 4V_2 \Rightarrow V_2 = 10$$

Special Cases

(1). when we have Current Source in branch of only one mesh.

(2). when we have a Current source in a branch Common to two meshes

Case-I



let $I_1 > I_2$

$I_2 = -5A$

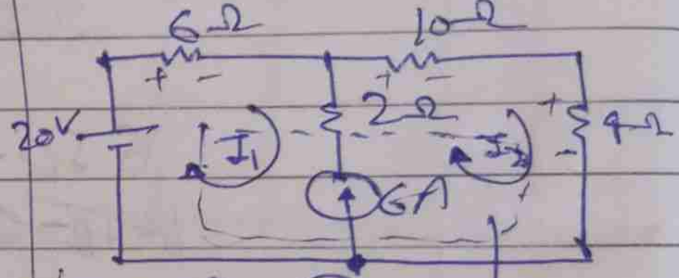
$4I_1 + 6(I_1 - I_2) = 10$

$10 I_1 = -20$

$\boxed{I_1 = -2}$

$I_{AB} = 3A$

Case-II



let $(I_1 > I_2)$ (P)

Super mesh

By Apply KVL in Super mesh

at (P) $I_2 = 6 + I_1$

$6I_1 + 10I_2 + 4I_2 - 20 = 0$

$6I_1 + 14I_2 = 20$

$3I_1 + 7I_2 = 10$

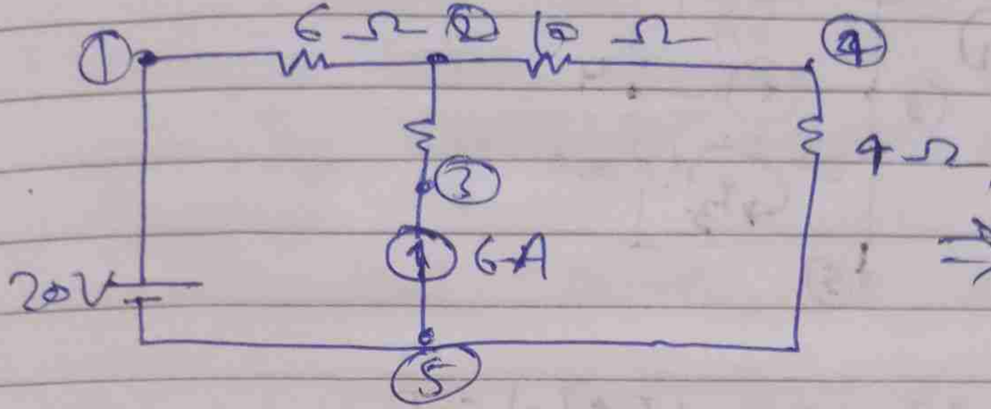
$3I_1 + 42 + 7I_1 = 10$

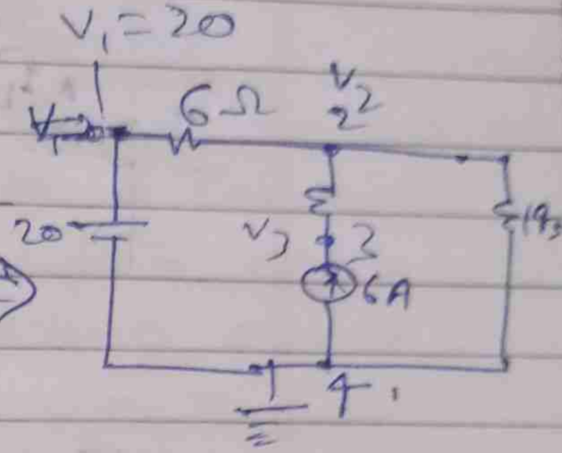
$10I_1 = -32$

$\boxed{I_1 = -3.2}$

$\boxed{I_2 = 2.8}$

Nodal Analysis method





$$\frac{20 - V_2}{6} + 6 = \frac{V_2}{14}$$

$$\frac{20}{6} + 6 = \frac{V_2}{6} + \frac{V_2}{14}$$

$$\frac{56}{\cancel{6}} = \frac{\overset{10}{\cancel{20}} V_2}{\cancel{6} \times \underset{7}{\cancel{14}}}$$

$$\boxed{39.2 = V_2}$$

$$\cancel{V_2 = I \times 6}$$

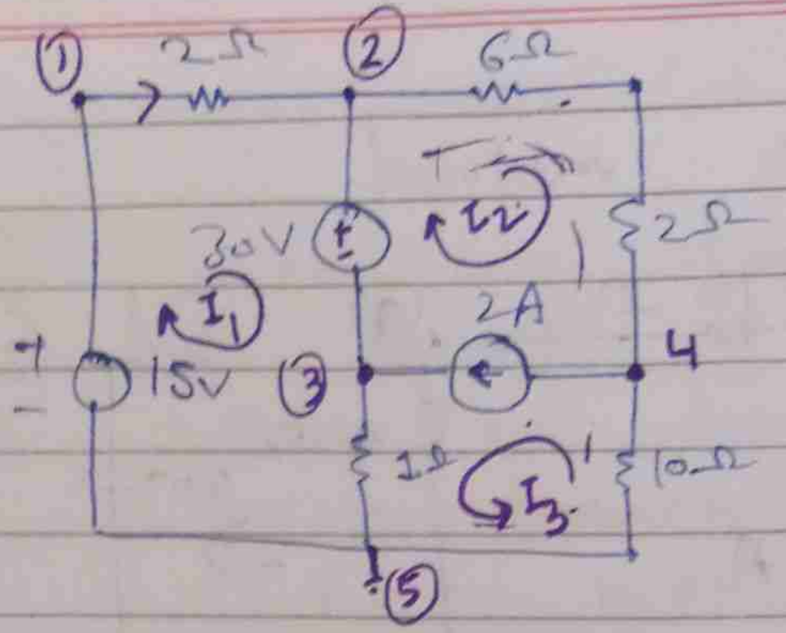
$$\cancel{\frac{39.2}{6} = I}$$

$$\cancel{I =} 6$$

$$\frac{39.2 - 20}{6} = I$$

$$3.2 = \frac{19.2}{6} = I$$

Q



$$-15 + 2I_1 + 30 + (I_1 + I_3) = 0$$

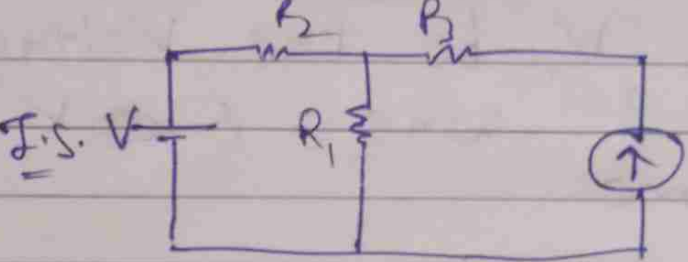
$$6I_2 + 2I_2 - 10I_3 + (I_3 + I_1) = 0$$

$$I_2 + I_3 = 2A$$

Superposition Theorem :-

in linear circuit

States that the Voltage across or Current through any element is equal to algebraic sum of voltages across or currents through that element when each independent source is acting alone.



Linear Element :-

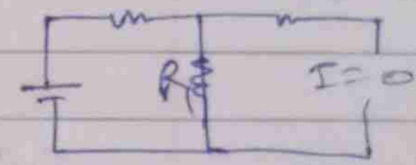
(i) Homogeneity (scaling)

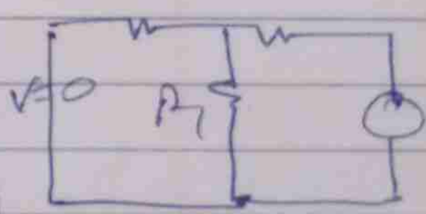
(ii) additivity

Exs-(i) $y = 2x$

$x_1 \rightarrow y_1$

$kx_1 \rightarrow ky_1$





(ii) $V = iR$

$i_1 \rightarrow V_1$

$Ki_1 \rightarrow KV_1$

(iii) $y = 2x^2$

$x_1 \rightarrow y_1^2$

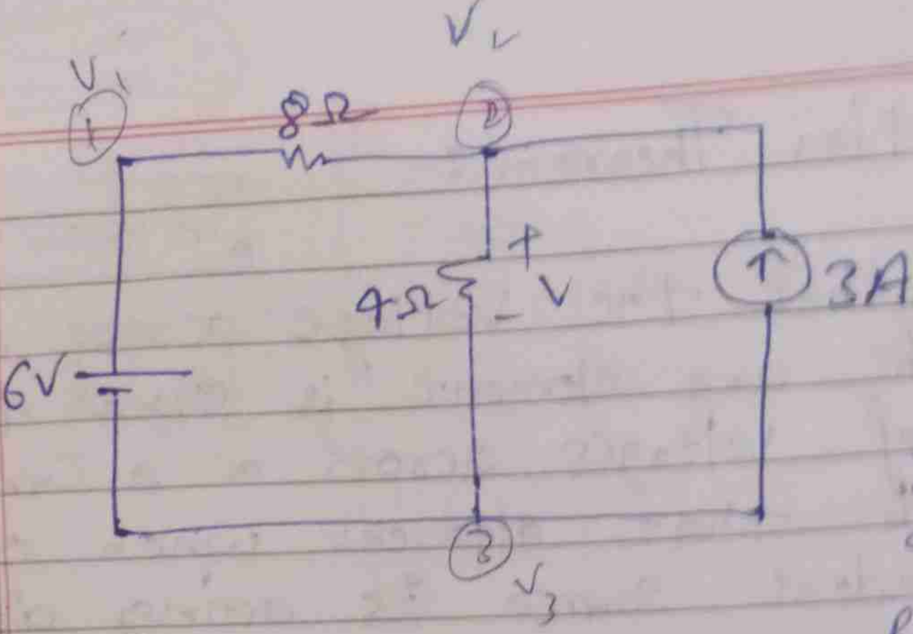
$Kx_1 \rightarrow ky_1^2$

Not setisfied

(iv) $y = mx + c$

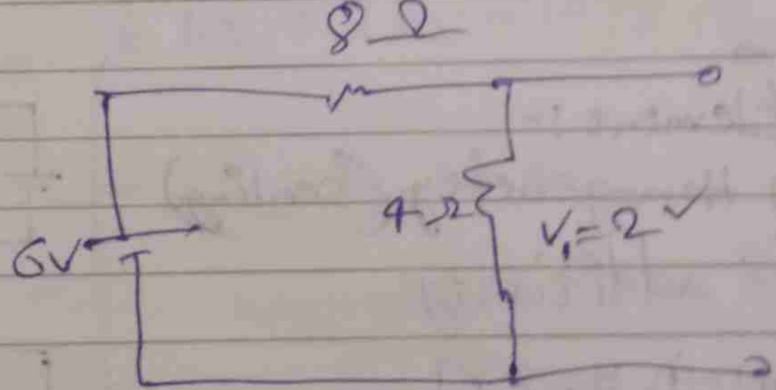
it is not linear System

Q



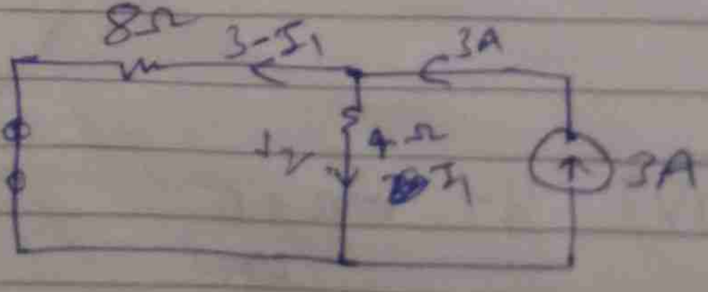
using Super Theo find voltage across 4Ω Res.

Sol^n let V_1 be the voltage across 4Ω when 6 V is acting alone



$$V_1 = \frac{6\times 4}{12} = \frac{V\times R_1}{R_1+R_2}$$

let V_2 be the voltage across 4Ω when 3A is acting alone



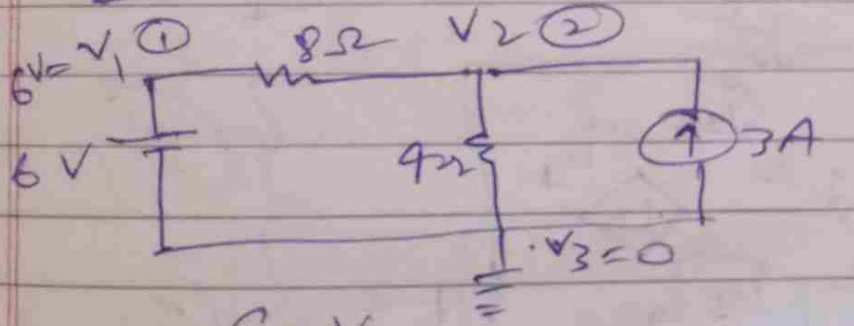
$$I_1 = \frac{3\times 8}{12} = 2A$$

$$V_2 = 4\times 2 = 8$$

There for using super. The the voltage across 4 Ω resistes

$$V = V_1 + V_2 = 10V$$

II Method



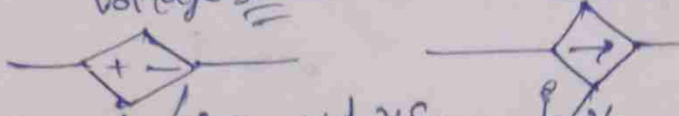
$$\frac{6-V_2}{8} + 3 = \frac{V_2}{4}$$

$$6 - V_2 + 24 = 2V_2$$

$$30 = 3V_2$$

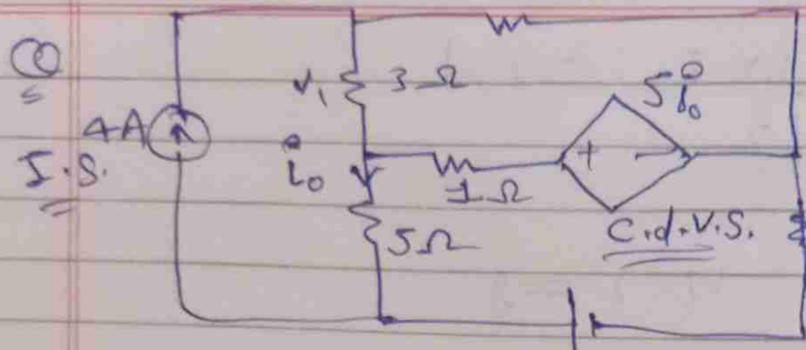
$$V_2 = 10$$

Voltage source   Current Source



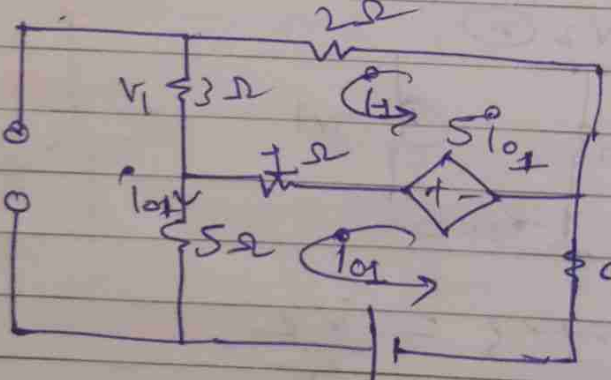
C.d.v.S → i_o/V_o ← V.d.V.S. i_o/V_o → V.d.C.S. → C.d.C.S.

Q.



find i_o using Super. theorm

Soln Step-I The circuit is as shown below when 4A source is turned of i.e. in the circuit there is only one 20V I.S. let now the current in 5Ω branch be i_{o1}



$$\cancel{+5i_{o1} + 20 + 4i_{o1} - 8i_{o1} + i_{o1} - i_I = 0}$$

$$5i_{o1} - i_1 = -20 \quad \text{.... (A)}$$

$$+2i_1 + 3i_1 + 5i_{o1} + 1(i_{o1} - i_{a}) = 0$$

$$6i_1 + 4i_{o1} = 0$$

$$3i_1 + 2i_{o1} = 0$$

Page 7

$i_1 = -\frac{2}{3} i_{o1}$

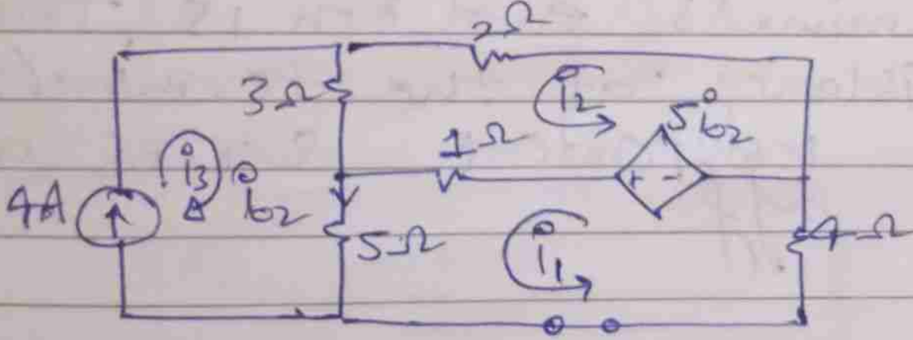
$5 i_{o1} + \frac{2}{3} i_{o1} = -20$

$17 i_{o1} = -60$

$i_{o1} = -\frac{60}{17}$

Step-II

The circuit is as shown below when 20 v source is turned of i.e. in the circuit there is only one 4A I.S., let now the current in 5Ω branch be i_{o2}



$i_3 = 4A$ $\qquad$ $i_1 = \cancel{i_{o2} + 4}$

$i_{o2} = i_1 + 4$

$i_{o2} = i_1 + 4 = -\frac{16}{17} + 4 = +\frac{52}{17}$

$5(i_1 + 4) + 4(i_1) - 5 i_{o2} + 1(i_1 - i_2) = 0$

$5 i_1 - i_2 = 0 \quad \Rightarrow 30 i_1 - 6 i_2 = 0$

$+2 i_2 + 3(i_2 + 4) + 1(i_2 - i_1) + 5(i_1 + 4) = 0$

$4 i_1 + 6 i_2 = -32 \Rightarrow 34 i_1 = -32$

$i_1 = -\frac{32}{34} = -\frac{16}{\ldots}$

$$i_o = i_{o1} + i_{o2}$$

$$= \frac{-60}{17} + \frac{52}{17}$$

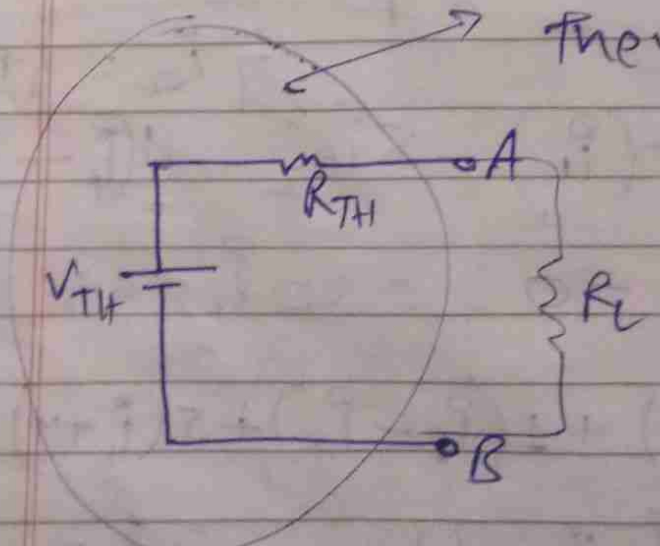
$$= \frac{-8}{17} A$$

2017
(BE-2018)

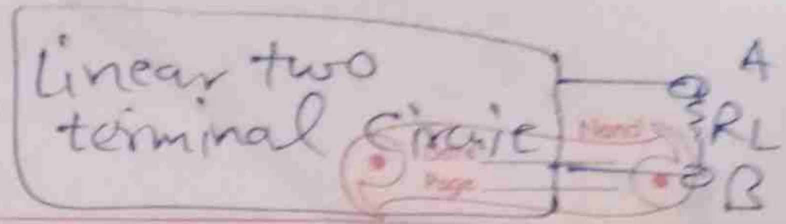
Thevenin's Theorem:-

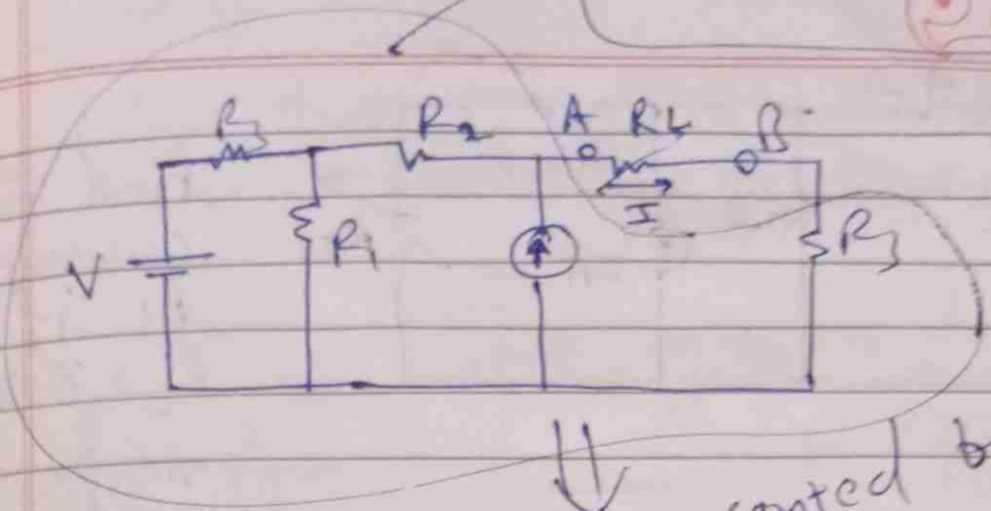
states that any linear two terminal network (circuit) can be replaced by an equivalent circuit consisting of a voltage source (V_{TH}) in series with a resistance (R_{TH}), where V_{TH} is the open circuit voltage across the terminals and R_{TH} is the eqvilant resistance at the terminals when all independent surces are turned off.

Thevenin Circuit

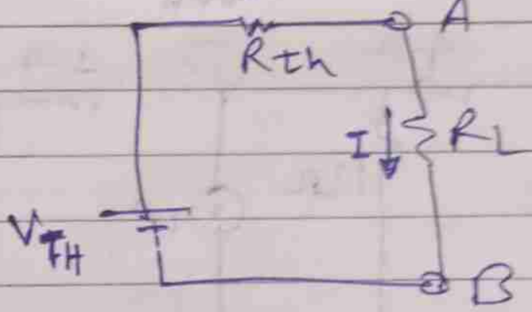


$$I = \frac{V_{TH}}{R_{TH} + R_L}$$

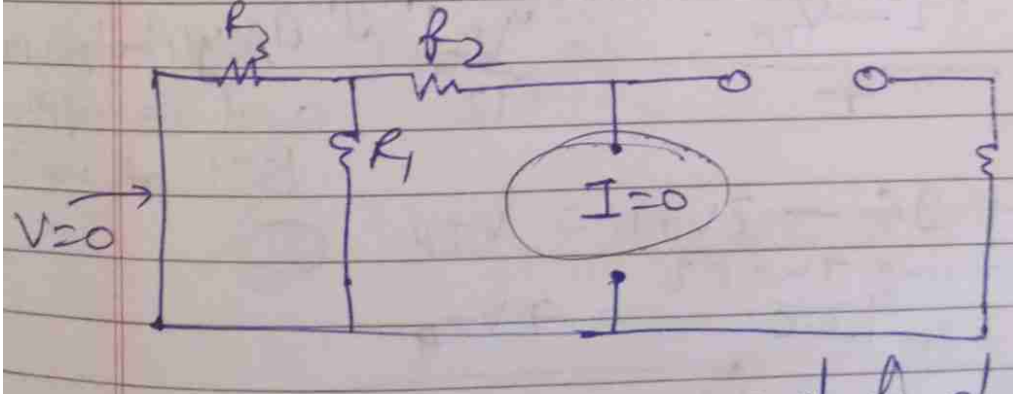




Represented by



How to find R_{TH} ?



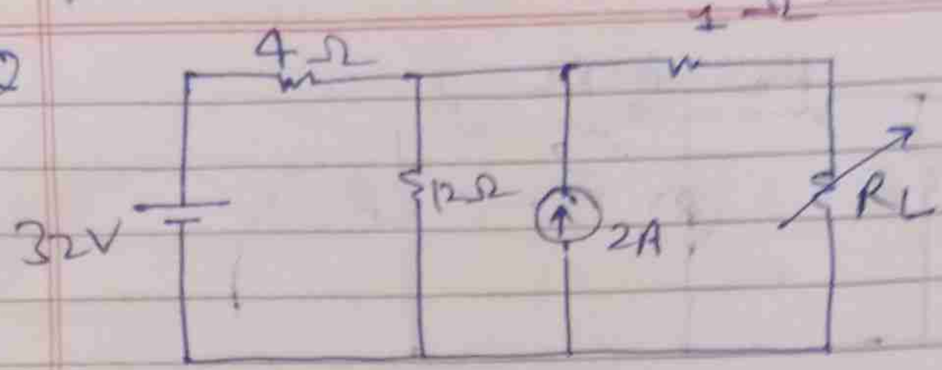
and find R_{TH}

$$R_{TH} = \frac{R_3 R_1}{R_1+R_3} + R_2$$ (in this circuit)

$$P = VI = I^2R = \frac{V^2}{R}$$

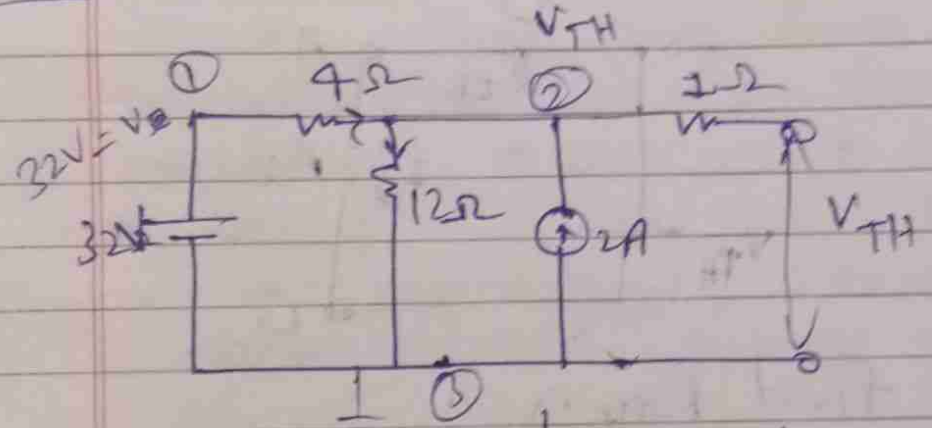
[1Ω कहाँ गया]

Q



Find ~~Circuit~~ current in R_L if R_L = 6, 16 f... respectively

Soln



First we find V_{TH} by applying Nodel voltage Analysis method and i.e. apply KCl at node ②

$$2 + \frac{32 - V_{TH}}{4} = \frac{V_{TH}}{12}$$

$$24 + 96 - 3V_{TH} = V_{TH}$$

solving the eq

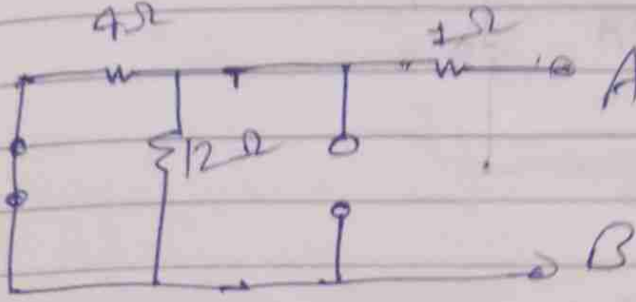
$$120 = 4V_{TH}$$

$$\boxed{30 = V_{TH}}$$

Now for finding R_{TH} we turn off all Independing Sources

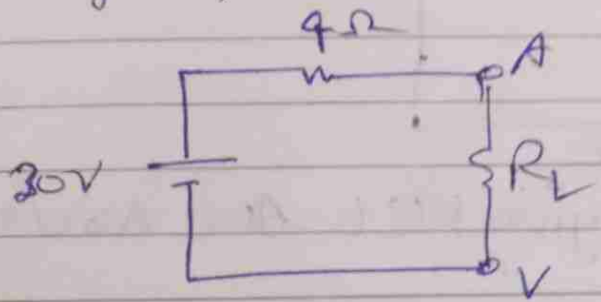
$\frac{1}{12}+\frac{1}{4}$

By turning off independent Sources the ckt. is as shown blw



$R_{TH} = R_{AB} = 4\,\Omega$

Therefore, The thevenin Eq. circuit



$$I = \frac{30}{4+R_L}$$

I when $R_L = 6\,\Omega$

$$I = \frac{30}{4+6} = 3A$$

$R_L = 16$

$$I = \frac{30}{4+16} = \frac{3}{2}$$

$R_L = 36$

$$I = \frac{30}{36+4} = \frac{3}{4}$$

Date ________
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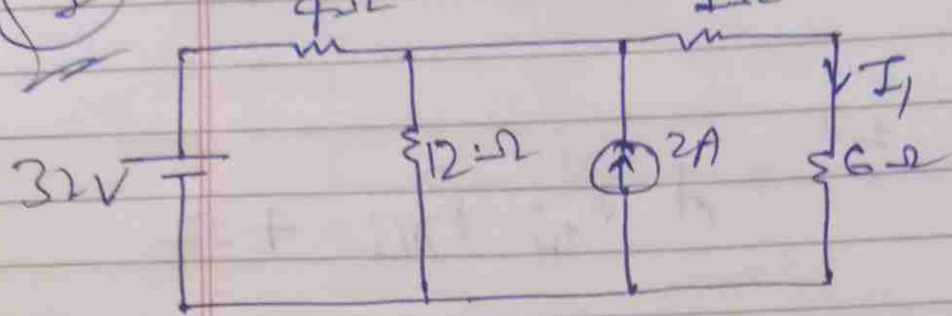
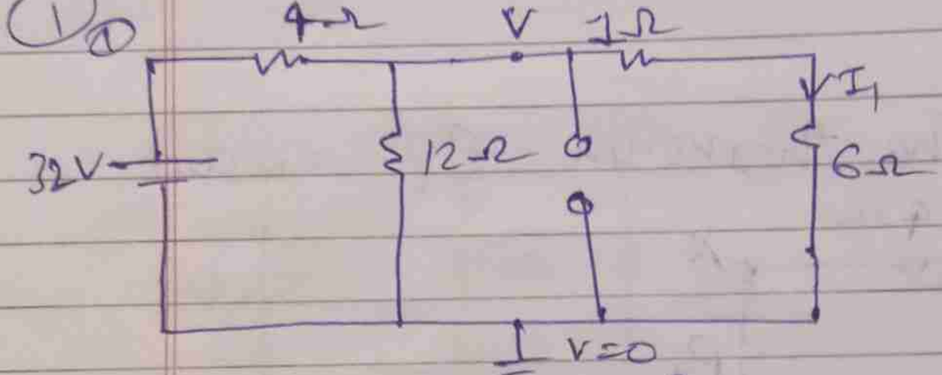
Check the Ans

(I)



(1)



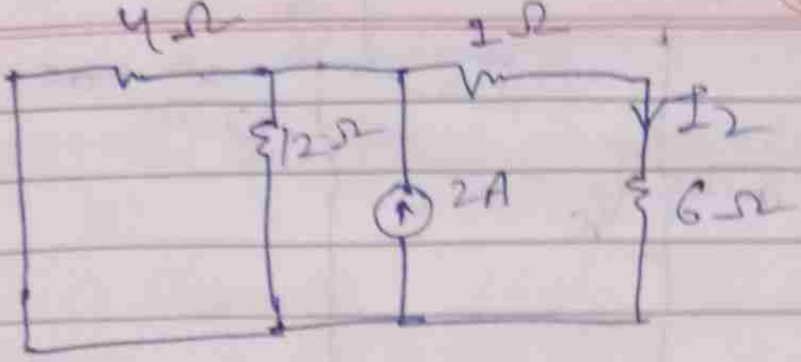
Now Applying KCL at node (2)

$$\frac{32-V}{4} = \frac{V}{12} + \frac{V}{7}$$

$$8 = \frac{V}{12} + \frac{V}{4} + \frac{V}{7}$$

$$8 = V\left(\frac{1}{12} + \frac{1}{4} + \frac{1}{7}\right)$$

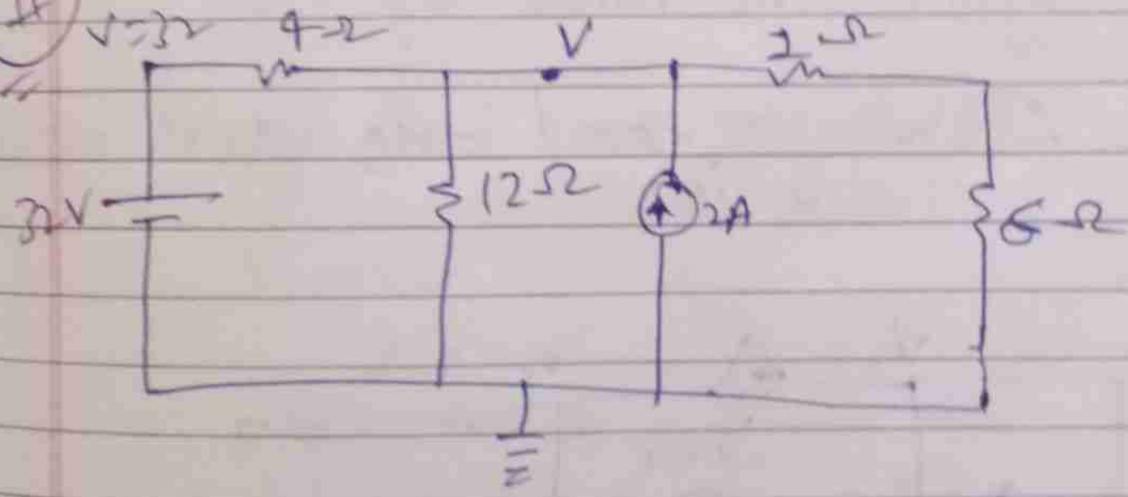
$$V = \frac{168}{10} \qquad I_1 = 2.4\,A = \frac{168}{10} \times \frac{1}{7}$$



$$I_2 = \frac{2\times3}{10} = 0.6A$$

$$I = I_1 + I_2$$
$$= 2.4 + 0.6 = \underline{3A}$$

(II)

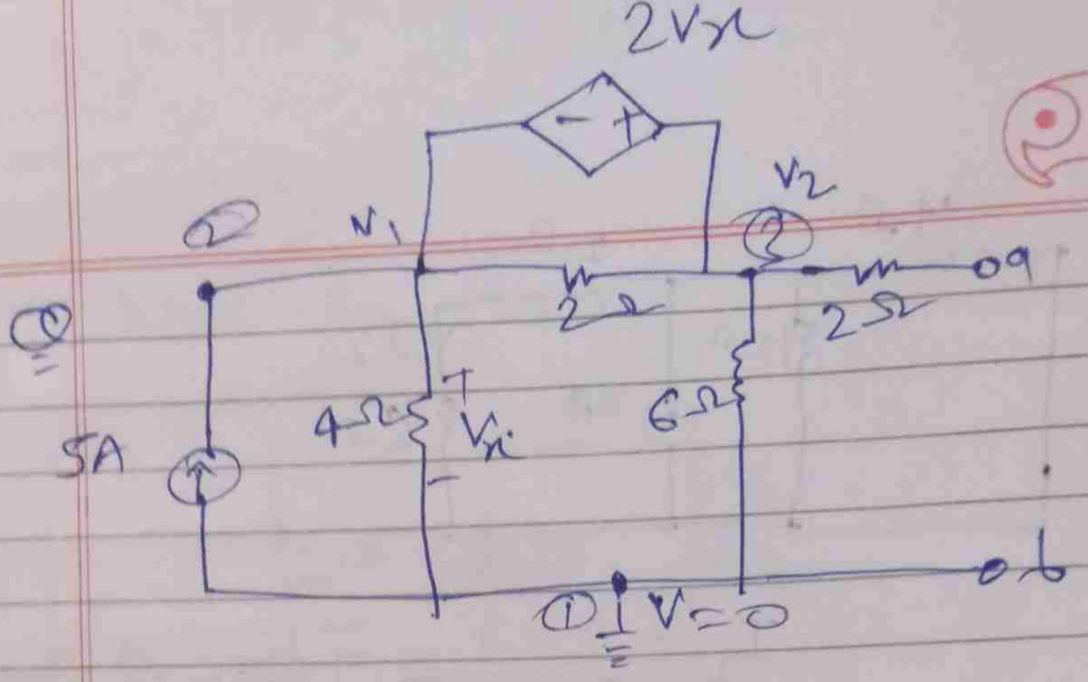


$$2 + \frac{32-V}{4} = \frac{V}{12} + \frac{V}{7}$$

$$10 = V\left(\frac{1}{12} + \frac{1}{4} + \frac{1}{7}\right)$$

$$V = 21V$$

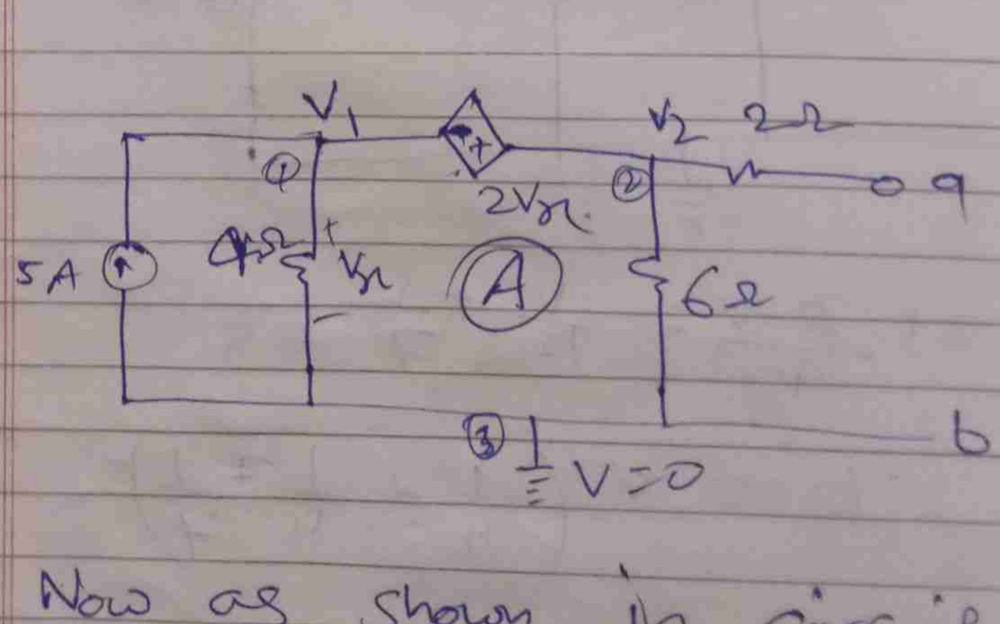
$$I = \frac{21}{7} = 3A$$



first we determine V_{TH} or V_{ab} by using Nodal Analysis method

(i) Since 2Ω is Connected is parallel with a dependent voltage source it is redundant and does not effect the value of V_{TH}.

∴ we removed this and new circuit is.



Now as shown in circuit there are three node ① ② ③ respectively let node ③ be reference node and voltage of node ① & ② be V_1 & V_2 respectively

By assuming Node ① & Node ② as one node called as Supernode because there is a voltage source b/w them. Now we apply KCl at this Supernode.

we get.

$$5 = \frac{V_1}{4} + \frac{V_2}{6}$$

Apply KVL at Mesh Ⓐ we get.

$$V_1 + 2V_1 = V_2$$

$$3V_1 = V_2$$

$$5 = \frac{V_1}{4} + \frac{\cancel{3}V_1}{\cancel{6}\,2}$$

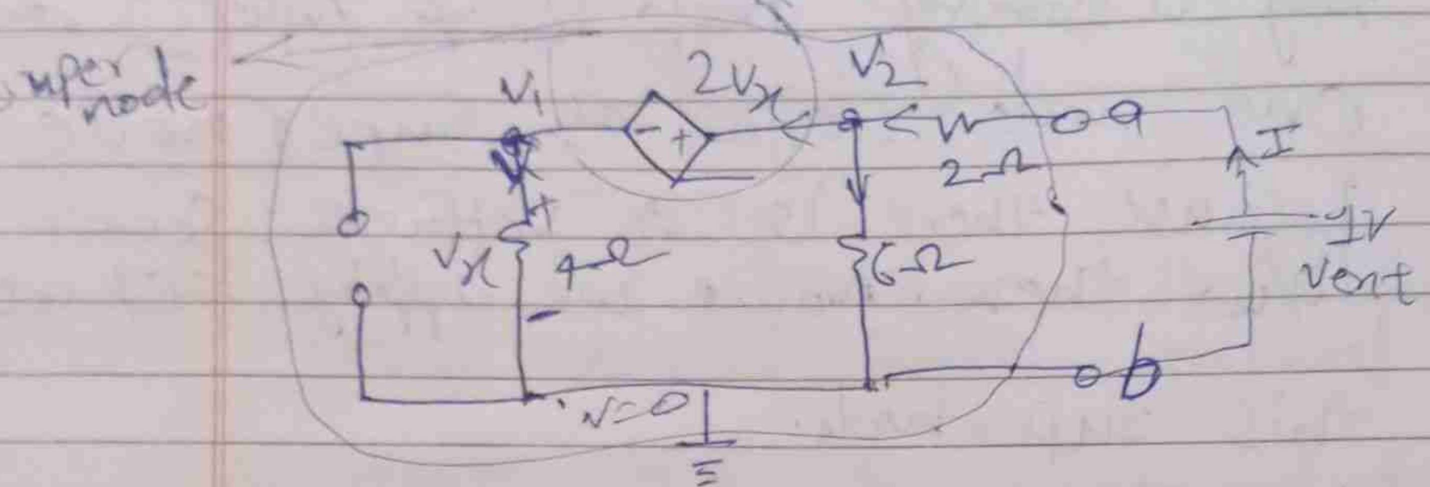
$$\frac{3V_1}{4} = 5$$

$$\boxed{V_2 = 20}$$

$$V_1 = \frac{20}{3}$$

$$\boxed{V_{TH} = 20V}$$

For finding R_{TH} we turn off all independent sources. The circuit after turning off I.S



Because the circuit has dependent surce therefore we apply external voltage Vext = 1V and find I in the circuit which will give

$$R_{TH} = \frac{V_{ext}}{I}$$

By applying KCl at Supernode we get

$$\frac{V_1}{4} + \frac{V_2}{6} = \frac{1 - V_2}{2}$$

$$\frac{1}{2} = \frac{V_1}{4} + \frac{V_2}{6} + \frac{V_2}{2}$$

$$\frac{1}{2} = \frac{V_1}{4} + \frac{V_1}{2} + \frac{3V_1}{2}$$

$V_1 + 2V_1 = V_2$

$3V_1 = V_2$

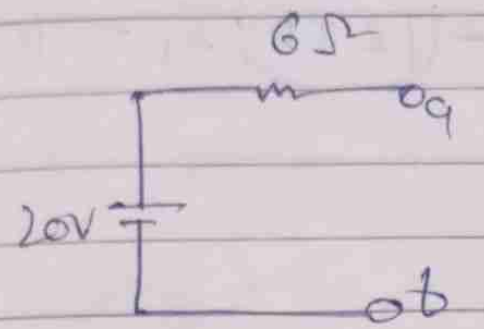
$V_2 = \frac{2}{3}V$

$\frac{9V_1}{4} = \frac{1}{2}$

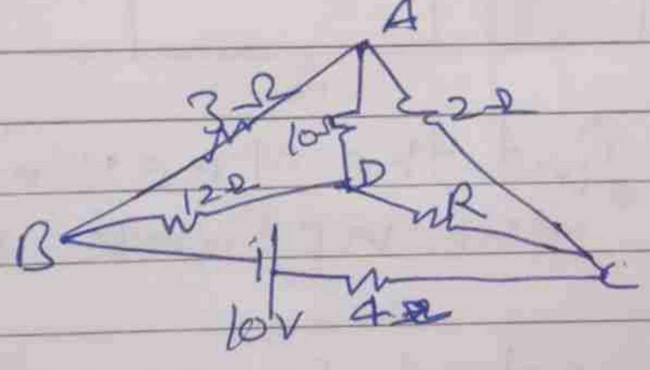
$V_1 = 2/9$

$$I = \frac{1 - \frac{2}{3}}{2} = \frac{1}{6} A ; R_{TH} = 6\Omega$$

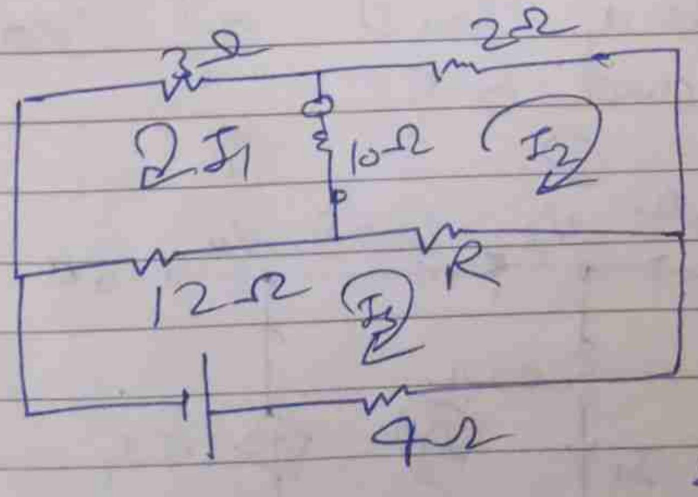
∴ Therefore Thevenin Eq. Ckt is



Q Find the value of R and Current through in the circuit shown in fig. when branch Ad carries no current (BE-2018)



Soln



$I_1 - I_2 = 0$

$I_1 = I_2$

$3I_1 + 10(I_1 - I_2) + 12(I_1 - I_3) = 0$ — ①

$2I_2 + R(I_2 - I_3) + 10(I_2 - I_1) = 0$

$4I_3 - 10 + 12(I_3 - I_1) + R(I_3 - I_1) = 0$

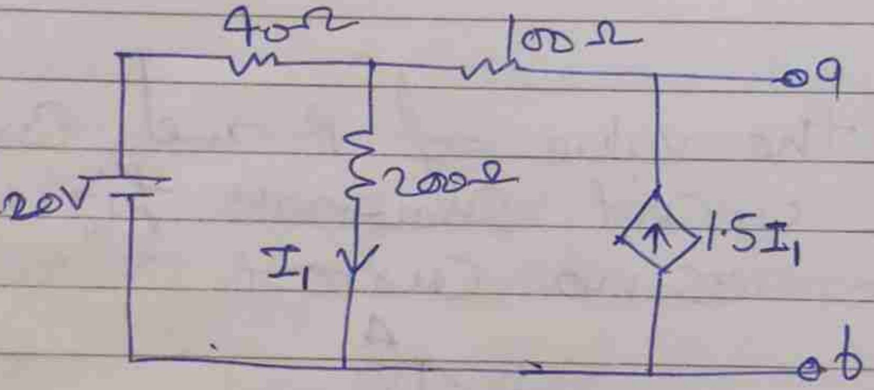
$15I_1 - 12I_3 = 0$

$5I_1 - 4I_3 = 0$ — ①

$(2+R)I_1 - RI_3 = 0$ — ②

$(16+R)I_3 - (12+R)I_1 = 10$ — ③

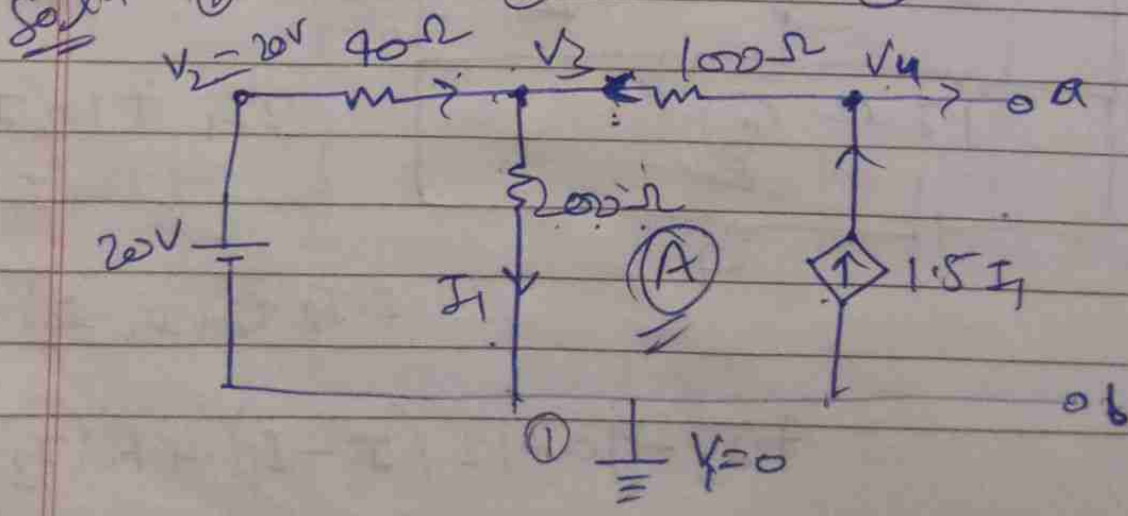
Q



① find the thevenin equivalent of the network shown in fig.

② what power will be delivered to a load of 100Ω at a and b?

Soln



$$V_A - \frac{3\times 9}{5} - 12$$

$$-\frac{3\times 25}{7} = V_B$$

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Page

Apply KCl at 3 node

$$\frac{20 - V_3}{40} + \frac{V_4 - V_3}{100} = \frac{V_3}{200}$$

Apply KVl at mesh A

$$\cancel{V_3\ 200 I_1 + 1.5 + 100\ V_4 = V_3}$$

$$\cancel{-V_3 + V_4 + V_4 = V_3}$$

$$\cancel{0 + V_3 + V_4 + 0 = 0}$$

$$200 I_1 + 0.5\, I_1 \times 40 + 20 = 0$$

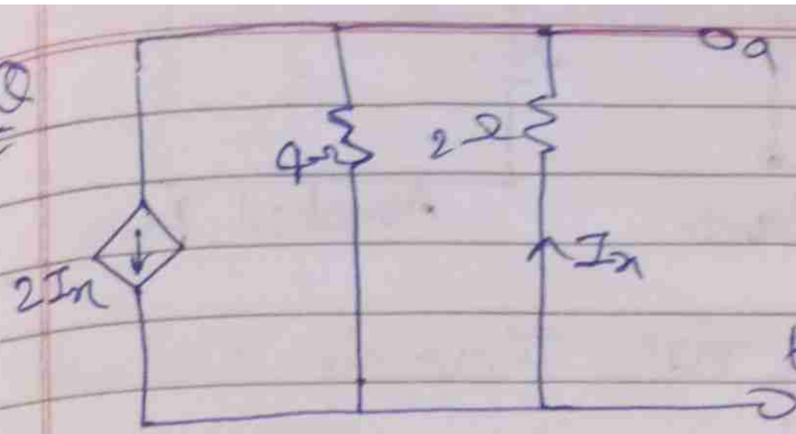
$$I_1 = \frac{-20}{180}$$

$$I_1 = -\frac{1}{9}$$

$$\frac{V_3 - 0}{200} = I_1$$

$$V_3 = -\frac{1}{9} \times 200$$

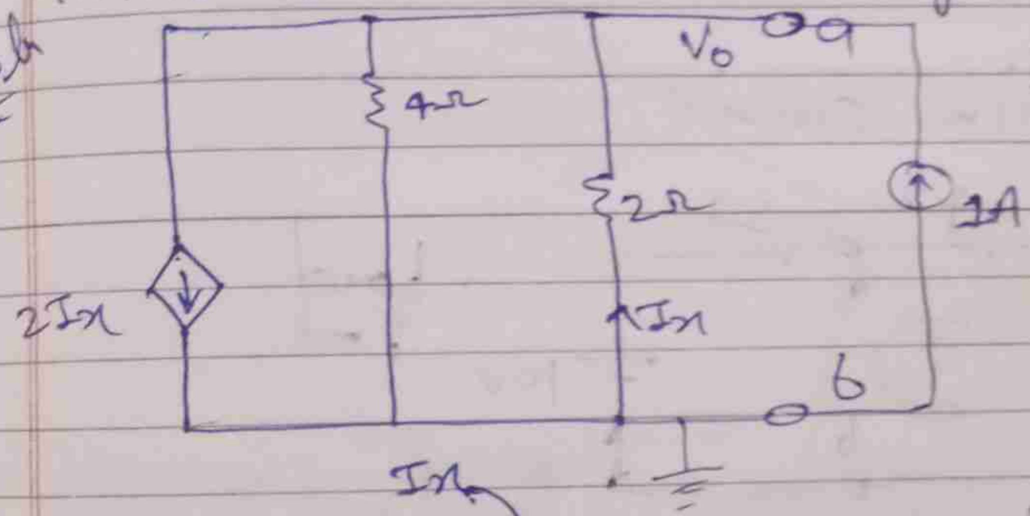
Q



find Thevinen eq. Circuit.

in this circuit does not has any In. S. . So in this circuit current will be zero

Sol



Ix

$$2\left(\frac{-V_o}{2}\right) + \frac{V_o}{4} + \frac{V_o}{2} = 1$$

$I_o = 1A$

$$\frac{V_o}{4} + \frac{2V_o}{4} - \frac{4V_o}{4} = 1$$

$$-\frac{V_o}{4} = 1$$

$$\boxed{V_o = -4}$$

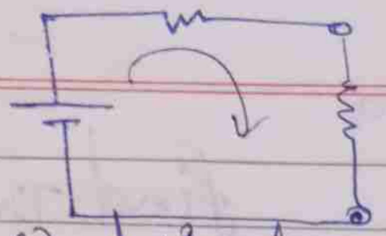
$$\frac{V_o}{I_o} = \frac{-4}{1} = -4\,\Omega$$

of circuit का Req. है

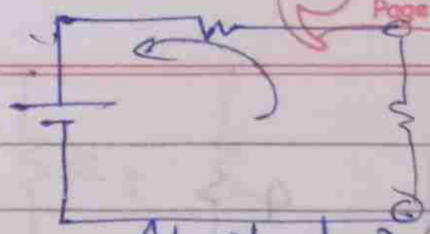
In this Circuit has d.s.. So it is resistance is of total circuit

This circuit delivering power

⇒ Thevenin



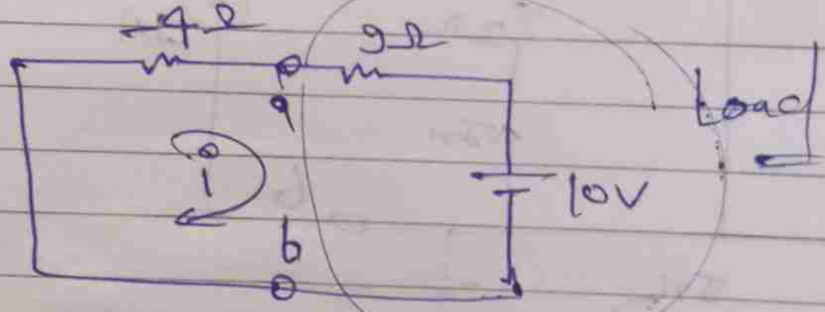
(Normal) delivered Power



Absorbed Power

⇒ Resi. -ve नहीं होता Thevenin Resi. -ve हो सकता है।

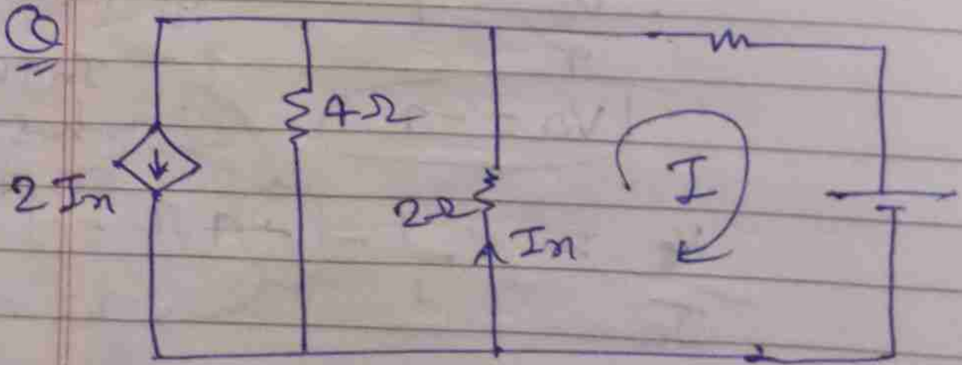
Thevenin circuit.



$$-4i+9i+10=0$$

$$i=-2A$$

Q

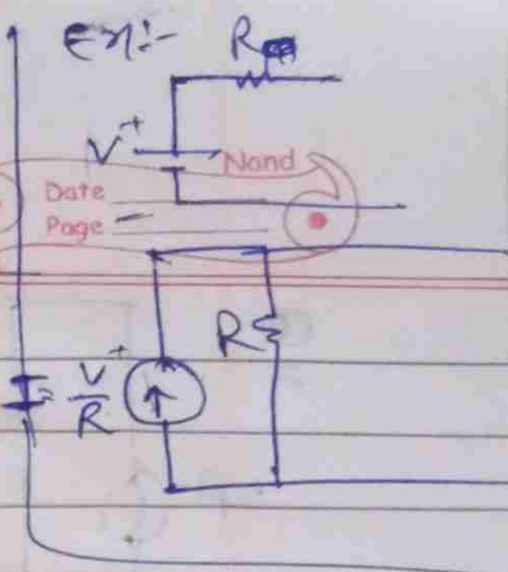


find (I) from nodal Analysis

for find dual Circuit

1. Current Source ⟷ Voltage Source
2. Resis. Series ⟷ Resis. Parallel

Ex:-

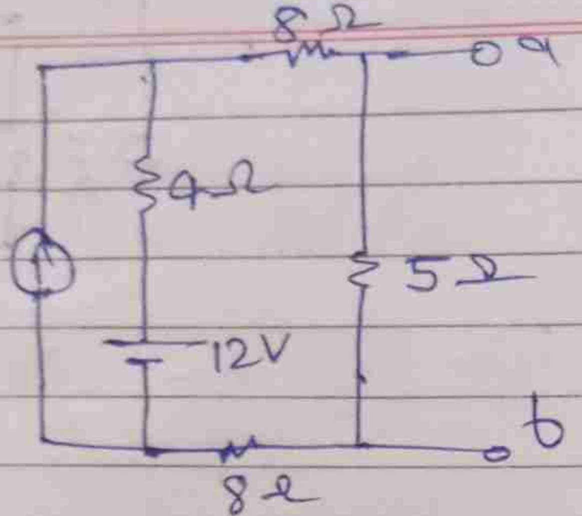


→ NORTON'S THEOREM

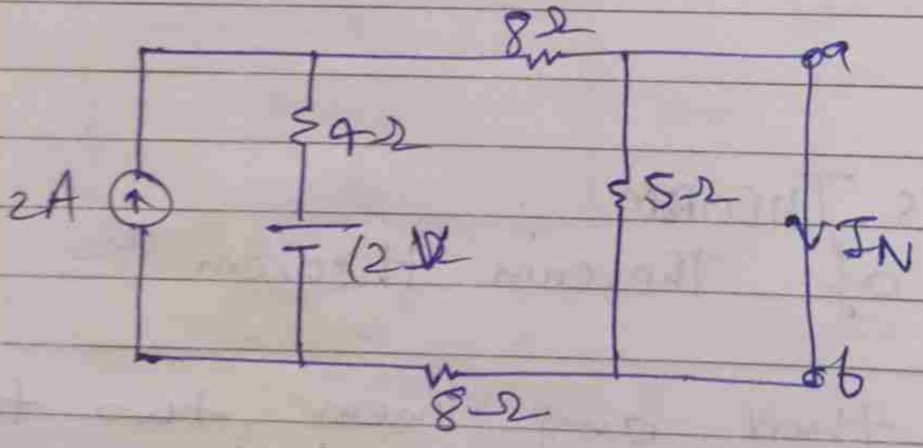
dual of Thevenin theorem

States that any linear two terminal circuit can be replaced by an equivalent circuit consisting of a current source (I_N) in parallel with a resistance (R_N) where I_N in the short circuit current ~~is~~ through the two terminal and R_N is ~~the~~ eq. resistance when all I. S. are turned off.

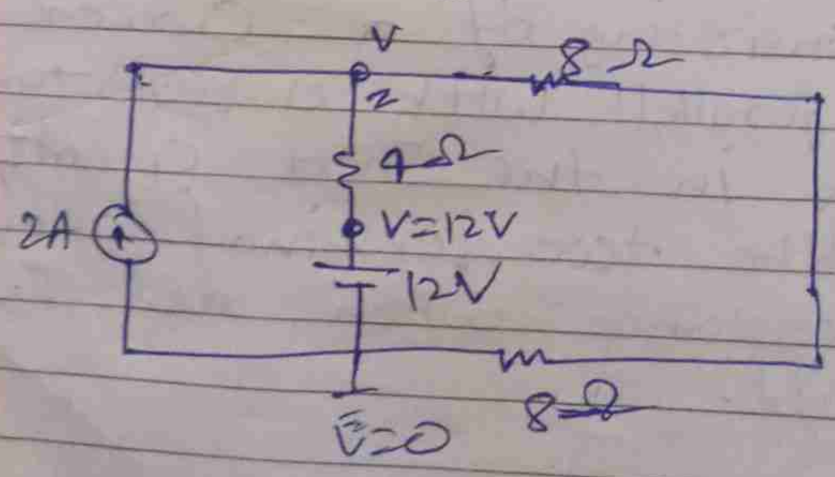
Q. find the Norton eq. on given circuit.



Soln We first determined I_n and for that we short the terminal a & b i.e. now the circuit is



⇓



Applying KCl at Node 2 we get

$$2 + \frac{12 - V}{4} = \frac{V}{16}$$

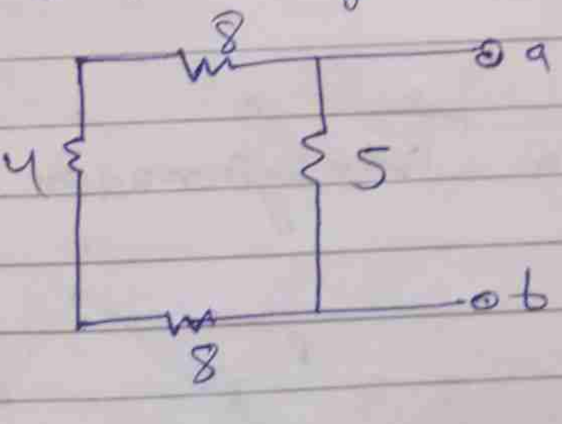
$$5 = \frac{V}{16} + \frac{4V}{16}$$

$$I_N = \frac{V}{16} = 1A$$

$$\frac{5V}{16} = 5$$

$$\boxed{V = 16}$$

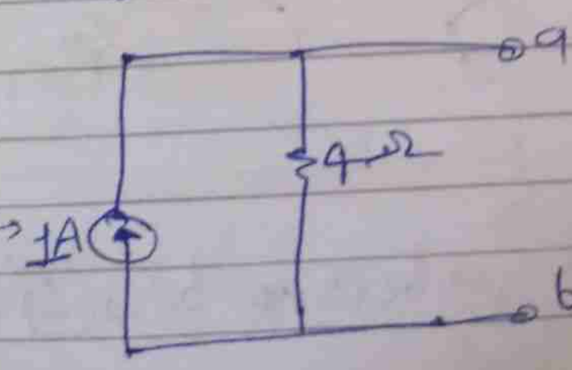
Now for finding R_N we turned of all I. S., thereafter the new circuit is

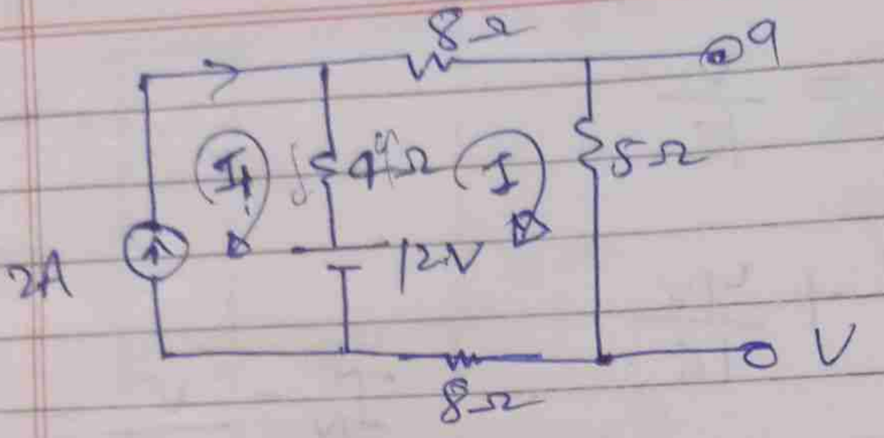


$\therefore R_N = 4\Omega$

Norton eq. circuit

for finding I_N





$V_{ab} = 5I = 4V$

$= 5 \times \frac{4}{5}$

$$8I + 5I + 8I - 12 + 4(I - I_1) = 0$$

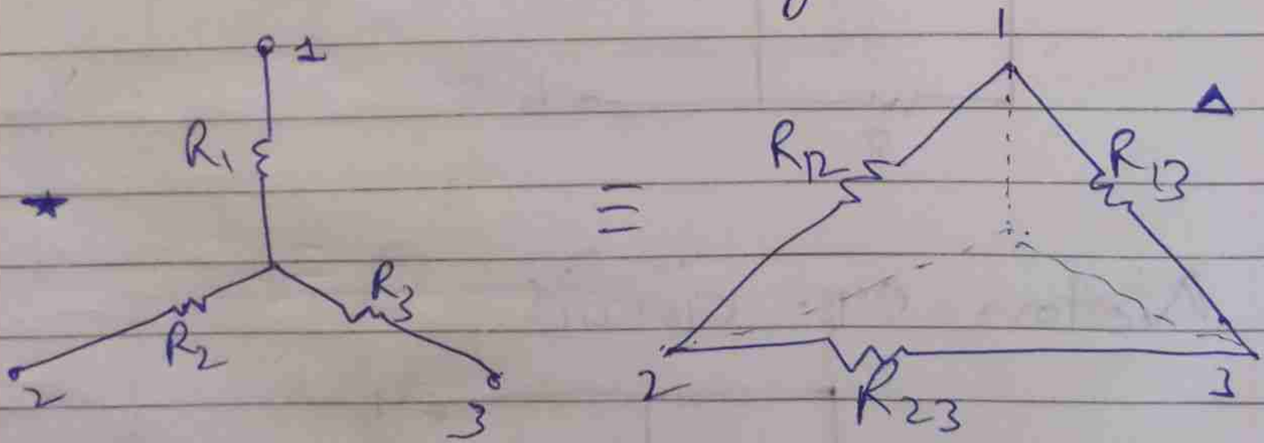
$I_1 = 2A$

~~8I + 5I + 8~~

$$25I = 20$$

$$I = \frac{4}{5}$$

Star - Delta Transformation :-



Connect abeftry b/w 1 & 2 and

$$R_1 + R_2 = \frac{R_{12}(R_{13} + R_{23})}{R_{12} + R_{13} + R_{23}} \quad (1)$$

Similarly $R_2+R_3 = \dfrac{R_{23} * (R_{12}+R_{13})}{R_{12}+R_{23}+R_{13}}$ — (B)

$$R_1+R_3 = \frac{R_{13} \times (R_{23}+R_{12})}{R_{12}+R_{13}+R_{23}} \quad \text{— (C)}$$

(A) − (B)

$$R_1-R_3 = \frac{R_{12} * R_{13} - R_{13}R_{23}}{R_{12}+R_{13}+R_{23}} \quad \text{— (D)}$$

(C) + (D)

$$\cancel{2}R_1 = \frac{\cancel{2}R_{12}R_{13} \cancel{- R_{13}R_{23}}}{R_{12}+R_{13}+R_{23}}$$

$$\boxed{R_1 = \frac{R_{12} \cdot R_{13}}{R_{12}+R_{13}+R_{23}}} \qquad \boxed{R_2 = \frac{R_{12} * R_{23}}{R_{12}+R_{13}+R_{23}}}$$

$$\boxed{R_3 = \frac{R_{13}R_{23}}{R_{12}+R_{13}+R_{23}}} \quad \text{— (f)}$$

$$\Rightarrow R_1R_2 + R_1R_3 + R_2R_3 = \frac{R_{12}^2 R_{13}R_{23} + R_{13}^2 R_{12}R_{23} + R_{23}^2 R_{12}R_{13}}{(R_{12}+R_{13}+R_{23})^2}$$

$$= \frac{\cancel{R_{12}} \cdot R_{12}R_{13}R_{23}}{R_{12}+R_{13}+R_{23}} \quad \text{— (e)}$$

$\frac{10+15}{2}$ C/f

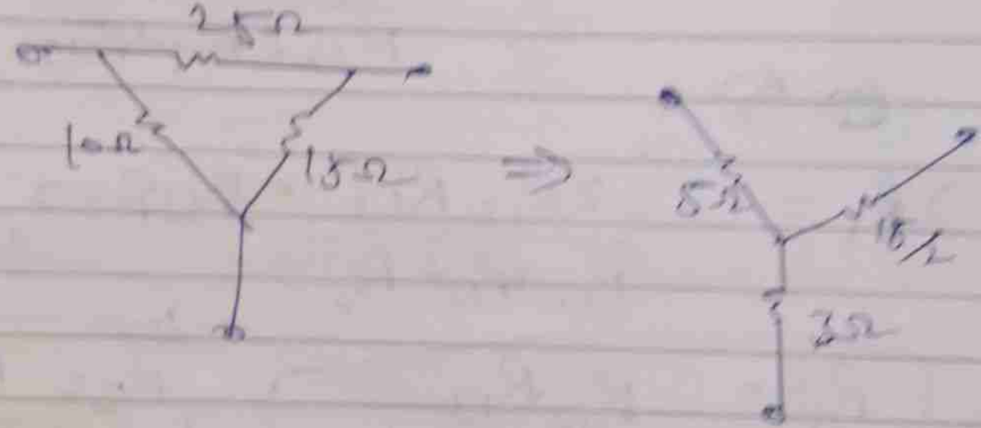
$$\frac{R_1R_2}{R_3} + R_1 + R_2 = R_{12}$$

$$\boxed{R_{12} = R_1+R_2+\frac{R_1R_2}{R_3}}$$

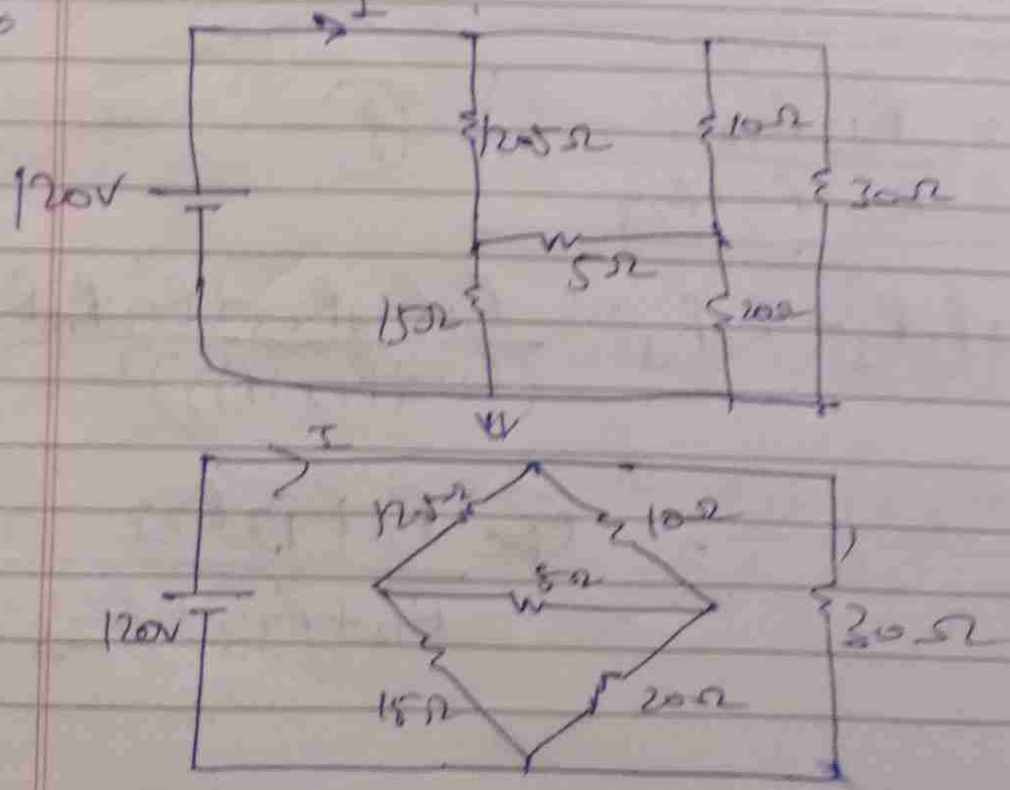
$$\boxed{R_{13} = R_1+R_3+\frac{R_1R_3}{R_2}}$$

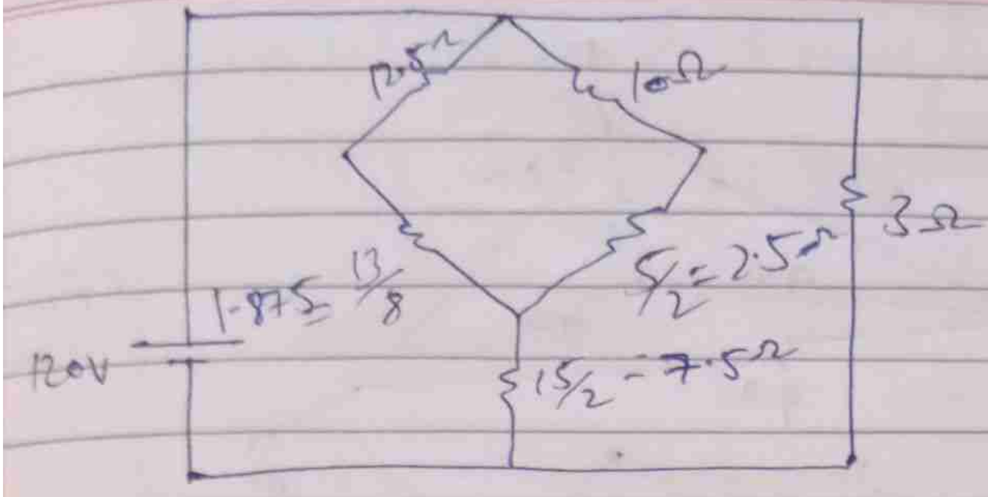
$$\boxed{R_{23} = R_2+R_3+\frac{R_2R_3}{R_1}}$$

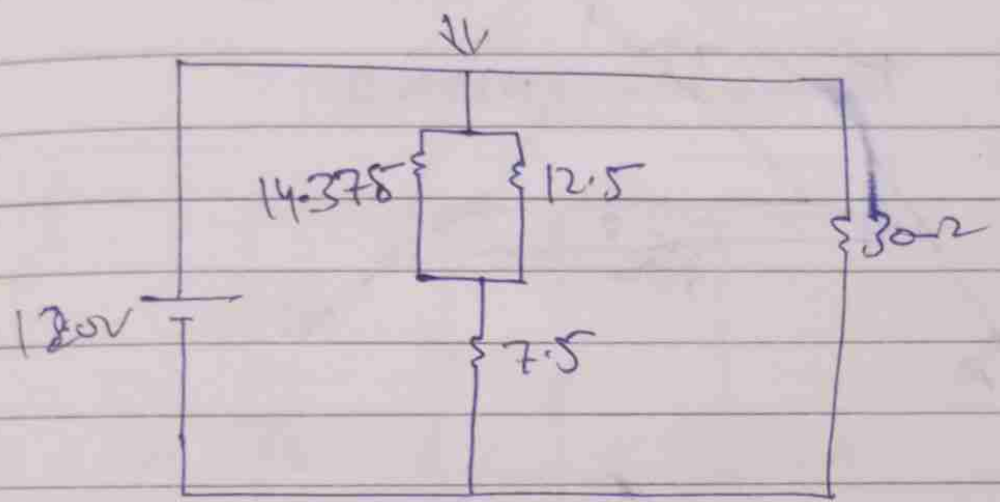
Q:

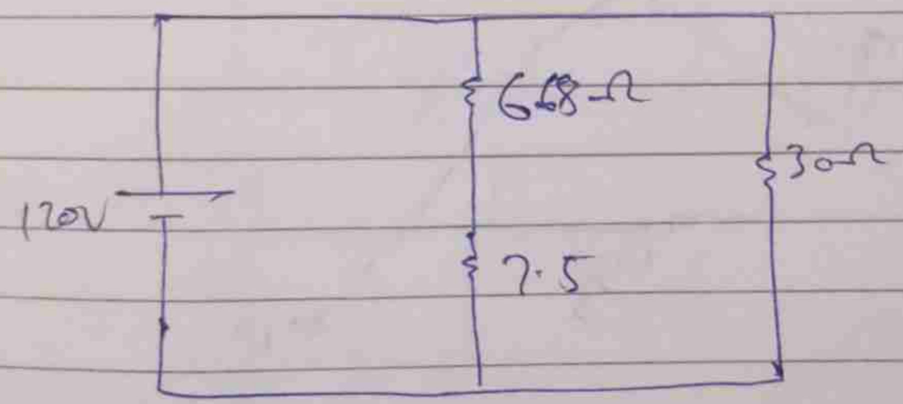


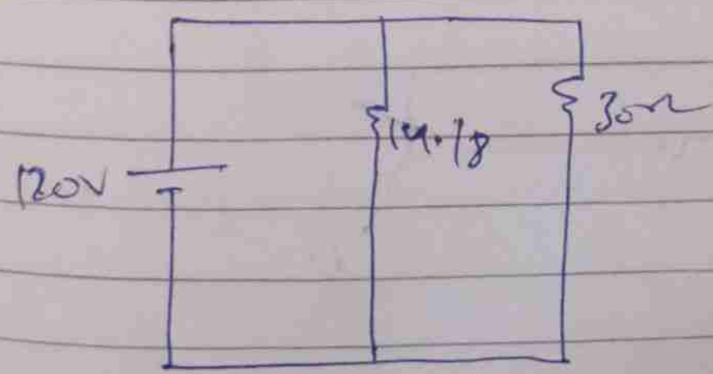
Q:



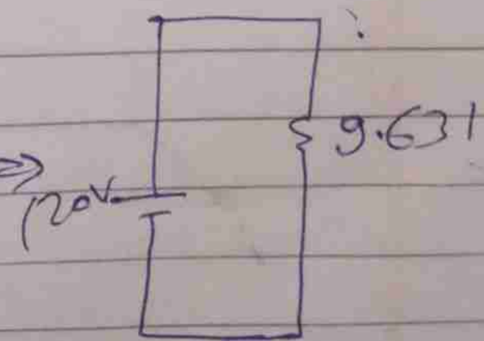








⇒

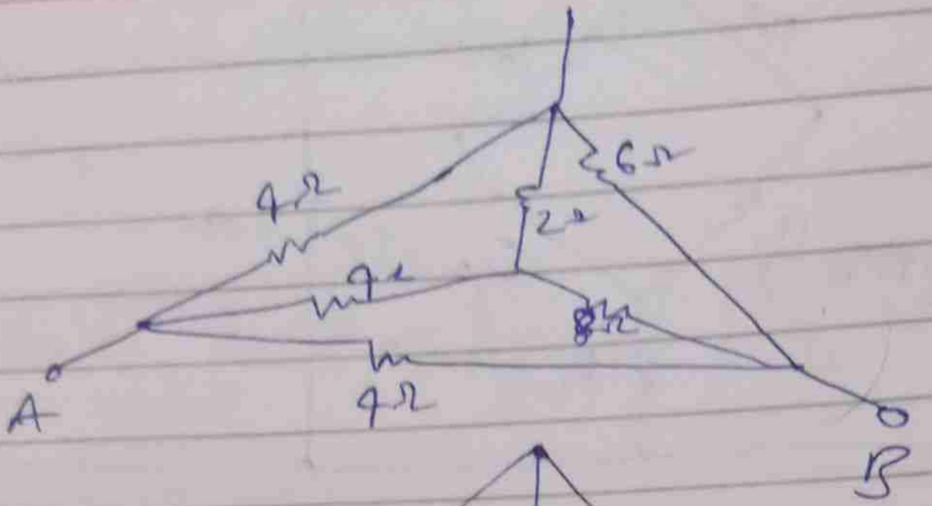


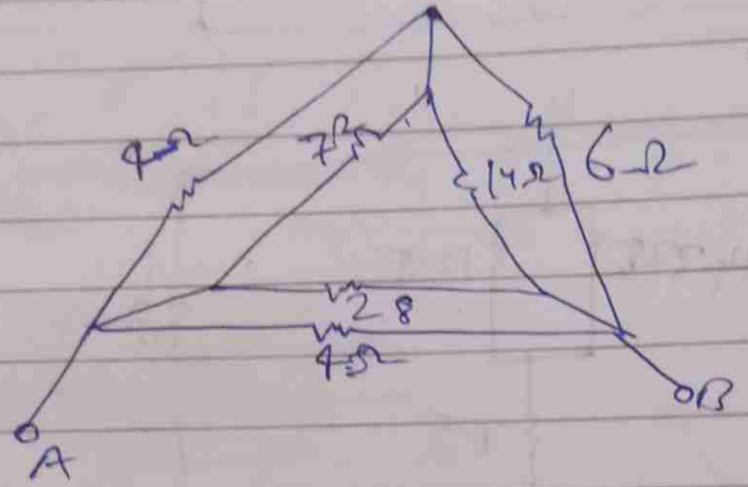
$$I = \frac{120}{9.631} =$$

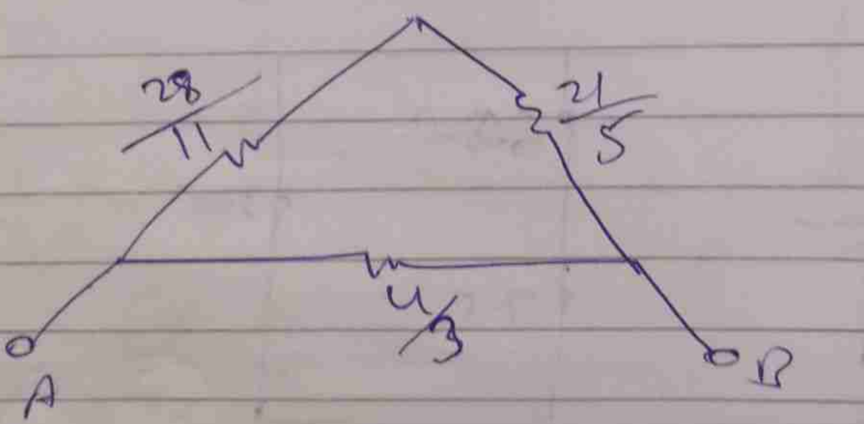
12.459A

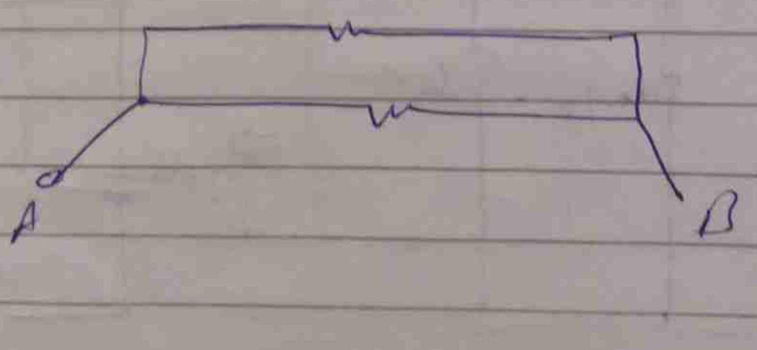
Q

$R_{AB} = ?$

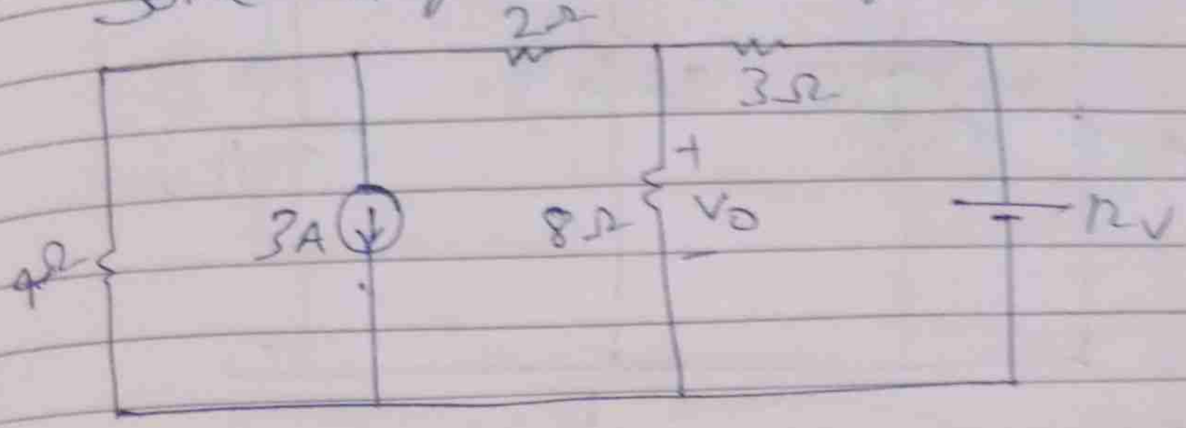




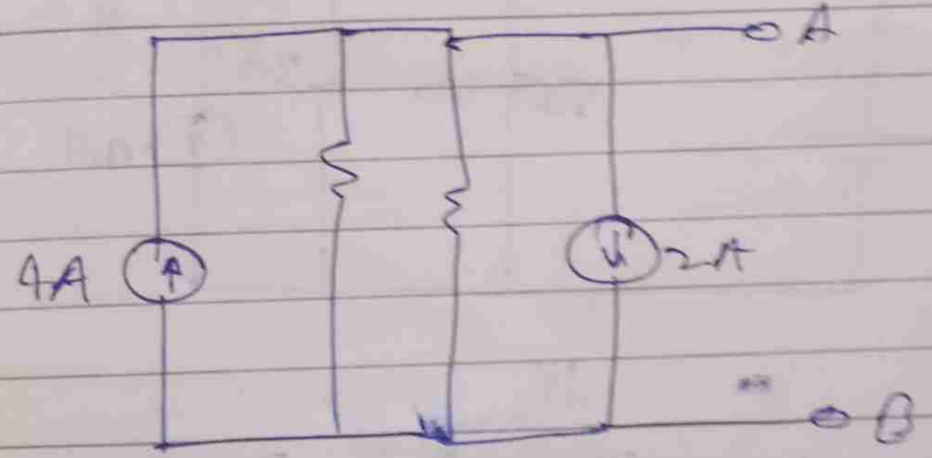




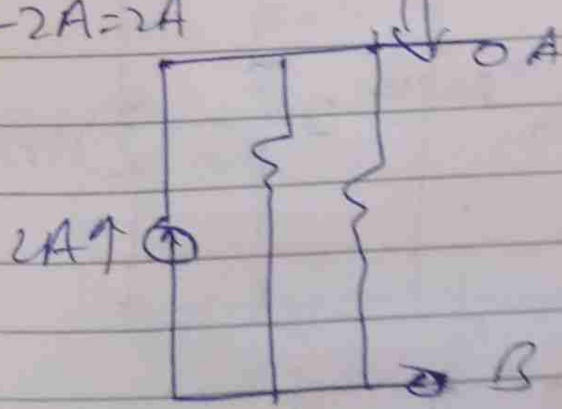
(c) Solve using Source transformation and find V_o

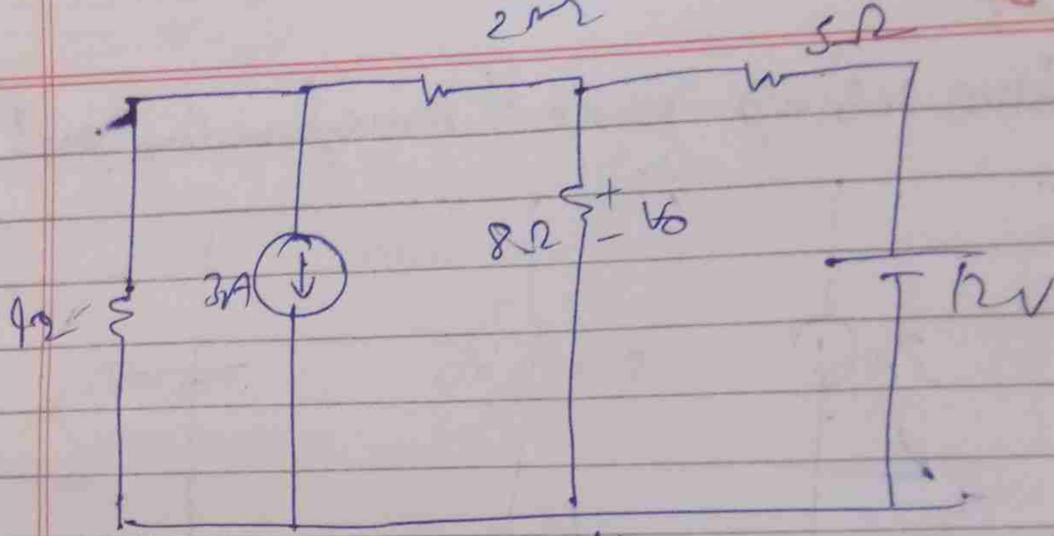


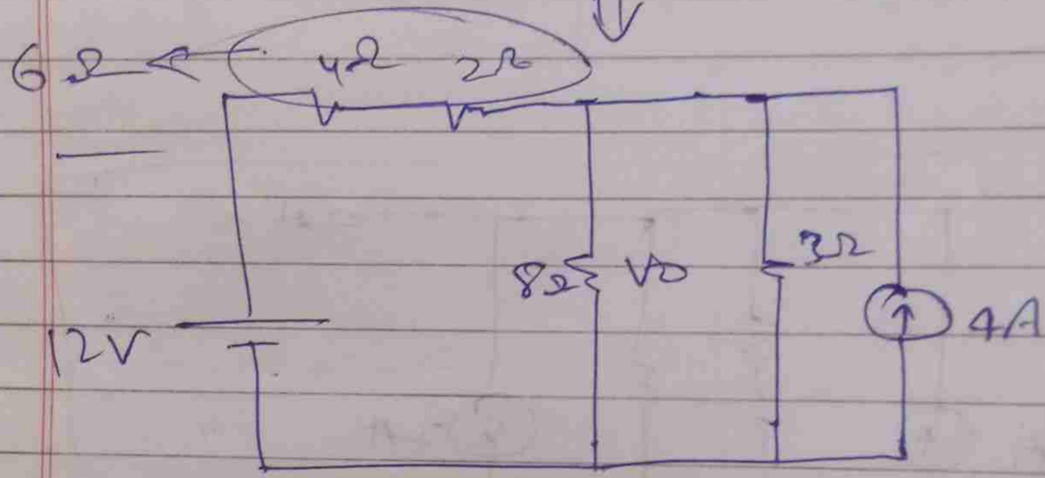
Note if

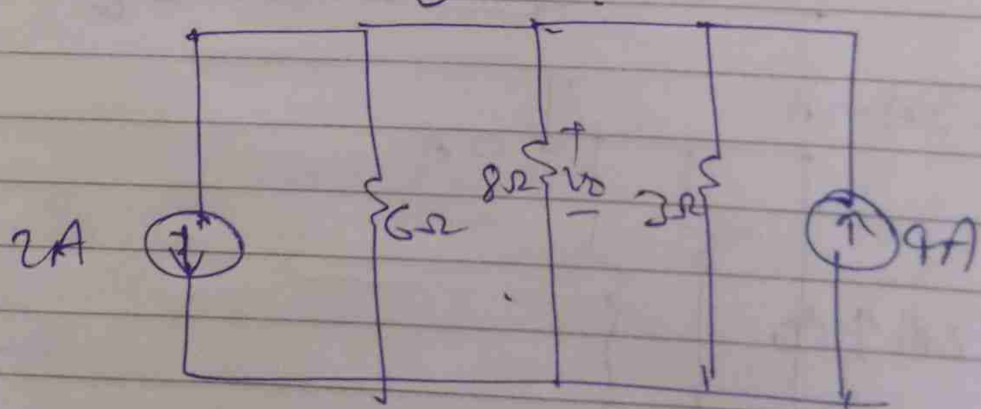


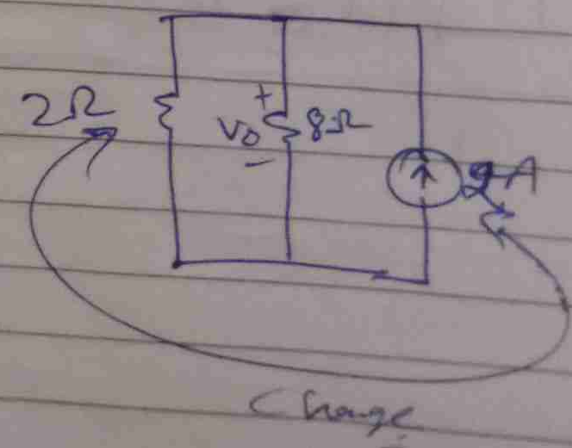
$4A - 2A = 2A$

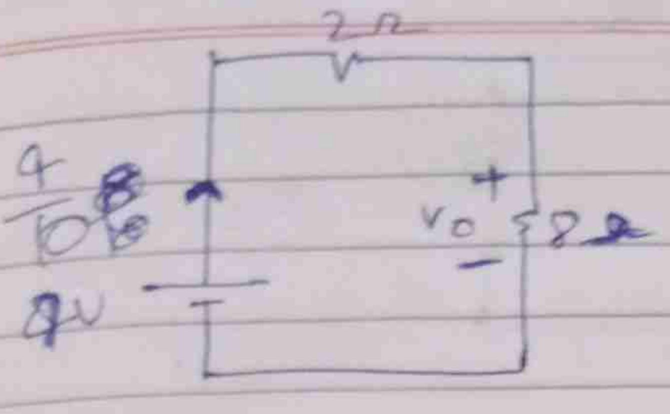



2Ω
5Ω
8Ω
+ Vo −
4Ω
3A
12V


6Ω
4Ω
2Ω
8Ω
Vo
3Ω
4A
12V


2A
6Ω
8Ω
+ Vo −
3Ω
4A

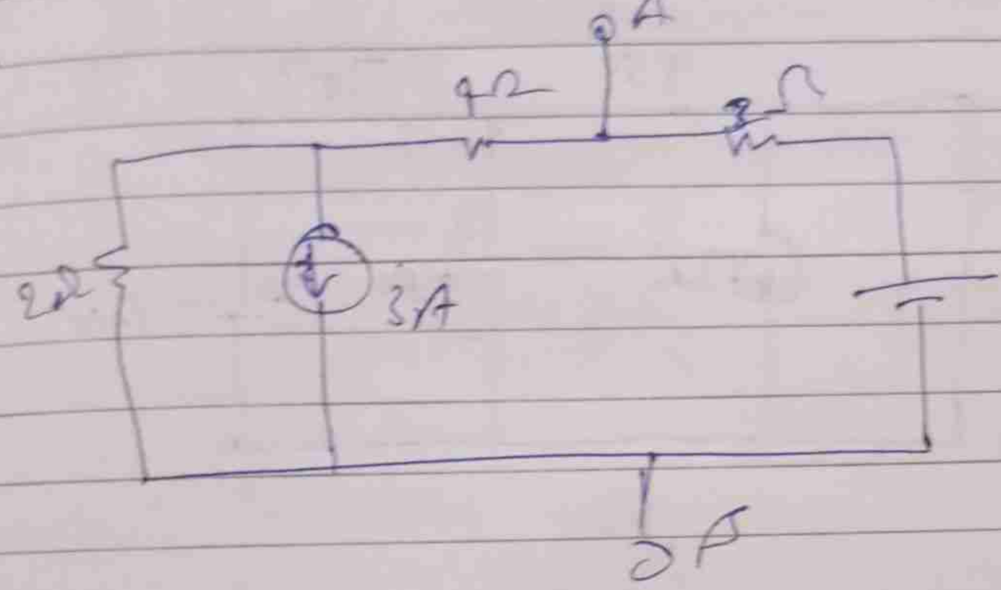

2Ω
+ Vo −
8Ω
4A
Change

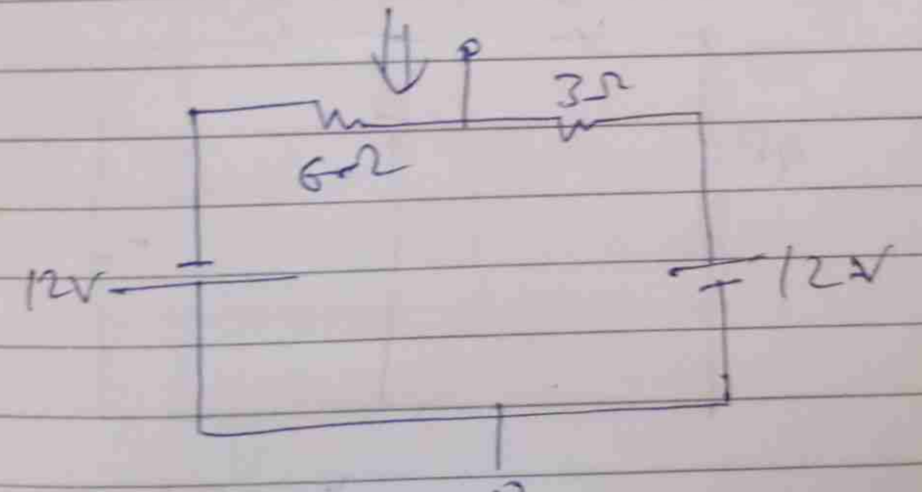


$V_0 = 3.2\,V$

$\cancel{V_0 = \frac{8\times 8}{10}} = \frac{4\times 8}{10}$

The.





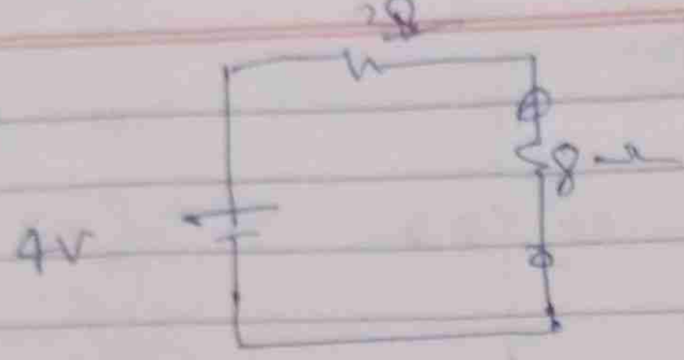
$12 + 6I + 3I + 12 = 0$

$9I = -24$

$I = \frac{-24}{9} = -\frac{8}{3}$

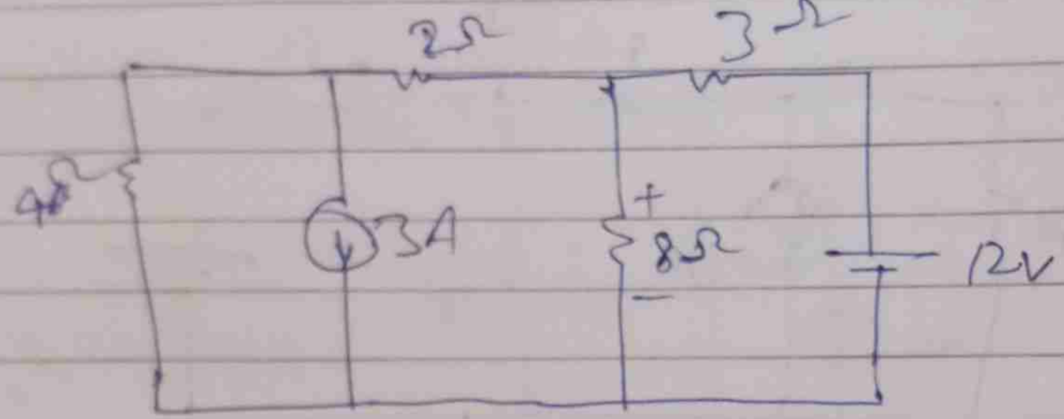
$-\frac{8}{3}\times 3 + 12 = V_{AB} = 0 \qquad V_{AB} = 4V$

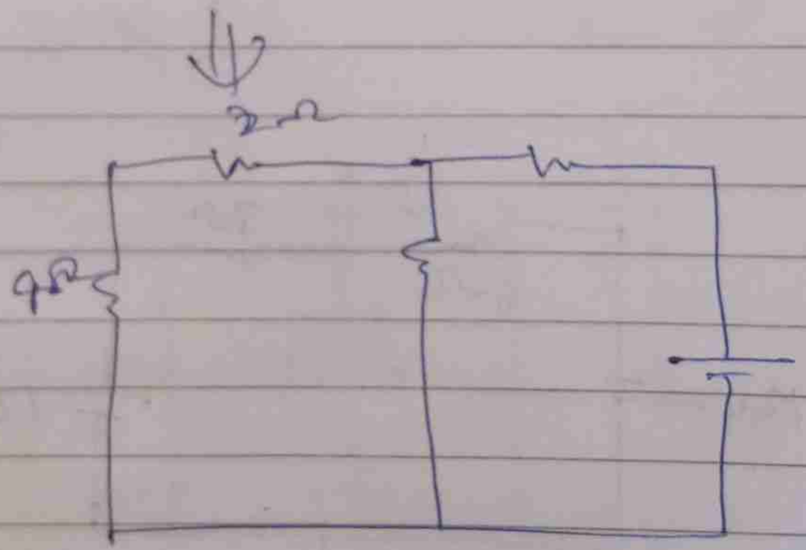
~~$V_A - V_B = 4V$~~

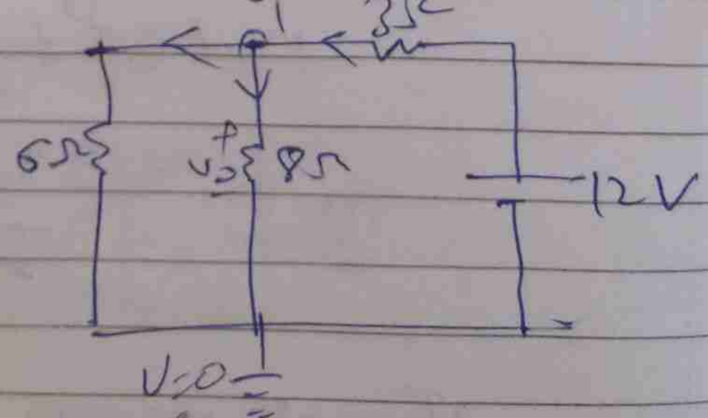


$V_0 = 3.2$

Super







$$\frac{V_1}{6} + \frac{V_1}{8} = \frac{12 - V_1}{3}$$

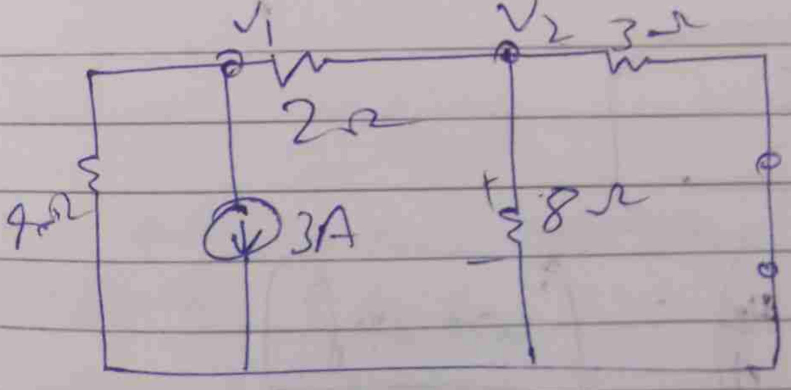
$$\frac{\cancel{7}\ 14}{\cancel{24}\ 48} V_1 = \frac{12 - V_1}{3}$$

$$\frac{7V_1}{24} + \frac{8V_1}{3 \times 8} = 4$$

$$\frac{15 V_1}{24} = 4$$

$$V_1 = \frac{48}{15} = \quad V_1 = 6.4$$

$$I_1 = 0.8\,\Omega$$



$$\frac{V_1}{\quad}$$

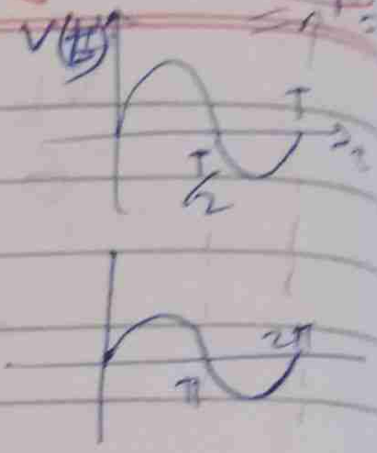
A.C. Circuit

Time period

$\Downarrow$ Sinusoid $\Rightarrow$

$\Downarrow$

(Periodic f^n)



Fourier series

Sinusoid:- $\begin{cases} V(t) = V_m \cos\omega t \\ V(t) = \boxed{V_m}\sin(\underbrace{\omega t}) \end{cases}$

ω → Angular freque... (radia...)

ωt → Argument (radian)

V_m → Amplitude of sinusoid or Peak value of sinusoid or Max. value of sinusoid

→ $\boxed{T = \frac{2\pi}{\omega}}$

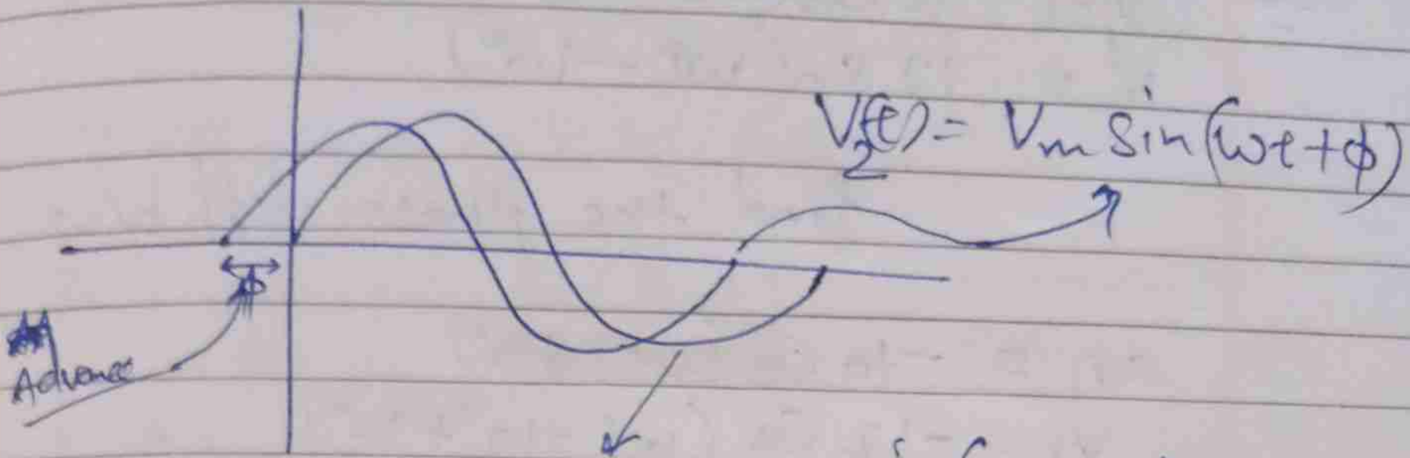
$\boxed{f = \frac{1}{T} \text{ Hz}}$ $\boxed{\omega = 2\pi f}$

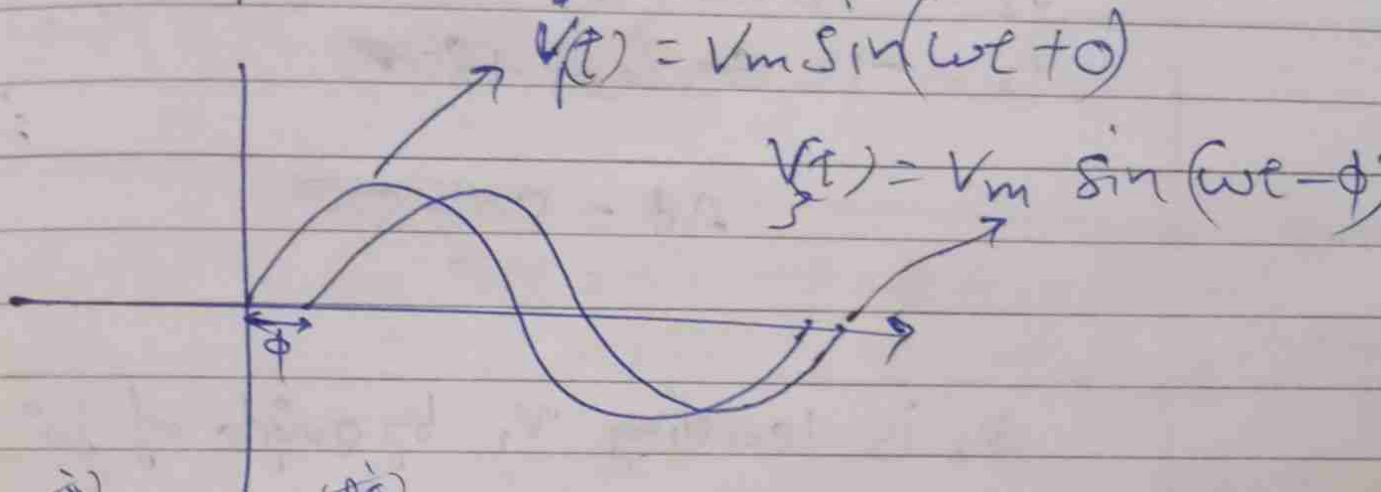
Hz → Hertz

→ $V(t) = V_m \sin(\omega t + \phi)$ → ϕ: Phase diff.

→ Periodic f^n:- $f(t) = f(t + nT)$

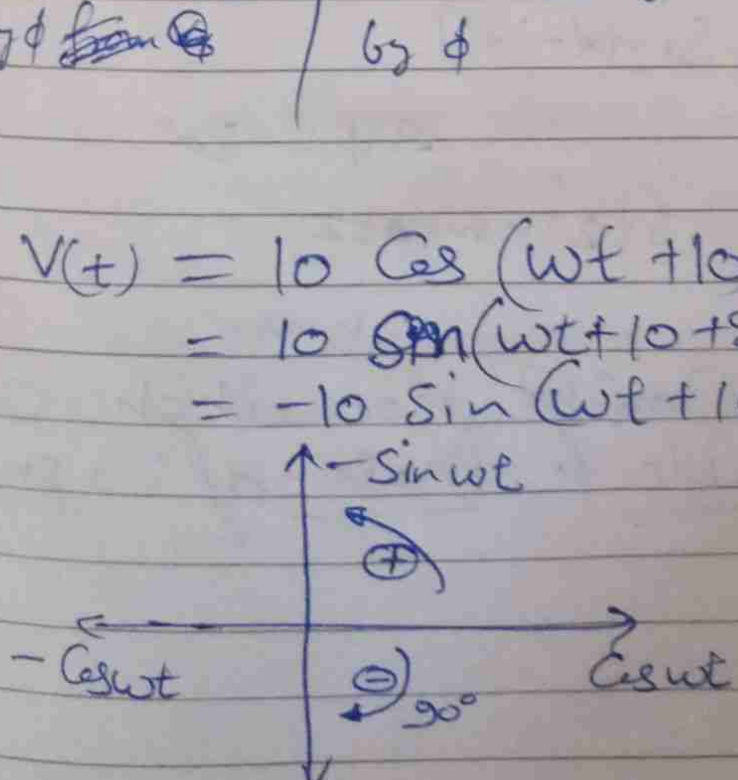
Phase:-





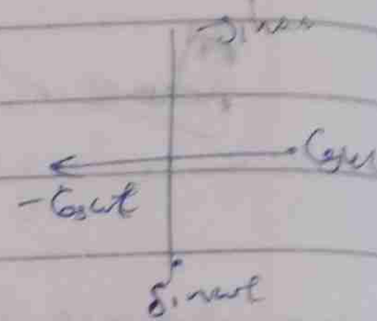
(आगे) leading	(पीछे) lagging
V_2 is leading V_1 by ϕ	V_1 is lagging V_2 by ϕ

$$\Rightarrow V(t) = 10\cos(\omega t + 10^\circ)$$
$$= 10\sin(\omega t + 10 + 90^\circ)$$
$$= -10\sin(\omega t + 10 - 90^\circ)$$
$$= -10\cos(\omega t + 10^\circ + 180^\circ)$$
$$= -10\cos(\omega t + 10 - 180^\circ)$$



Q $v_1 = -10\cos(\omega t + 50^\circ)$
$v_2 = 12\sin(\omega t - 10^\circ)$

find the phase diff. b/w v_1 & v_2



$v_1 = -10\cos(\omega t + 50^\circ)$
$v_2 = -12\cos(\omega t - 10^\circ + 90^\circ)$
$v_2 = -12\cos(\omega t + 80^\circ)$

$$\Delta\phi = 80^\circ - 50^\circ$$
$$= 30^\circ$$

v_2 is leading v_1 by angle of 30°

or

$v_1 = 10\sin(\omega t + 50 - 90)^\circ = 10\sin(\omega t - 40^\circ)$
$v_2 = 12\sin(\omega t - 10^\circ)$

$$\Delta\phi = 30^\circ$$

Phasor :- ← Steinmetz

It is a complex ~~no.~~ number which contains the amplitude & phase of a sinusiod

$Z = x + jy \quad j = \sqrt{-1}$

Cartision

Polarform $Z = r\angle\phi = \sqrt{x^2+y^2} \angle \tan^{-1}(y/x)$

$Z = re^{j\phi}$
$= r(\cos\phi + j\sin\phi)$

$\rightarrow Z = Z_1 + Z_2 = (x_1 + x_2) + j(y_1 + y_2)$

$\rightarrow Z = Z_1 Z_2 = r_1 r_2 (\angle\phi_1 + \phi_2)$

$\rightarrow Z = \frac{Z_1}{Z_2} = \frac{r_1}{r_2}(\angle\phi_1 - \phi_2)$

$\Rightarrow Z = (Z_1)^{1/2} = (r_1)^{1/2} (\angle\phi/2)$

$\Rightarrow v(t) = V_m \cos(\omega t + \phi) \rightarrow v(t) = Re[V_m e^{j(\omega t + \phi)}]$

$v(t) = V_m \sin(\omega t + \phi) \longrightarrow v(t) = Im[V_m e^{j(\omega t + \phi)}]$

$\Downarrow$

$\rightarrow$ Time domain representation

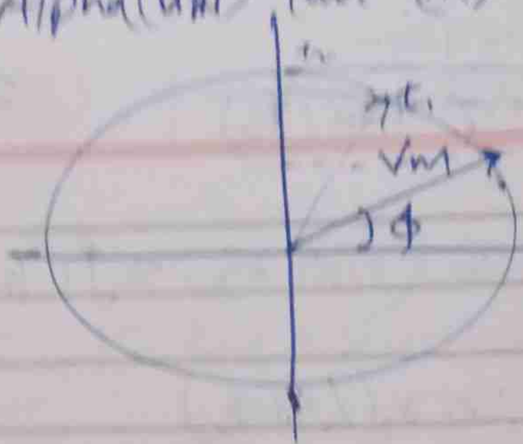
$Re[\bar{V} e^{j\omega t}]$

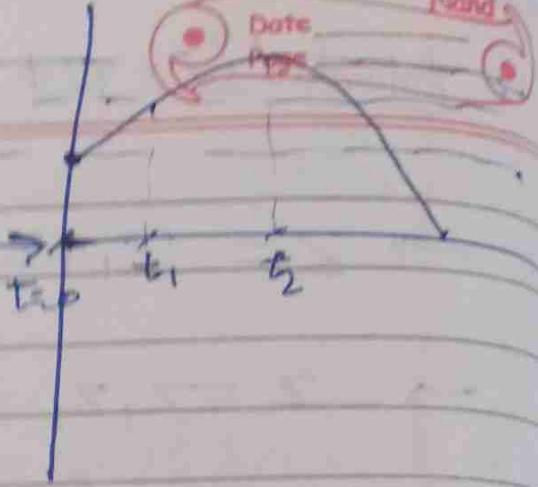
$\bar{V} \rightarrow$ Phasor, $e^{j\omega t} \rightarrow$ Sinor

Phase domain representatia $\longrightarrow \bar{V} = V_m e^{j\phi} = V_m \angle\phi$

$\rightarrow$ for adding and substrating any two voltage equate they have same angular frequency.

#(B) Step (i) ON (ii) Shift (iii) Rec (iv) Rec(25.724, 45.51) (v) enter (vi)
(vii) Alpha (viii) tan (ix) 22.742





Evaluate

(c) $\left(40\angle 50^\circ + 20\angle -30\right)^{1/2}$

$\left(25.711 + \hat{j}\,30.64 + 17.32 - \hat{j}10\right)^{1/2}$

$\left(43.031 + \hat{j}\,20.64\right)^{1/2}$

$\left(47.72\angle 25.62\right)^{1/2}$

$= 6.90\angle 12.81$

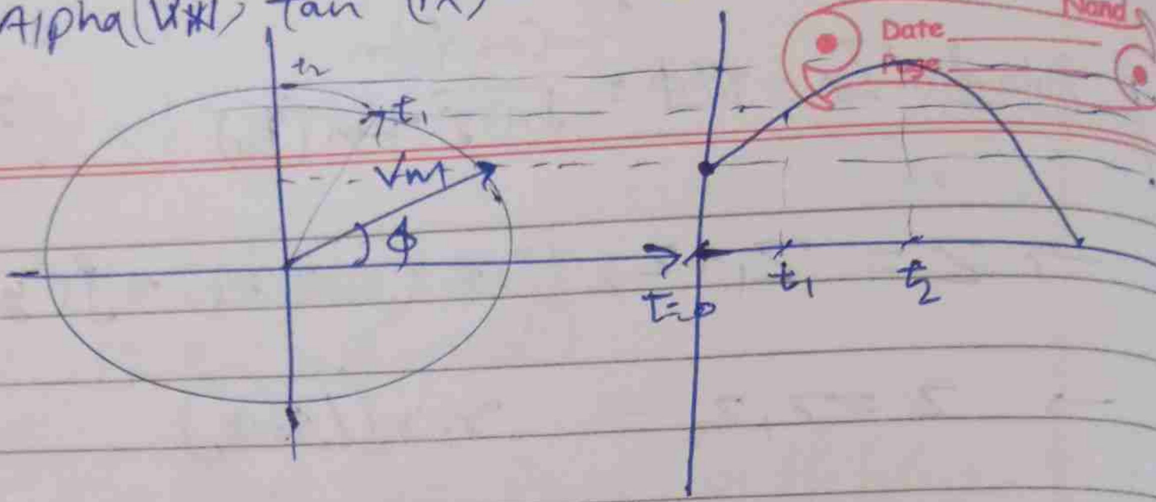
Transform these sinusoids into phasors

$i = 6\cos(50t - 40^\circ)A = 6\angle -40^\circ A$

$v = -4\sin(30t + 50^\circ)V$

$= 4\cos(30t + 140^\circ) = 4\angle 140^\circ\ V$

#② Type Step (i) ON (ii) Shift (iii) Rec ... (vii) Alpha (viii) tan (ix) 22.742



Evaluate

(a) $$\left(40\angle 50^\circ + 20\angle -30\right)^{1/2}$$

$$\left(25.711 + j\,30.64 + 17.32 - j10\right)^{1/2}$$

$$\left(43.031 + j\,20.64\right)^{1/2}$$

$$\left(47.72\angle 25.62\right)^{1/2}$$

$$= 6.90\angle 12.81$$

Transform these sinusoids into phasors

$$i = 6\cos(50t - 40^\circ)A = 6\angle -40^\circ A$$

$$v = -4\sin(30t + 50^\circ)V$$

$$= 4\cos(30t + 140^\circ) = 4\angle 140^\circ\ V$$

sin, -cos, cos, sin

① Type

Step! - (i) ON (ii) shift (iii) Pol (iv) Pol(19.14, 22.742) (v) enter (vi) Value 29.724 for angle (vii) Alpha (viii) tan (ix) enter 49.91

(190)

$\Rightarrow$ If $V_1 = -10\sin(\omega t - 30^\circ)\,V = 10\angle 60^\circ$

$V_2 = 20\cos(\omega t + 45^\circ)\,V = 20\angle 45^\circ$

find ~~V_1~~ ~~V_2~~ $V_1 + V_2$

$V_1 = 5 + j8.6$

$V_2 = 14.14 + j14.142$

$V_1 + V_2 = 19.14 + j22.742$ — Pol ① Type ; Rec ② Type

$= 29.724\angle 49.91$

$= 29.72\cos(\omega t + 49.91)$

$V(t) = V_m\cos(\omega t + \phi)$

$\frac{dv}{dt} = -\omega V_m \sin(\omega t + \phi)$

$= \omega V_m \cos(\omega t + \phi + 90)$

$= Re[\omega V_m e^{j\phi} e^{j90} \cdot e^{j\omega t}$

$= Re[j\omega V_m e^{j\phi} \cdot e^{j\omega t}]$

Phase of $\frac{dv}{dt} = j\omega \bar{V}$

Date
Page

$\Rightarrow \int v\,dt$

$\int V_m \cos(\omega t + \phi)$

$\frac{V_m}{\omega} \sin(\omega t + \phi)$ ~~+c~~

$\frac{V_m}{\omega} \cos(\omega t + \phi - 90^\circ) = Re\left[\frac{V_m}{\omega} e^{j\phi} e^{-j90}\right.$

e^{-j90}

$\cos(-90)$

$+ j \sin(-90)$

$\frac{-j V_m}{\omega} \angle\phi$

$= \frac{\bar{V}}{j\omega}$

Q Solve using phasor algebra find $i(t)$ if

$4i + 8\int i\,dt - 3\frac{di}{dt} = 50 \cos(2t + 75^\circ)$

Integral phaser differential eq.

$4\bar{I} + \frac{8\bar{I}}{j \times 2} - 3 \times 2 j \bar{I} = 50 \angle 75^\circ$

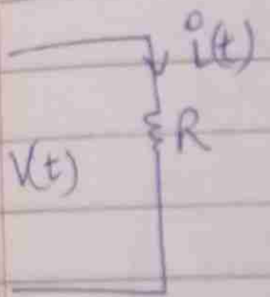
$\bar{I}(4 - 10\hat{j}) = 50\angle 75^\circ$

$$\bar{I} = \frac{50\angle 75^\circ}{(4 - \hat{j}10)} = \frac{50\angle 75^\circ}{10.7703\angle 68.198}$$

$$= \cancel{46.4239\angle 6.802}$$

$$= 4.64\angle 143.1$$

Phasor relationship for elements:-



$i(t) = I_m \cos(\omega t + \phi) \Rightarrow \bar{I} = I_m \angle \phi$

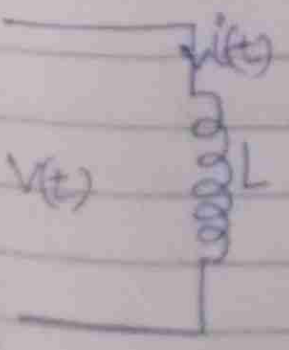
$$\boxed{v = iR}$$

$v(t) = R I_m \cos(\omega t + \phi)$ -

$\bar{V} = R I_m \angle \phi$

$$\boxed{\bar{V} = R\bar{I}}$$

Inductor :-



$i(t) = I_m \cos(\omega t + \phi)$

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

$v(t) = -L\omega I_m \sin(\omega t + \phi)$

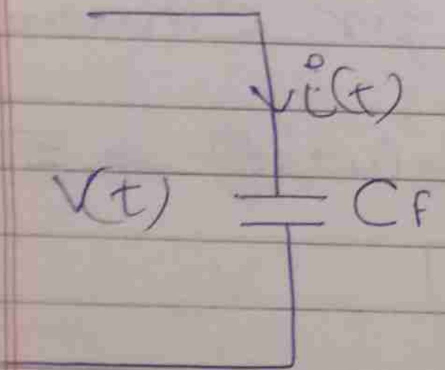
$= \omega L \cos(\omega t + \phi + 90)$

$$v(t) = Re\left[\omega L I_m e^{j\phi} e^{j90^\circ} e^{j\omega t}\right]$$

$$\boxed{\bar{V} = j\omega L I_m \angle\phi}$$

$$\boxed{\bar{V} = j\omega L \bar{I}}$$

Capacitor:-



$$v(t) = V_m \cos(\omega t + \phi)$$

$$i(t) = C\frac{dv}{dt}$$

$$\boxed{\bar{I} = j\omega C \bar{V}}$$

Impedance:-

$$Z = \frac{\bar{V}}{\bar{I}}$$

$\downarrow$

This is the property of oppose the sinusoids

→ $Z = R$ (for pure Resistive element circuit)

→ $Z = j\omega L$ (for pure inductive circuit)

→ $Z = \frac{1}{j\omega C} = \frac{-j}{\omega C}$ (for pure Capacitive element circuit)

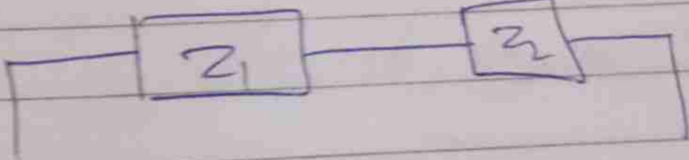
$$\boxed{Z = R + jX}$$

$R = Re(Z)$

$X = Im(Z)$

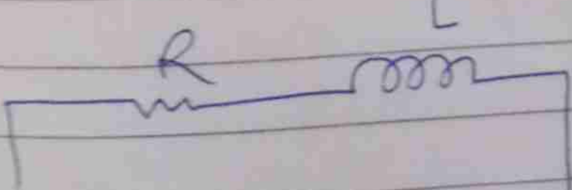
Reactance

⇒



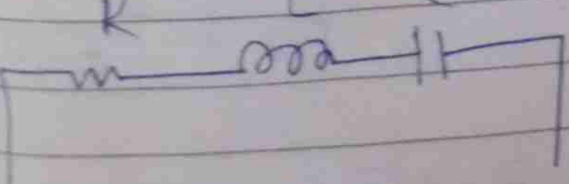
$$Z = Z_1 + Z_2$$

⇒



$Z = R + j\omega L$

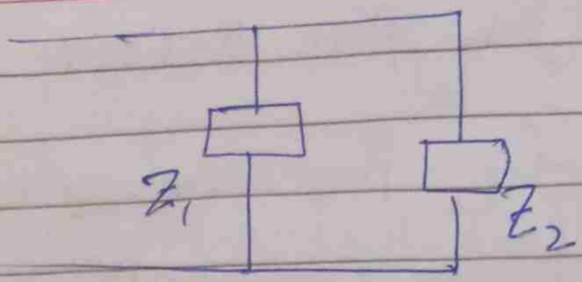
⇒



$Z = R + j\omega L - \frac{j}{\omega C}$

$Z = R + j\left(\omega L + \frac{1}{\omega C}\right)$

$\Rightarrow$



$$Z = \frac{Z_1 \times Z_2}{Z_1 + Z_2}$$

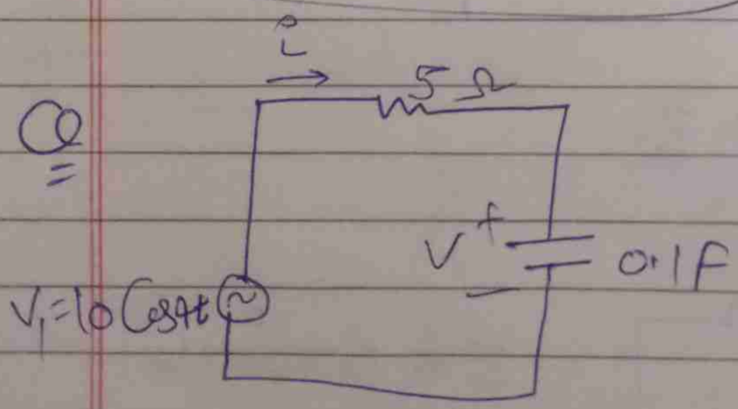
$$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \cdots + \frac{1}{Z_N}$$

$$Y = Y_1 + Y_2 + \cdots + Y_N$$

$$Y = \frac{1}{Z}$$

$\downarrow$ Admittance

Q



find i, v

Sol

$Z_1 = 5\Omega$ $\qquad Z_2 = -\frac{j}{0.1 \times 4} = -j2.5$

$$Z = Z_1 + Z_2$$

$$= (5 - j(2.5))\ \Omega$$

$\bar{V} = 10\angle 0^\circ$

$Z\bar{I} = \bar{V}$

$\bar{I} = \frac{\bar{V}}{Z} = \frac{10\angle 0^\circ}{5 - j(2.5)}$

$= \frac{10\angle 0^\circ}{5.59\angle -26.56}$

$= 1.78\angle 26.56$

$i(t) = 1.788\cos(4t + 26.56)$

$V = \bar{I} \times Z_2$

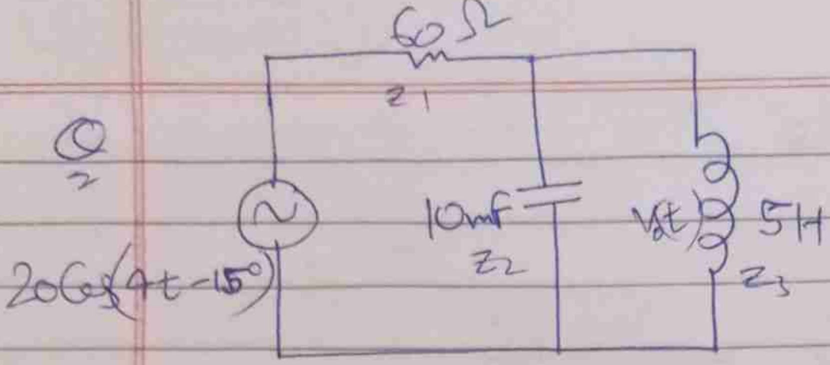
$Z_2 = 0 - j2.5$

$V = (1.788\cos 4t + 26.56) \times (0 \cdot j(2.5))$

$V = (1.788\angle 26.56) \times \left(\frac{1}{0.4\angle 90^\circ}\right)$

$V = 4.47\angle -63.44$

Q 2



$$V_0 = \frac{\bar{V}_S \times Z_{EQ}}{Z_1 + Z_{EQ}}$$

$$Z_{Eq} = \frac{Z_2 \times Z_3}{Z_2 + Z_3} = \frac{-j20 \times j25}{j20 - j25}$$

$$= \frac{25 \times 20}{-j5}$$

$Z_1 = 60\,\Omega$ $\quad Z_3 = j20$

$$Z_2 = \frac{-j}{10 \times 10^{-3} \times 4}$$

$$= -j25$$

$$Z_{EQ} = j100\,\Omega$$

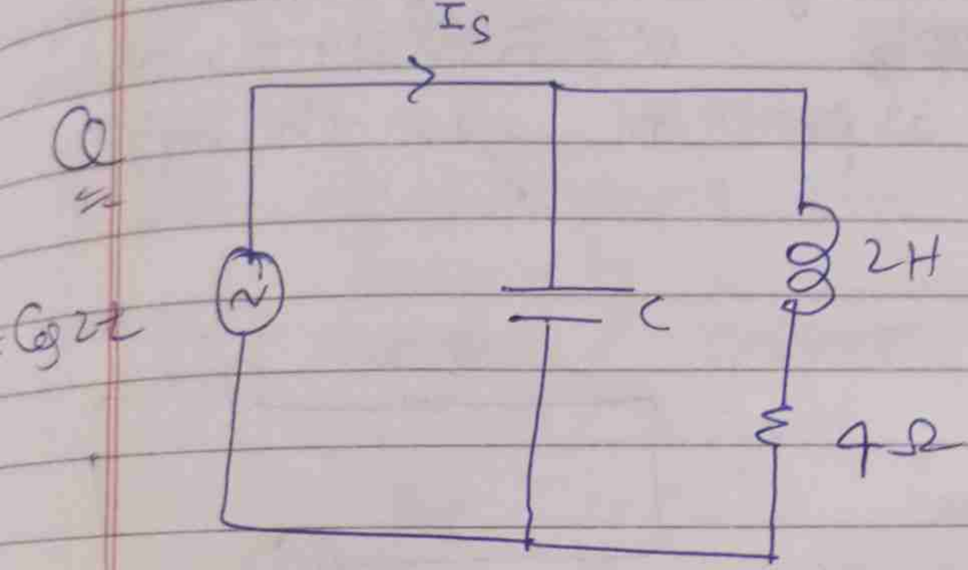
$$V_0 = \frac{20\angle{-15} \times 100\angle{90}}{60 + j100}$$

$$= \frac{2000\angle{75}}{116.61\angle{59.036}}$$

$$= 17.1518\angle{15.964}$$

$$V_o(t) = 17.15 \cos(4t + 15.96)$$

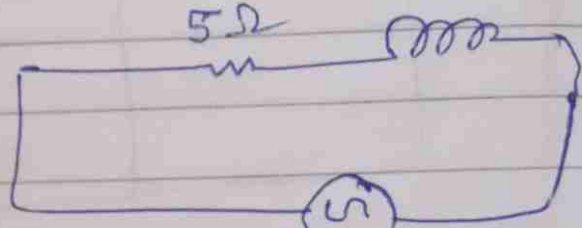
Q



$C = ?$

Q A Coil has an inductor of 20mH and a resistance of 5Ω. If it is Connected across a supply $V = 50\sin 314t$. Obtain a similar expression for the supply Current.

Soln



$V = 50\sin 314t$

$\bar{V} = 50\angle 0°$

$Z = (5 + (6.28)j)\,\Omega$

$\bar{I} = \frac{\bar{V}}{Z} = \frac{50\angle 0°}{5+(6.28)\hat{j}}$

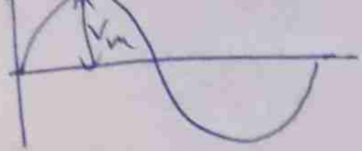
$\bar{I} = \frac{50\angle 0°}{8.027\angle 51.47}$

$\bar{I} = 6.228\angle -51.47$

$\bar{I} = 6.228\sin(314t - 51.47)\,A$

Q A parallel circuit of two branches, one Containing a Coil of resistance 5Ω and inductance 38.2mH, the other a non-inductive resistance 16Ω in Series with a Capacitor of 300μF

#



$V_{rms} = \frac{V_m}{\sqrt{2}}$

$V = V_m \angle \phi$

$\left\{ \begin{array}{l} \bar{V} = V_{rms} \angle \phi \\ \bar{I} = I_{rms} \angle \phi \end{array} \right\}$

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Capacitance. The Circuit is connected in ~~para~~ to a 240V, 50Hz Supply

determine (i) the current in each branch

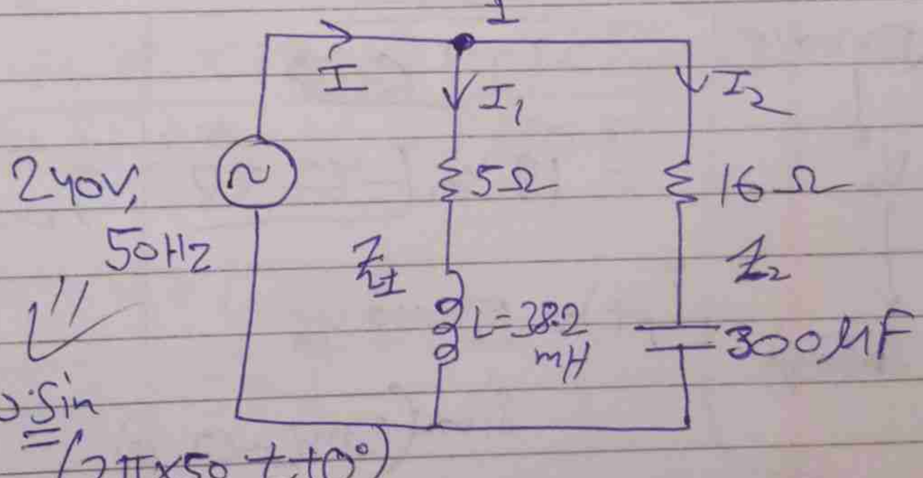
(ii) The total current

(iii) The circuit phase angle.

(iv) The circuit impidance.

(v) The components of equivelent circuit consisting of resistance and reactance

Sol^n



$V(t) = \sqrt{2} \times 240 \sin (2\pi \times 50\, t + 0°)$

any one choose

or

$V(t) = \sqrt{2} \times 240 \sin (2\pi \cancel{\times 50} 50 t + 0°)$

$Z_1 = 5 + j \times 314 \times 38.2 \times 10^{-3}$

$Z_1 = 5 + \hat{j}(11.9948)$

$Z_1 = 5 + \hat{j}(12) = 13 \angle 67.38$

$\omega = 314$

$\frac{100000}{314 \times 300}$

$$Z_2 = 16 - \frac{j}{\omega C}$$

$$= 16 - j(10.61)$$

$$= 19.19 \angle -33.54$$

I_{rms} (mtg)

=

V_{rms}

$\bar{V} = 240 \angle 0^\circ$

or

$\bar{V} = \sqrt{2} \times 240 \angle 0^\circ$

V_m

I_m (peak)

$$\bar{I}_1 = \frac{\bar{V}}{Z_1}$$

$$\bar{I}_1 = \frac{240 \angle 0^\circ}{13 \angle 67.38}$$

$$= 18.46 \angle -67.38$$

$$i_1(t) = \sqrt{2} \times 18.46 \sin(314t - 67.38)$$

$$\bar{I}_2 = \frac{\bar{V}}{Z_2}$$

$$\bar{I}_2 = \frac{240 \angle 0^\circ}{19.19 \angle -33.54}$$

$$\bar{I}_2 = 12.50 \angle 33.54$$

Ans (i)

$$\boxed{\bar{I} = \bar{I}_1 + \bar{I}_2}$$

Apply KCL at point 1

$$\bar{I} = 18.46 \angle -67.38 + 12.50 \angle 33.54$$

$$= 7.1 - j(17.03) + 10.41 + j(6.9)$$

$Z = R + jX \rightarrow$ Inductive

$Z = R - jX \rightarrow$ Capacitive

$\bar{I} = 17.51 - 10.13(\hat{j})$

$\bar{I} = 20.22 \angle -30.05$

Ans (ii) $\bar{I} = \sqrt{2} \times 20.22 \sin(314t - 30.05)$

Ans (iii) $= 30.05^{\circ}$

$$Z = \frac{Z_1 \times Z_2}{Z_1 + Z_2} = \frac{\bar{V}}{\bar{I}}$$

$$\Downarrow$$

$$Z = \frac{13 \angle 67.38 \times 19.19 \angle -33.54}{5 + \hat{j}(12) + 16 - \hat{j}(10.61)}$$

$$Z = \frac{249.47 \angle 33.84}{21 + 1.39\hat{j}}$$

$$Z = \frac{249.47 \angle 33.84}{21.04 \angle 3.78}$$

Ans (iv) $Z = 11.85 \angle 30.06$

$$Z = \frac{~~10.25 \angle 5.93~~}{10.25 + (5.93)\hat{j}}$$

Ans $= 11.85 = Z$ (Angle ko no likhe)

$$Z = \frac{V}{I}$$

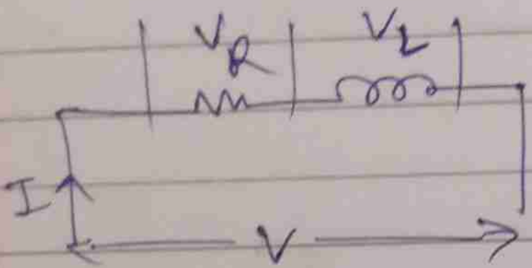
$$= \frac{240 \angle 0^{\circ}}{20.22 \angle -30.05}$$

$$= 11.86 \angle 30.05$$

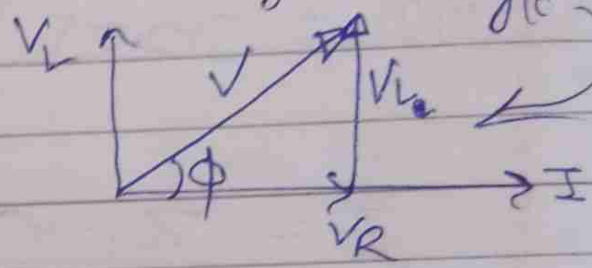
(iv)

Phasor Diagram (Voltage & Impedance triangle)

Ex



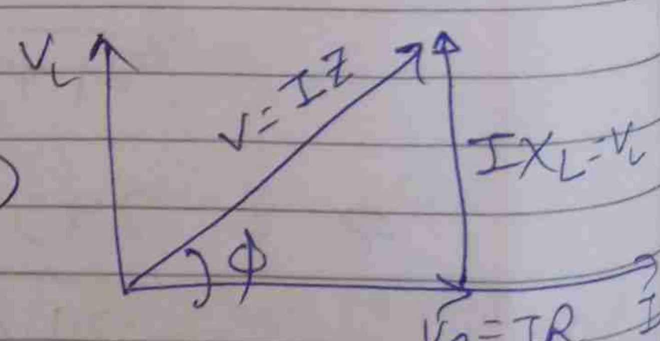
Voltage triangle



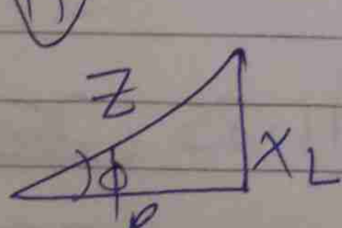
$\boxed{V = V_R + \hat{j} V_L}$ $\quad V = \sqrt{V_L^2 + V_R^2}$

$\tan\phi = \frac{V_L}{V_R}$ $\quad \cos\phi = \frac{V_R}{V}$

Impedance triangle ⇒

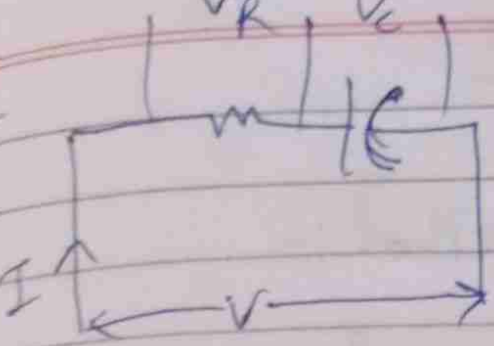


⇓

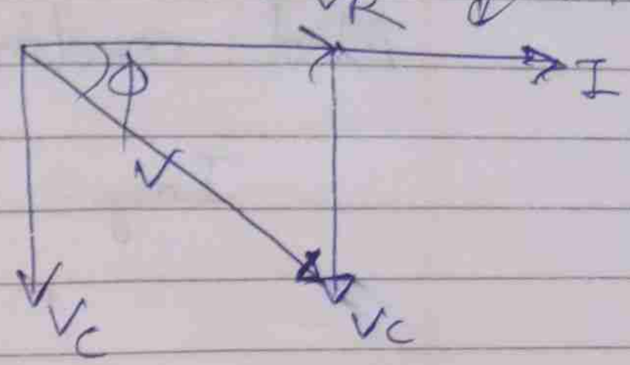


(Power factor) ⇔ $\cos\phi = \frac{R}{Z}$

Ex:-



voltage triangle

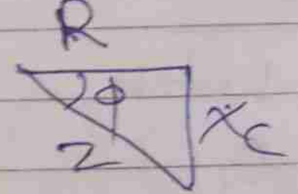


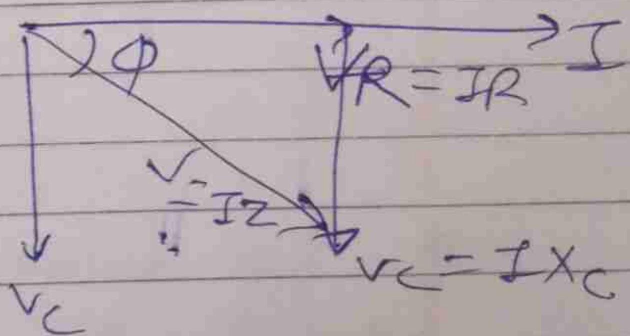
$$V = V_R - jV_C$$

$$V = \sqrt{V_R^2 + V_C^2}$$

$$\cos\phi = \frac{V_R}{V}$$

Impedance triangle





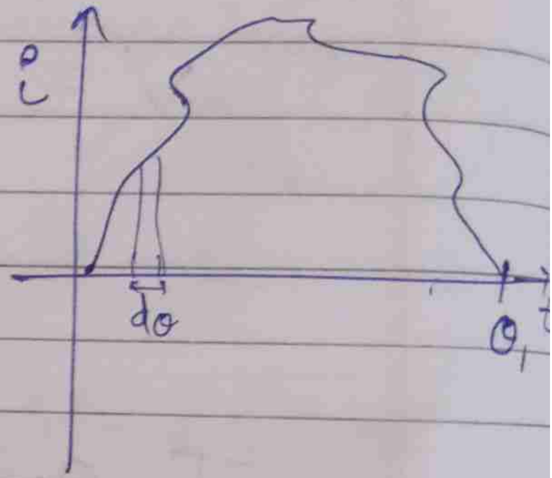
$$\cos\phi = \frac{R}{Z}$$

Average Value:-

Mid ordinate method:-

$$I_{avg} = \frac{i_1 + i_2 + \cdots i_n}{n}$$

Integration Method:-



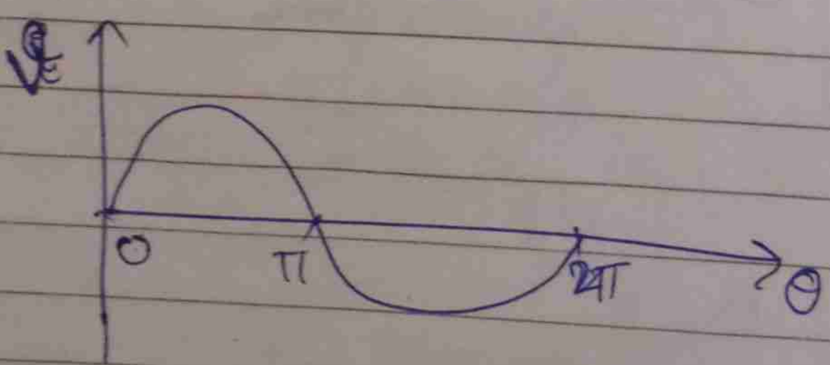
$$dA = i\,d\theta$$

$$A = \int_0^{\theta_1} i\,d\theta$$

$$\text{Avg. Value} = \frac{\text{Area}}{\text{Base width}}$$

$$= \frac{1}{\theta_1} \int_0^{\theta_1} i\,d\theta$$

⇒



$\int \sin\theta = \cos\theta + 1$

$\int \cos\theta = -\sin\theta$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta\, d\theta = \frac{1}{2\pi} V_m [\cos\theta]_0^{2\pi}$$

Avg. of Half Cycle

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\theta\, d\theta$$

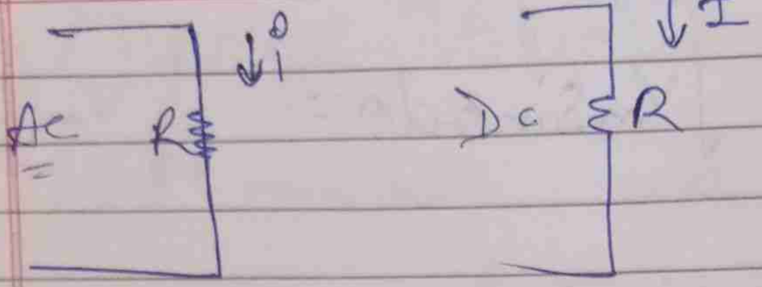
$$= \frac{1}{\pi} V_m [-\cos\theta]_0^{\pi}$$

$$= \frac{2}{\pi} V_m$$

RMS Value

RMS or Effective value of an alternating current is equal to that dc current which when flowing through a given resistive network delivers same amount of power to the circuit as is delivered by alternating current flowing through the same circuit

$\cos 2\theta = 1 - 2\sin^2\theta$



$$I_{eff}^2 R = \frac{1}{T}\int_0^T i^2 R\, dt$$

$$I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2\, dt}$$

$$\text{Form Factor}(K_f) = \frac{\text{RMS Value}}{\text{Average value}}$$

$$\text{Peak Factor}(K_p) = \frac{\text{Peak Value}}{\text{RMS value}}$$

Ex 1.

$$V_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (V_m \sin\theta)^2\, d\theta}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi \times 2}\int_0^{2\pi} (1 - \cos 2\theta)\, d\theta}$$

$(1,0) \quad (2,-4V) \quad y + \cancel{4}$

$y = \frac{-4}{\cancel{-1}}(x-1) \quad \cancel{4x+4}$

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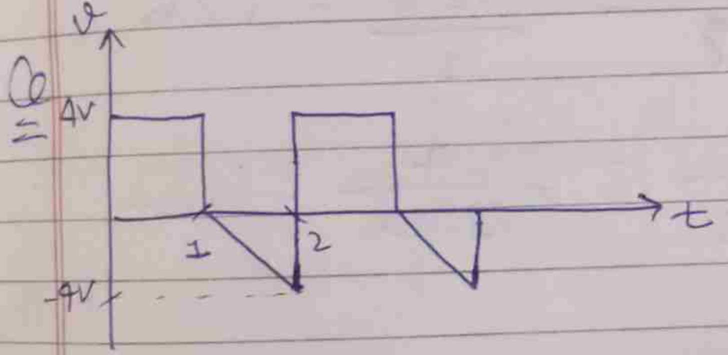
$$V_{rms} = \sqrt{\frac{V_m^2}{4\pi}\left[\theta + \frac{\sin 2\theta}{2}\right]_0^{2\pi}}$$

$$V_{rms} = \sqrt{\frac{V_m^2}{\underset{2}{\cancel{4\pi}}}\left(\cancel{2\pi}\right)}$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

Q



find avg, RMS, FF, PF.

Sol^n

avg:

$v = 4 \qquad 0<t<1$

$v = -4t+4 \qquad 1<t<2$

$$avg = \frac{1}{2}\left\{\int_0^1 4\,dt + \int_1^2 (-4t+4)\,dt\right\}$$

$$= \frac{1}{2}\left\{\left[4t\right]_0^1 + \left[\frac{-4t^2}{2} + 4t\right]_1^2\right\}$$

$$= \frac{1}{2}\left[4-2\right] = 1$$

$\int_0^{\pi} \sin\theta \, d\theta \quad [-\cos\theta]_0^{\pi}$

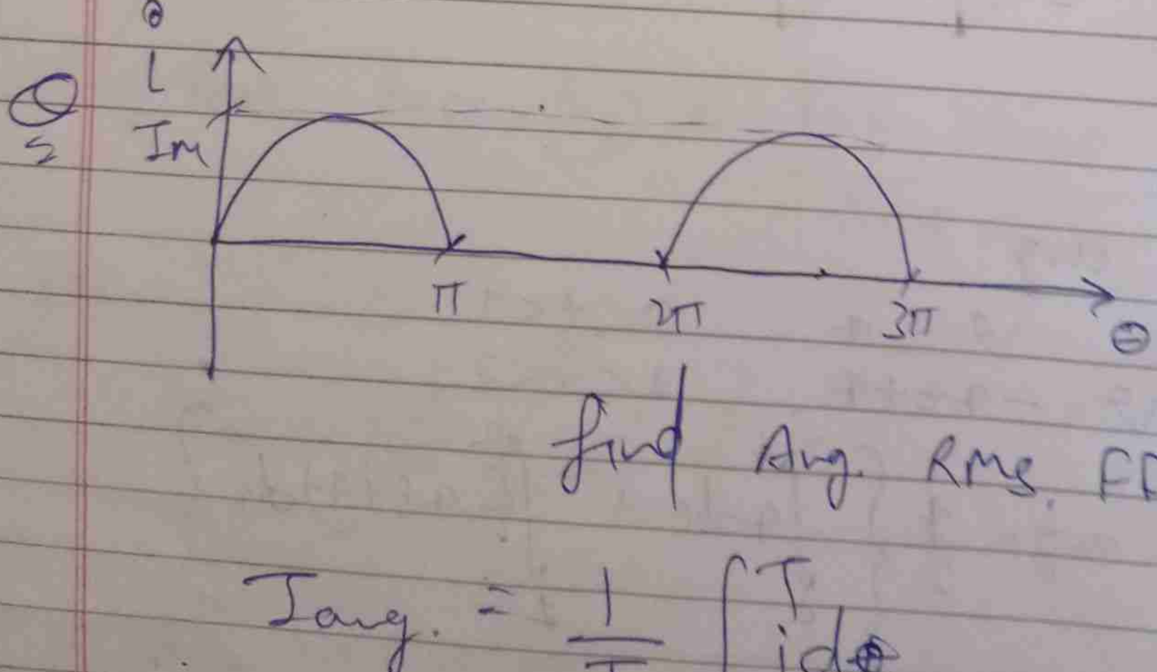
$$V_{rms} = \sqrt{\frac{1}{2}\left\{\int_0^1 16\,dt + \int_1^2 (-4t+4)^2\,dt\right\}}$$

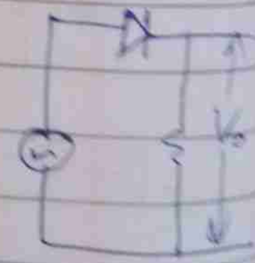
$$= \sqrt{\frac{1}{2}\left\{16 + 42.6 + 32 - 64 - 5.3 - \cancel{16} + \cancel{16}\right.}$$

$$= 3.26$$

$$K_F = F.F = \frac{Rms}{Avg.} = \frac{3.26}{1} = 3.26$$

$$K_P = P.F = \frac{Peak}{Rms} = \frac{4}{3.26} = 1.22$$





find Avg. Rms. FF, PF

$$I_{avg.} = \frac{1}{T}\int_0^T i\,d\theta$$

$16t^2+16-32t$ $\left(\frac{16t^3}{3}+16t-16t^2\right]^2$

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$$= \frac{1}{2\pi}\left\{\int_0^{\pi} I_m \sin\theta \, d\theta + \int_{\pi}^{2\pi} 0 \, d\theta\right\}$$

$$= \frac{I_m}{\pi}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}\sin^2\theta \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi}(1-\cos 2\theta)\, d\theta}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\left(\theta+\frac{\sin 2\theta}{2}\right]_0^{\pi}}$$

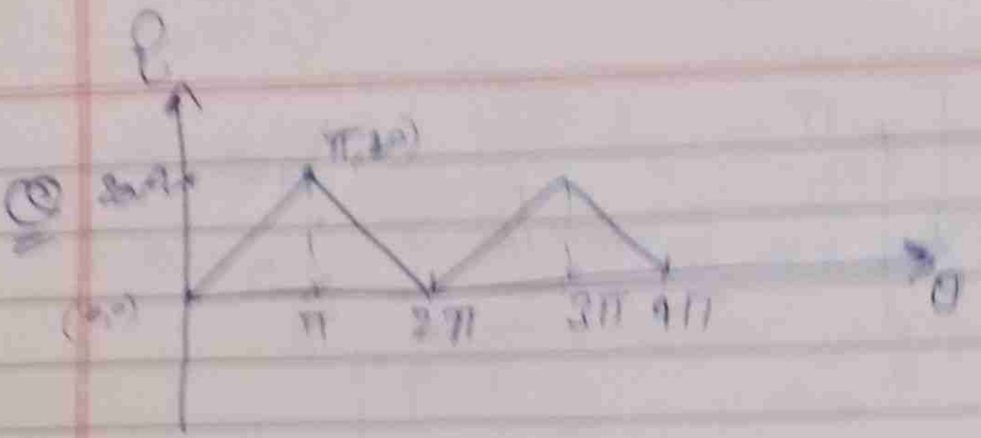
$$= \sqrt{\frac{I_m^2}{4\pi}(\pi)}$$

$$= \frac{I_m}{2}$$

$$F.F. = \frac{I_m/2}{I_m/\pi} = \pi/2$$

$$Pf = \frac{I_m}{I_m/2} = 2$$

$i \; \frac{20}{\pi} \theta$



find Avg & Rms

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} i \, d\theta$$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} \frac{20}{\pi}\theta \, d\theta$$

$$= \frac{1}{\pi} \times \frac{20}{\pi}\left[\theta^2\right]_0^{\pi}$$

$$= \frac{1}{\pi} \times \frac{20}{\cancel{\pi}}\left[\pi^2\right]$$

$$= \frac{1}{\pi} \times 20\pi = 20$$

$$I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2 \, d\theta}$$

$$= \sqrt{\frac{1}{\pi}\int_0^{\pi} \frac{400}{\pi^2}\theta^2 \, d\theta}$$

Power

$P = A + B$

Real power / active power

$V = V_m \cos(\omega t + \theta_v)$

$i = I_m \cos(\omega t + \theta_i)$

$P = Vi$

$P = V_m I_m \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$

$= \underbrace{\frac{V_m I_m}{2} \cos(\theta_v - \theta_i)}_{A} + \underbrace{\frac{V_m I_m}{2} \cos(2\omega t + \theta_v + \theta_i)}_{B}$

$P = \frac{1}{2} \text{Re}[V I^*]$

$P = \text{Re}[\bar{V}_{rms} \bar{I}^*_{rms}]$

$P = V_{rms} \cdot I_{rms} \cdot \cos(\theta_v - \theta_i)$

$P = S \cos(\theta_v - \theta_i)$

$V = V_m \angle \theta_v$

$I^* = I_m \angle -\theta_i$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

$I_{rms} = \frac{I_m}{\sqrt{2}}$

S → APPARENT POWER

$\cos(\theta_v - \theta_i)$ → POWER FECTOR

$$V = I Z$$

Phaser Voltage — Phaser Current

$$\cos(\theta_v - \theta_i) = \frac{P}{S} = \text{P.F. } \underline{\text{Angle}} = \text{PF}$$

→ $Z = |Z| \cdot \angle(\theta_v - \theta_i)$

Impidance angle = P.F. angle

→ Power fector depending on circuit load.

→ Power fector leading and lagging

→ If load is pure Resistive load then

$P.F. = 0$

$$S = \frac{1}{2} V I^*$$

Complex Power

$$S = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i) + j \frac{V_m I_m}{2} \sin(\theta_v - \theta_i)$$

Real power — Reactiv power

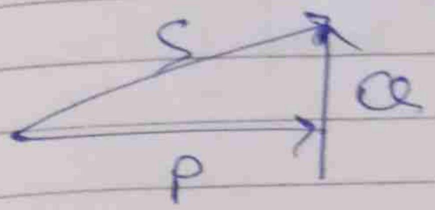
$$S = P + jQ$$

Volt Amp — watt — Volt Amp Reactive

$$S = \underbrace{\tfrac{1}{2} V I^*}_{\text{Peak}} = \underbrace{V I^*}_{\text{Rms}} = I I^* Z = I^2 Z$$

$V = IZ$

Power triangle



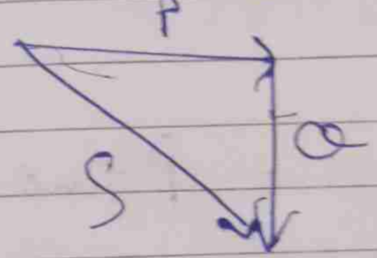
← lagging load

Inductive load

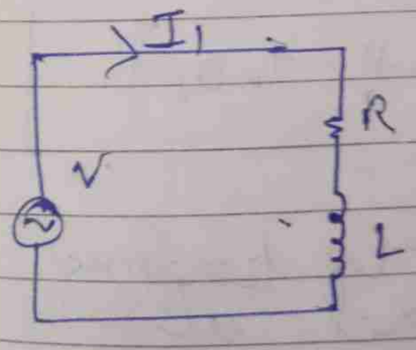
$Q > 0$ Inductive

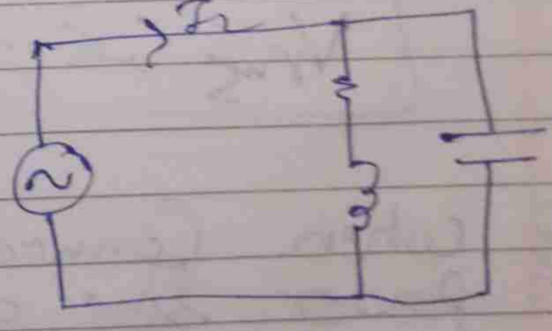
$Z_C = \frac{-j}{\omega C} \Longleftrightarrow Q < 0$ Capacitive

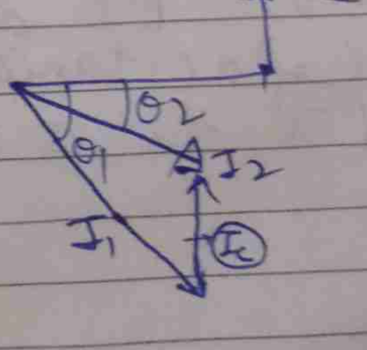
$Q = 0$ pure Resistive

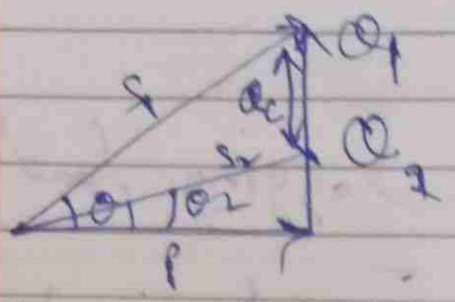


Power factor Correction









$$Q_c = Q_1 - Q_2 = P(\tan\theta_1 - \tan\theta_2)$$

$$P = S_1 \cos\theta_1$$

$$Q_1 = S_1 \sin\theta_1 = P\tan\theta_1$$

$$P = S_2 \cos\theta_2$$

$$Q_2 = S_2 \sin\theta_2 = P\tan\theta_2$$

$$\boxed{V_{rms}\,\omega C = P(\tan\theta_1 - \tan\theta_2)}$$

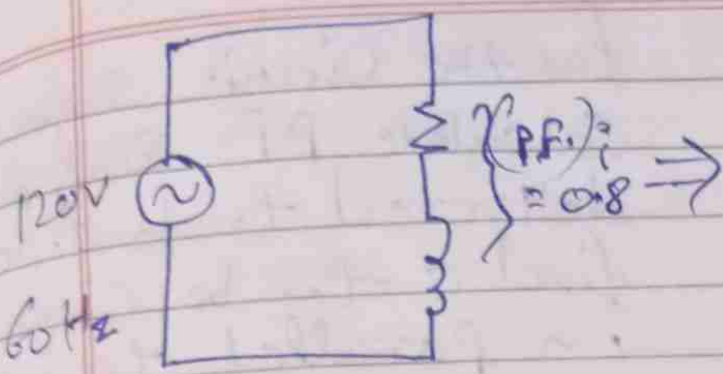
Q: when connected to 120V (rms) 60 Hz power line a load absorbs 4 kW at a lagging p.f of 0.8. find the value of capacitance necessary to raise the p.f to 0.95

120

0.95 → 0.32

t. 36.88

0.8



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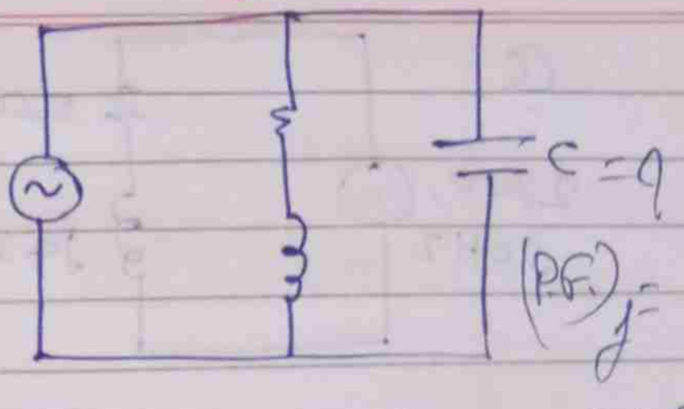


$$\boxed{V_{rms}^2 \, \omega C = P\left(\underbrace{\tan\theta_1}_{\text{पहले}} - \underbrace{\tan\theta_2}_{\text{बाद}}\right)}$$

$$(120)^2 \times 2 \times \pi \times 60 \times C = 4000\,(0.7497$$

$$\cancel{= 0.?}$$

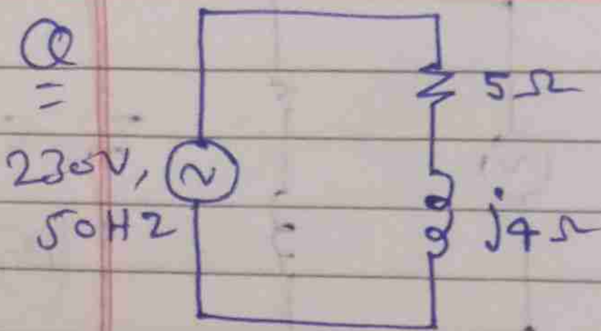
$$-0.32868\,2706)$$

$$C = \frac{1684.4}{1728000 \times 3.14}$$

$$= \frac{1684.4}{542.5920}$$

$$= 3.104\ \cancel{\times 10}$$

Q



for the Circuit shown ab
Calculate P.F., Real pow
dellivered to load. Then
find C to be Connecte
in parallel to impro
P.F. to 0.93

$$Z = 5 + j4 \xrightarrow{} \text{P.F. angle}$$

$$Z = 6.403 \angle 38.65$$

$$I = \frac{V}{Z} = \frac{230}{6.403 \angle 38.65}$$

$$I = 35.92 \angle -38.65$$

$$\cos 38.65 = 0.7809$$

$$V_{rms}^2 \omega C = P(\tan\theta_1 - \tan\theta_2)$$

$$P = VI\cos\theta$$
$$P = 230 \times 3.592 \times 0.7809$$
$$P = \cancel{2.1906}\ 6451.1 W$$

$$P_{real} = I_{rms}^2 \times R = (35.92)^2 \times 5$$
$$= 6451.232$$

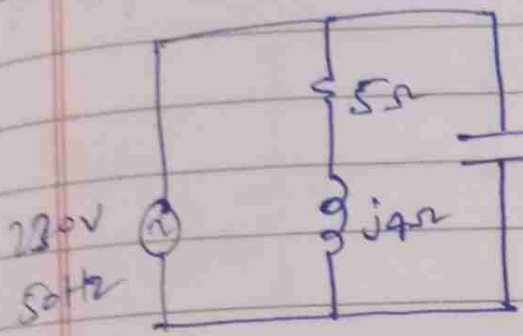
$$P_{apparent} = S_{app} = V_{rms} \times I_{rms} = 82.61.6$$

Complex power $= S = P + jQ$

$= 6451.232 + j\,5160.98$

$\Downarrow$

volt amp reactive



$$V_{rms}^2 \, \omega C = P(\tan\theta_1 - \tan\theta_2)$$

$$(230)^2 \times 2 \times \pi \times 50 \times C = 6451.1\,(0.7997 - 0.3957)$$

$$= \frac{2610.76017}{16610600}$$

$$= \cancel{(1.571)}$$

$$= 157.12\,\mu F$$

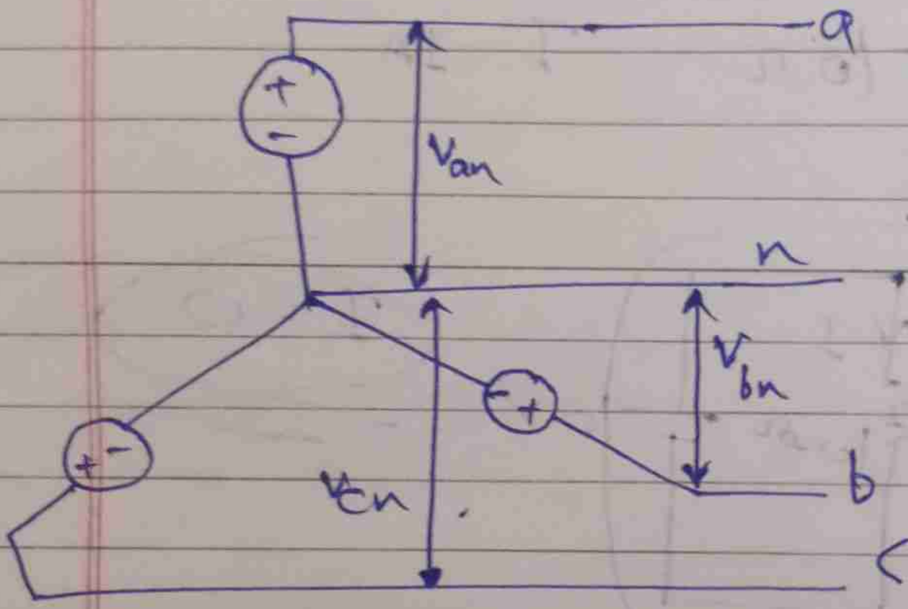
$$Z = \frac{Z_1 \times Z_2}{Z_1 + Z_2}$$

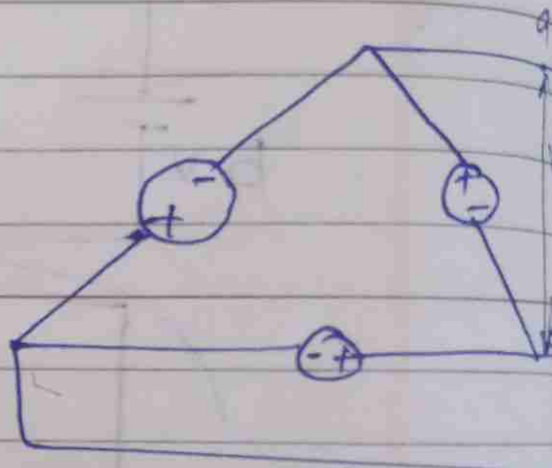
$$= \frac{(5+j4)(-j20)}{(5-j16)} = \frac{20\angle{-90} \times 6.4031\angle 38.65}{7.8102\angle{-50.19}}$$

$$16.396\angle{-1.16} = \frac{128.062\angle{-51.35}}{7.8102\angle{-50.19}}$$

Three Phase System

→ Three Sources Connected to load by three or four wires

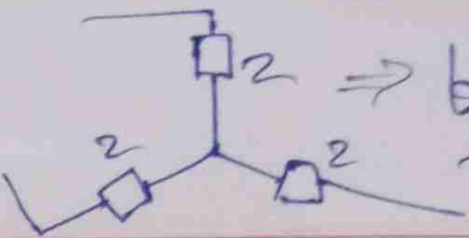




Balanced System

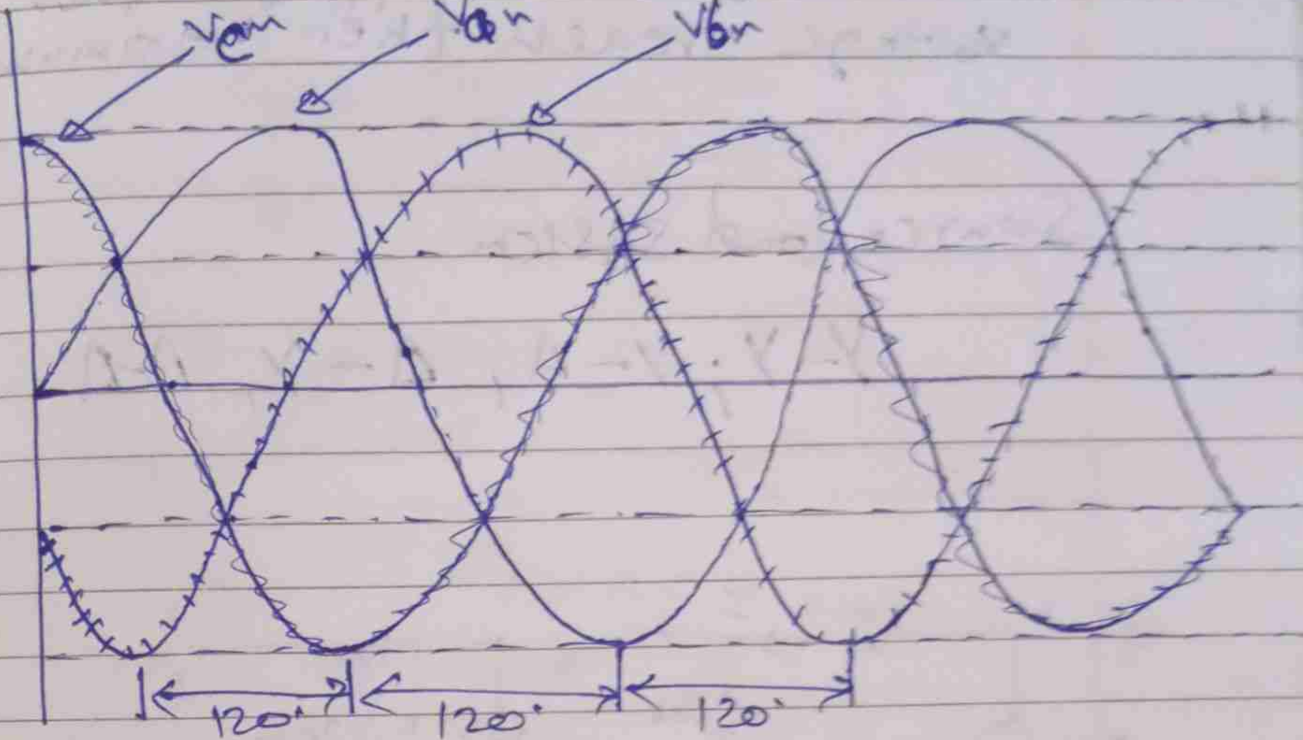
Balanced Voltage ⇓ amplitude & angular frequency are same & 120° out of Phase

Balanced load



$\Rightarrow$ balance Source

line voltage

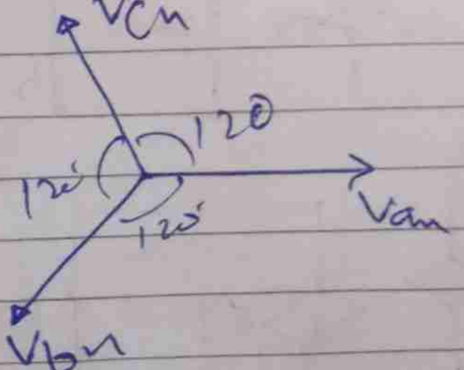


$V_{an} = V\angle 0°$

$V_{bn} = V\angle -120$

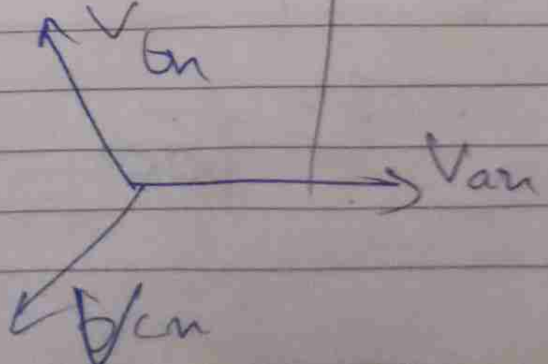
$V_{cn} = V\angle -240° = V\angle 120°$

Phase sequence
abcabc....



$V_{an} + V_{bn} + V_{cn} = 0$
for balance Source

acb $\Rightarrow$



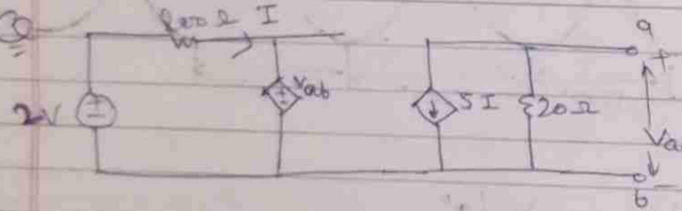
Date ______ Page ______

Phase Sequence:- Time order in which voltage reach their maximum

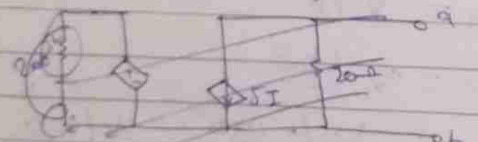
Source load system

Y-Y; Y-Δ, Δ-Y, Δ-Δ.

Q.

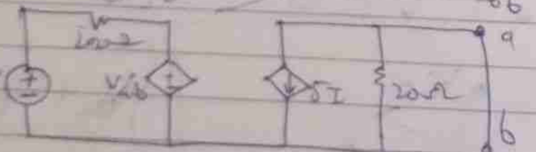


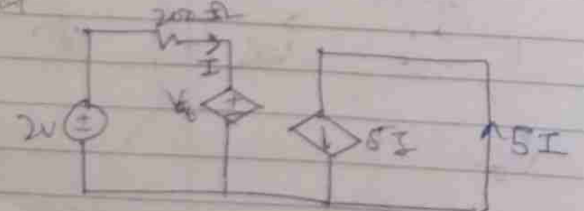
I_{sc} +ve



In Norton Short circuit

Current always choose low resistor path



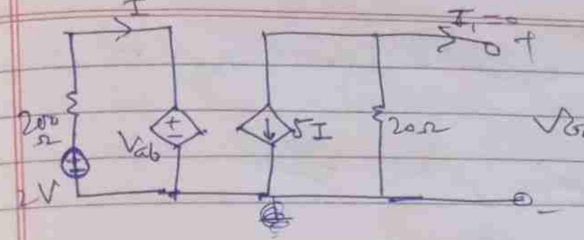


$V_{ab} = 0$

$I = \frac{1}{100}$

$I_N = 5 \times \frac{1}{100} = \frac{1}{20}$

Date ______ Page ______



$I_N = \frac{1}{20}$

$R_N = 40\Omega$

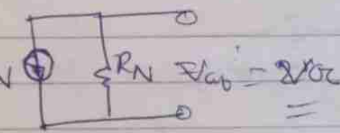
$V_{ab} = V_{oc}$

$2 - 200I - V_{oc} = 0$

$V_{oc} = 2 - 200I$

$V_{oc} + 5I(20) = 0$

$V_{oc} = -2V$



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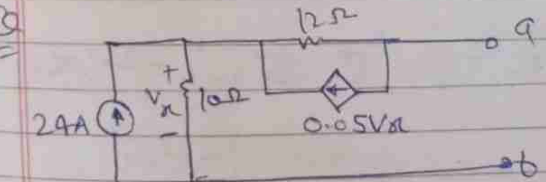
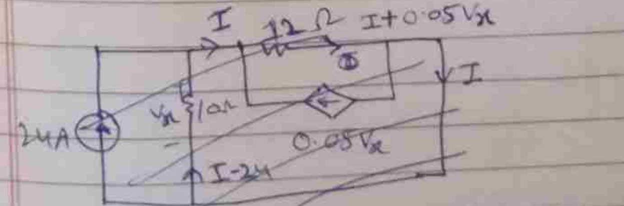
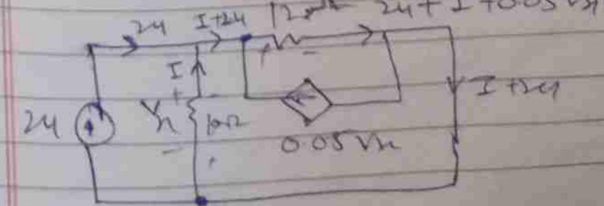


Resistance -ve
नहीं होता



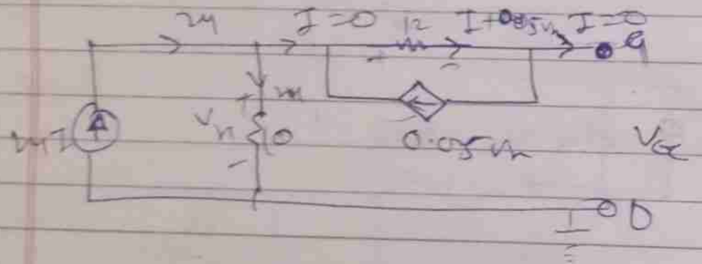


$\cancel{+10I + 12(24 + I + 0.05 V_x) = 0}$

$\cancel{V_x = -I\,10}$

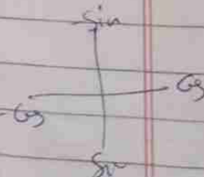
$24 + I_3 = I_1 + I_2$

$24 + 0.05 V_x = \frac{V_x}{12} + \frac{V_x}{10}$



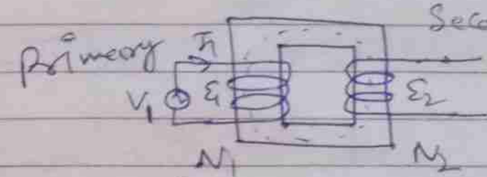
$V_{oc} + 12(0.05 V_x) - 24 \times 10 = 0$

$V_x = 10 \times 24$



Transformer

→ It is a Electrical who transfor electricity from one circuit to another circuit



$\boxed{V_1 = -E_1}$

$\phi = \frac{mmf}{R_l} = \frac{NI}{R_l}$

Relectance

if $N_1 > N_2$

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

$V_1 > V_2$

then

High voltage Binding

Low Voltage Binding

$\phi = \phi_m \sin\omega t$, $\omega \rightarrow 2\pi f$

$\frac{d\phi}{dt} = \omega\phi_m \cos\omega t = \omega\phi_m \sin(\frac{\pi}{2} - \omega t)$

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

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

$= -\omega \phi_m N_1 \sin\left(\frac{\pi}{2} - \omega t\right)$

$e_1 = \omega \phi_m N_1 \sin\left(\omega t - \frac{\pi}{2}\right)$ — (b)

$E_{max} = 2\pi f \phi_m N_1$

$\boxed{E_{rms} = \frac{E_{max}}{\sqrt{2}} = 4.44 f \phi_m N_1}$ — (2)

$\boxed{(E_2)_{rms} = 4.44 f \phi_m N_2}$ — (1)

Transformation Ratio $\boxed{K = \frac{N_2}{N_1}}$

(1) (2)

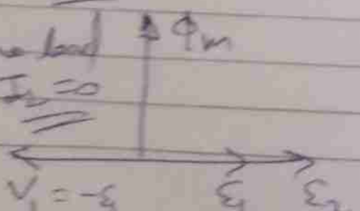
$\boxed{\frac{E_1}{N_1} = \frac{E_2}{N_2}}$

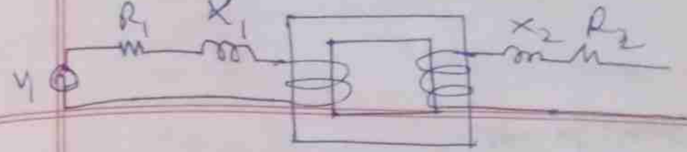
$\boxed{E_1 I_1 = E_2 I_2}$

$\boxed{\frac{V_1}{V_2} \frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{1}{K} = \alpha = \text{Turns Ratio}}$

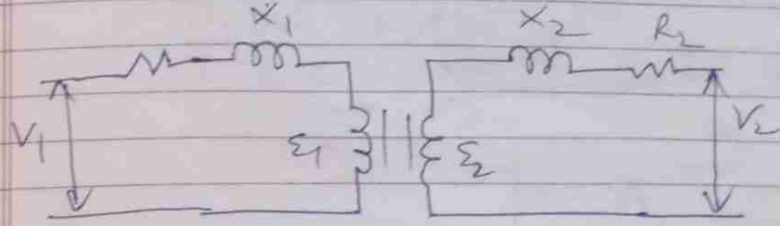
(a) & (b)

no load $I_2 = 0$





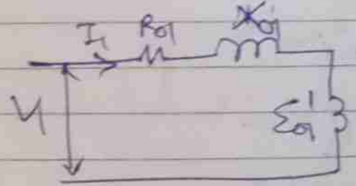
Equvelient Circuit



Add primeryside refer

R_{01} = Eq. Resistance seen from Premiary side

X_{01} = Indetace



$R_{01} = R_1 + \left(\frac{N_1}{N_2}\right)^2 R_2$

$= R_1 + R_2'$

$X_{01} = X_1 + \left(\frac{N_1}{N_2}\right)^2 X_2$

$= X_1 + X_2'$

$E_{01}' = E_1 + \left(\frac{N_1}{N_2}\right) E_2$

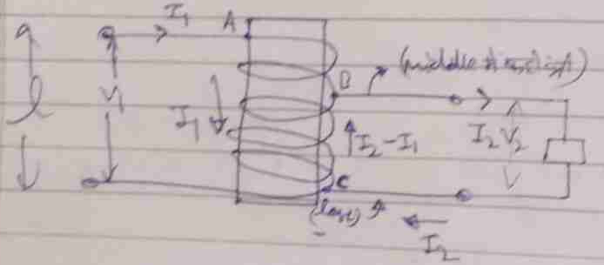
→ for Secondry refer

$R_{02} = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1$

$X_{02} = X_2 + \left(\frac{N_2}{N_1}\right)^2 R_2$

$E_{02}' = E_2 + \left(\frac{N_2}{N_1}\right) E_1$

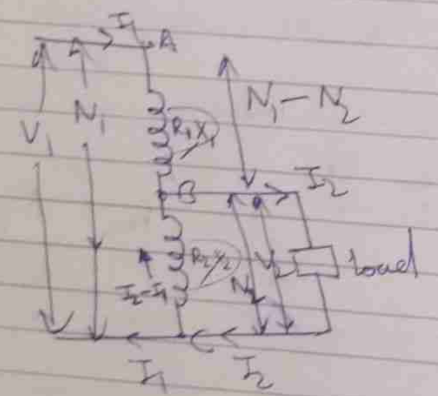
Auto Transformer



$AC = N_1$

$BC = N_2$

Q



$I_{CB} = I_2 - I_1$

(P) से In simple Transfr

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

$$I_1 N_1 = I_2 N_2$$

Cu loss $= I^2 R$

Core loss → hysteresis loss → $P_h = k_h f B_m^n$

Core loss → eddy current loss → $P_e = k_e f B_m^2$

Prove ⇒ $I_1(N_1 - N_2) = (I_2 - I_1) N_2$

$$mmf_{AB} = I_1(N_1 - N_2) = I_1 N_1 - I_1 N_2$$
$$= I_2 N_2 - I_1 N_2$$
$$= N_2(I_2 - I_1)$$
$$= mmf_{CB}$$

$P = VI \cos\phi$

$P_1 = V_1 I_1 \cos\phi_1$

$P_2 = V_2 I_2 \cos\phi_2$

No loss — (P)

$V_1 I_1 = V_2 I_2$

$\cos\phi_1 = 1$, $\cos\phi_2 = 2$ } only Resistance होने से $Z = 1$

$wt. = D \times vol$

→ Wire same h — wire cross section area

$V = A \times l$ → wire length

$l \propto N$ → no of loops

$A \propto I$ → current (I = heavy)

wt. of $AB \propto (N_1 - N_2) I$

wt of $BC \propto$ ~~N_2~~ $(I_2 - I_1) N$

wt. $\propto NI$

(AB+BC) wt $\propto N_1 I_1 - N_2 I_2 + N_2 I_2 - N_1 I_1$

$\propto 2N_1 I_1 - 2N_2 I_1$

wt of Auto Transformer $\propto 2I_1(N_1 - N_2)$

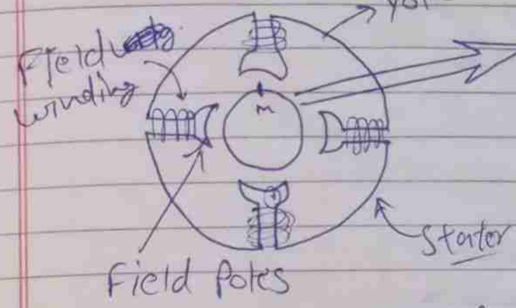
wt of simple Tr. $\propto N_1 I_1 + N_2 I_2 \propto 2N_1 I_1$

$$\frac{\text{wt. of Auto}}{\text{wt. of Simple}} = \frac{2(N_1 - N_2) I_1}{2N_1 I_1}$$

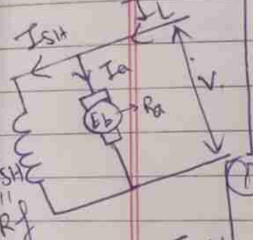
$$\boxed{\frac{\text{Wt of Auto}}{\text{wt. of Simple}} = 1 - k}$$

DC Motor Animation

DC Motor

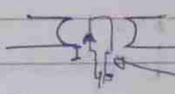


$f = \frac{PN}{120}$ — P → No of poles, N → Speed in RPM



$I_L = I_a + I_{SH}$ → Line current

① से मशीन में ... = ϕ/pol



$E_b = V - I_a R_a$ — Shunt Emf, Supply, Arm. Cur, Armature Resistance

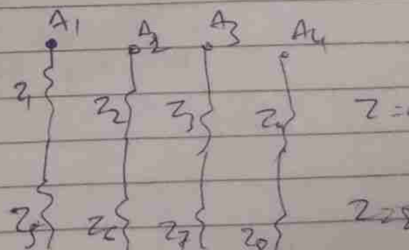
total flux in 1 revolution = $P\phi$

then flux cutting in N revolution $= NP\phi$

Total No of Arm Conductors → Z

No of ll^{el} paths → A

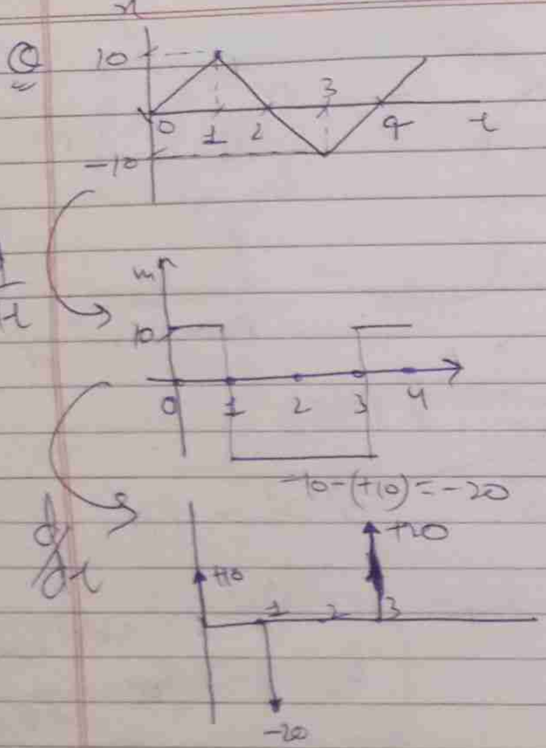
$\frac{Z}{A}$



Emf eq. of DC generator = total flux cut $= \frac{Z}{A} NP\phi$

(1, 10)　10　$\cancel{\frac{20}{2}}$

(3, -10)　10 - 10 - 10

Q


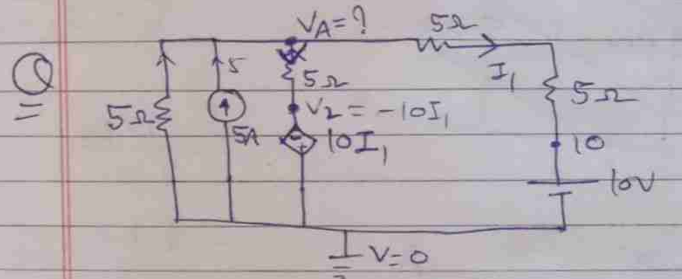
Impulse

given :- impels

find : Step

रेखा :- Area at an ~~Instant~~ is equal to the change in step at that ~~state~~ Instant

Change in step at a instant is equal to the change in slope at that perticular instant

Q


$$\cancel{\frac{-V_A}{5} + 5 + \frac{V_2 - V_A}{5} = \frac{10 - V_A}{10}}$$

$$\cancel{\frac{V_2 - V_A}{5} = 10I_1}$$

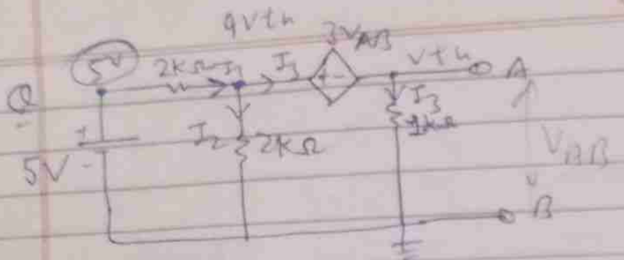
$$5 + I_2 = I_3 + I_1$$

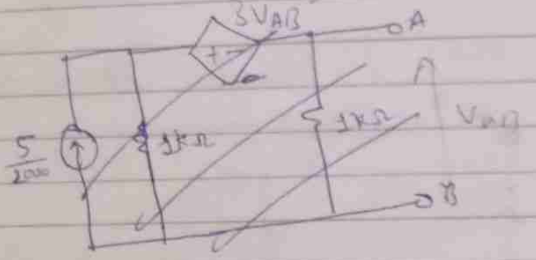
$$5 + \frac{-V_A}{5} = \frac{V_A + 10I_1}{5} + \frac{V_A - 10}{10}$$

$$V_A + 4I_1 = 12$$

$$V_A - 10I_1 - 10 = 0$$

$$V_A - 10I_1 = 10$$

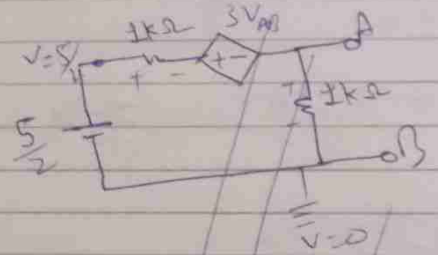




$$I_1 = I_2 + I_3$$

$$\frac{5 - 4V_{th}}{2k} = \frac{4V_{th}}{2k} + \frac{V_{th}}{1k}$$

$$V_{th} = \frac{1}{2}$$



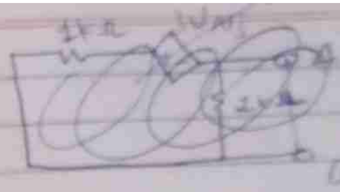
$$\frac{5}{2} + 1000I + 3V_{AB} + 1000I = 0$$

$$V_{AB} = 1000I$$

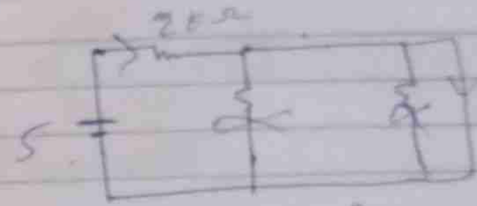
$$\frac{5}{2} + V_{AB} + 3V_{AB} + V_{AB} = 0$$

$$V_{AB} = -\frac{5}{2}$$

$$V_{AB} = -\frac{5}{8}$$



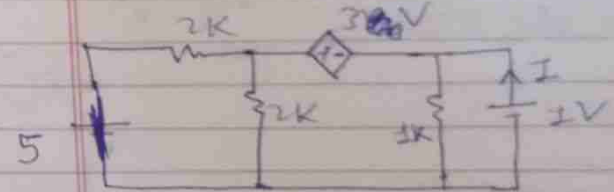
$V_{AB} = 0$

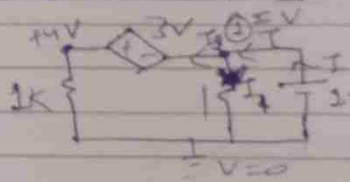


$$I_{AC} = \frac{5}{2k}$$

$2.5\ m$

$$R_{th} = \frac{\frac{1}{2}}{\frac{5}{2k}} = 200\ \Omega$$





$$I = I_1 + I_2$$

$$I = \frac{1 - 0}{1k} + \frac{4}{1k}$$

$$I = \frac{1}{k} + \frac{4}{k} = \frac{5}{k} = \frac{5}{1000}$$

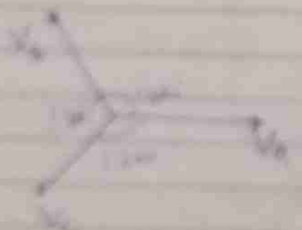
Balanced
Three phase System

→ Three loads

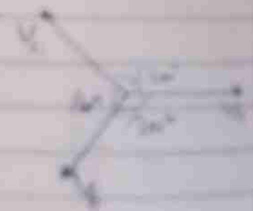
Balanced load

→ Phase Sequence

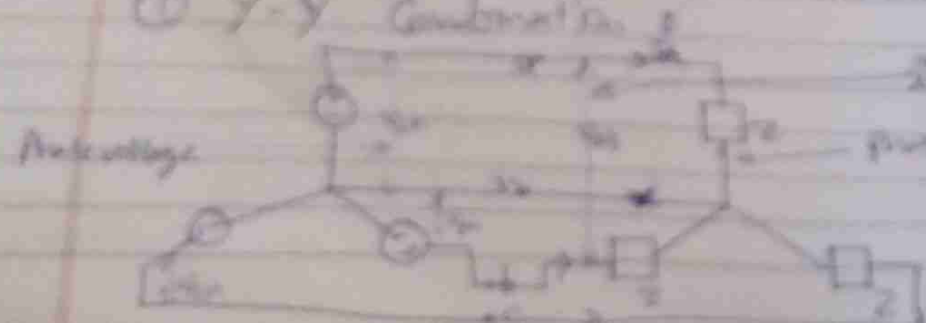
abc sequence
$V_a = V\angle 0^\circ$
$V_c = V\angle -120^\circ$
$V_b = V\angle -240^\circ$



abc sequence
$V_a = V\angle 0^\circ$
$V_b = V\angle -120^\circ$
$V_c = V\angle -240^\circ$



Source load System
① Y-Y Combination



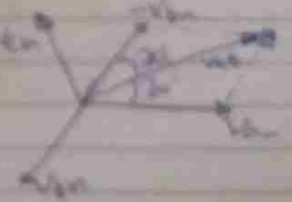
→ For Star Connected load line Current = Phase Current

Let
$V_{an} = V\angle 0^\circ$
$V_{bn} = V\angle -120^\circ$
$V_{cn} = V\angle -240^\circ$

In ab

$-V_{an} + V_{bn} + V_{ab} = 0$

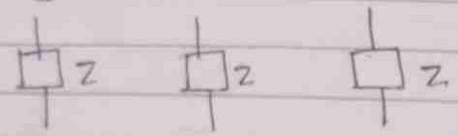
$V_{ab} = V_{an} - V_{bn}$
$= V\angle 0^\circ - V\angle -120^\circ$
$= V(1\angle 0^\circ - 1\angle -120^\circ)$
$= V(1 + j0 + 0.5 + j0.866)$
$= V(1.5 + j0.866)$
$= V(1.732\angle 29.99)$
$= V\sqrt{3}\angle 30$
$V_{ab} = V\sqrt{3}\angle 30^\circ$



Balanced

Three phase System

→ Three loads

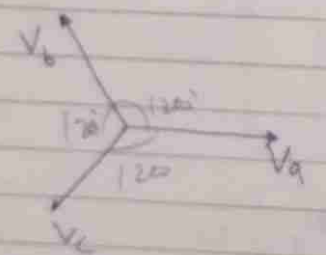


Balanced load

→ Phase Sequence

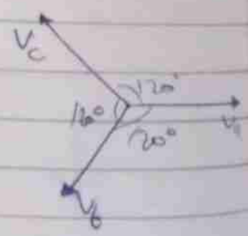
acb sequence, −ve seq.

$$V_a = V\angle 0^\circ$$
$$V_c = V\angle -120^\circ$$
$$V_b = V\angle -240^\circ$$



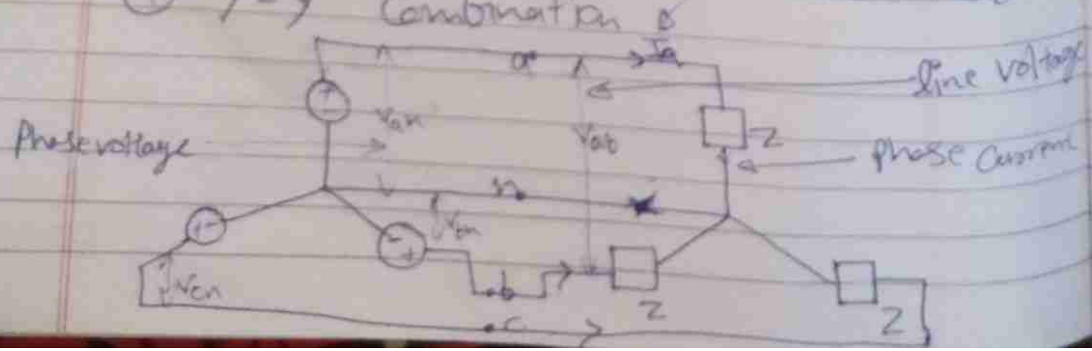
abc seq. +ve seq.

$$V_a = V\angle 0^\circ$$
$$V_b = V\angle -120^\circ$$
$$V_c = V\angle -240^\circ$$



Source load System

① Y-Y Combination



→ For Star Connected load line Current = Phase Current

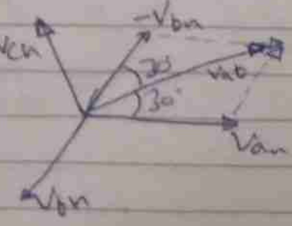
let

$$V_{an} = V\angle 0^\circ$$
$$V_{bn} = V\angle -120^\circ$$
$$V_{cn} = V\angle -240^\circ$$

in ab

$$-V_{an} + V_{bn} + V_{ab} = 0$$

$$V_{ab} = V_{an} - V_{bn}$$
$$= V\angle 0^\circ - V\angle -120^\circ$$
$$= V\left(1\angle 0^\circ - 1\angle -120^\circ\right)$$
$$= V\left(1 + j0 + 0.5 + j0.866\right)$$
$$= V\left(1.5 + j0.866\right)$$
$$= V\left(1.732\angle 29.99\right)$$
$$= V\sqrt{3}\angle 29.99$$
$$V_{ab} = V\sqrt{3}\angle 30^\circ$$



for: bc

$$-V_{bn} + V_{cn} + V_{bc} = 0$$

$$V_{bc} = V_{bn} - V_{cn}$$

$$= \cancel{V}\left(V\angle -120^\circ - V\angle -240^\circ\right)$$

$$= V\left(1\angle -120^\circ - \cancel{V}\angle -240^\circ\right)$$

$$= V\left(-0.5 - j0.866 + 0.5 - j0.866\right)$$

$$V_{bc} = V(0 - j1.732)$$

$$V_{bc} = \sqrt{3}V\angle -90^\circ$$

for ca

$$V_{ca} = V_{cn} - V_{an}$$

$$= V\angle -240 - V\angle 0^\circ$$

$$= V(-1.5 + j0.866)$$

$$= \sqrt{3}V\angle 150^\circ$$

$$= \sqrt{3}V\angle -210^\circ$$

$$I_a = \frac{V_{an}}{Z} = \frac{V}{Z}\angle 0^\circ$$

$$I_a = I\angle 0^\circ$$

$$I_b = I\angle -120^\circ$$

$$I_c = I\angle -240^\circ$$

$$I_n = I_a + I_b + I_c$$

$$= I\left(1\angle 0^\circ + 1\angle -120^\circ + 1\angle -240^\circ\right)$$

$$= I\left(1 + 0j + (-0.5 - j0.8660) + -0.5 + j0.866\right)$$

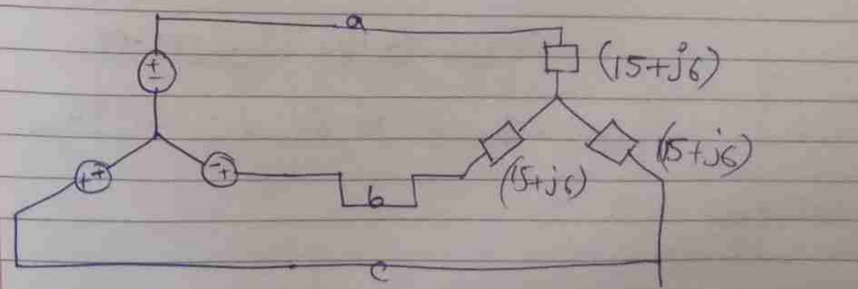
$$I_n = 0$$

$\Downarrow$

Same potential

In valanced System $I_n = 0$

Q



Given for the ckt phase seq abc find line voltage & line current. $V_{an} = 110\angle 0^\circ$

given $V_{an} = V\angle 0°$

$V_{bn} = V\angle -120$
$V_{cn} = V\angle -240'$ } because system is balanced

$V_{ab} = V_{an} - V_{bn}$

$= \sqrt{3} \cdot V\angle 30$

$V_{bc} = \sqrt{3} V\angle -90'$

$V_{ca} = \sqrt{3} V\angle -210' = \sqrt{3} V\angle 150'$

$I_a = \frac{V\angle 0'}{Z} = \frac{V\angle 0'}{15+j6} = \frac{V\angle 0°}{16.15\angle 21.8}$

$V(0.0619)\angle -21.8$

$V(0.0574 - j0.02298)$

$v = 110$ $\quad I_a = 6.81\angle -21.8$

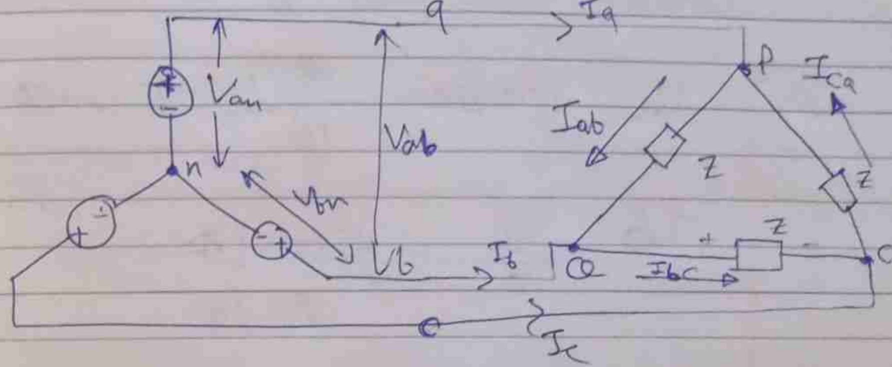
$I_b = 6.81\angle -141.86$

$I_c = 6.81\angle -261.86$

$W_1 - W_2 = W_i^{o} + x^2 W_{Cu}$

iron loss $\quad$ Cu loss

(2) Y-Δ Combination



balanced abc =

$V_{ab} = V\angle 0°$

$V_{bc} = V\angle -120$

$V_{ca} = V\angle -240 = V\angle +120$

$I_{ab} = \frac{V_{ab}}{Z} = \frac{V\angle 0°}{Z} = I\angle 0'$

$I_{bc} = \frac{V\angle -120'}{Z} = I\angle -120'$

$I_{ca} = \frac{V\angle +120}{Z} = I\angle -240'$ (240)

at P

$I_a = I_{ab} - I_{ca}$

$= I(1\angle 0' - 1\angle -240)$

$= I(1 + 0j + 0.5 + j0.866)$

$= I(1.5 + j0.866)$

$= \sqrt{3} I\angle -30'$

at Q

$I_b = I_{bc} - I_{ab}$

$= I(1\angle -120 - 1\angle 0')$

$= \sqrt{3} I\angle -150'$

$I_c = \sqrt{3} I\angle -270$

$= \sqrt{3} I\angle 90'$

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(Q) A balanced abc sequence ~~by~~ Y - Connected source with $V_{an} = 100 \angle 10^\circ$ V is connected to Δ Connected blanced load $Z = 8 + j4$ Ω/phase. Calculate the phase + line Current.

Soln

$V_{an} = 100 \angle 10^\circ$

$\boxed{V_{ab} = \sqrt{3}\, 100 \angle 40^\circ}$ Rember

$I_{ab} = \dfrac{V_{ab}}{Z} = \dfrac{\sqrt{3}\, 100 \angle 40^\circ}{8 + j4}$

$= \dfrac{\sqrt{3}\, 100 \angle 40^\circ}{8.944 \angle 26.56}$

$= 19.3649 \angle 13.44$ A

$I_{bc} = 19.3649 \angle -106.57$

$I_{ca} = 19.3649 \angle -226.57$

$I_a = \sqrt{3} \times 19.3649 \angle 13.43 - 30^\circ$

$= 33.53 \angle -16.57$

abc → +ve seq.
acb → -ve seq

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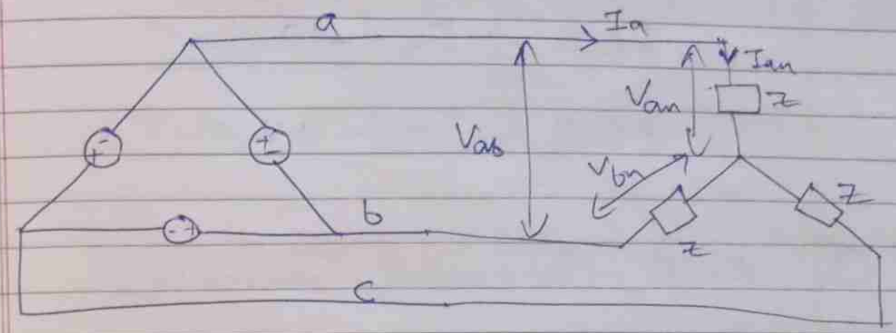
(3) Δ - Y Connected System



$V_{ab} = V \angle 0^\circ$ then $V_{an} = \dfrac{V}{\sqrt{3}} \angle -30^\circ$

$I_a = I_{an} = \dfrac{V_{an}}{Z}$

(Q) A balanced Y Connected load with phase ~~having an~~ impedance of $(40 + j25)$ Ω ~~per phase~~ is applied by balanced, positive sequence Δ Connected Source with line voltage of 210V Calculate phase current.

Soln

$Z = 40 + j25$ Ω

$V_{ab} = 210 \angle 0^\circ$

$V_{bc} = 210 \angle -120^\circ$

$V_{ac} = 210 \angle -240^\circ$

$V_{an} = \dfrac{210}{\sqrt{3}} \angle -30^\circ$

$I_a = \dfrac{210 \angle -30^\circ}{\sqrt{3} \times (40 + j25)}$

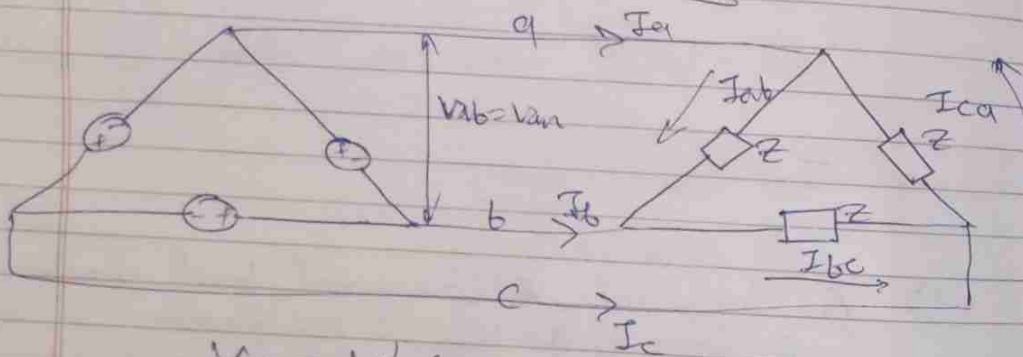
$= \dfrac{210 \angle -30^\circ}{\sqrt{3} \times 47.16 \angle 32.005}$

$I_a = 2.56 \angle -62.005$

$I_b = 2.56 \angle -182.005$

$I_c = 2.56 \angle -302.005$

(Q) Δ-Δ Connected Source:-



$V_{ab} = V \angle 0°$

$\begin{cases} I_a = \sqrt{3}\, I \angle -30° \\ I_{ab} = I \angle 0° \end{cases}$

Q a balanced Δ connected load with phase impedance of $20 - j15\ \Omega$ is connected to a Δ connected +ve sequence generator having. Calculate the phase current of load & line currents.

RYB, & RBY

$V_{ab} = V_{RY}$ | V_{Rn}, V_{Yn}; V_{Bn}

Soln

$Z = 20 - j15$

$V_{ab} = 330 \angle 0°$

$V_{an} = \frac{330 \angle 0°}{\sqrt{3}}$

$I_{ab} = \frac{330 \angle 0°}{(20 - j15)}$

$= \frac{330 \angle 0°}{25(\quad)}$

$I_{ab} = 13.2 \angle 36.86$ A

$I_{bc} = 13.2 \angle -83.14$

$I_{ca} = 13.2 \angle -203.15$

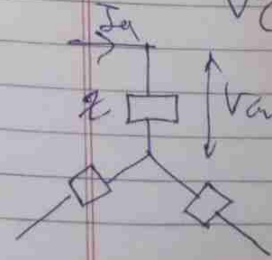
Power in Balanced 3ϕ System

rms value $= V_p$

$V_{an} = \sqrt{2}\, V_p \cos(\omega t)$

$V_{bn} = \sqrt{2}\, V_p \cos(\omega t - 120°)$

$V_{cn} = \sqrt{2}\, V_p \cos(\omega t - 240°)$



$I_a = \sqrt{3}\, I_p \cos(\omega t - \theta)$

$I_b = \sqrt{3}\, I_p \cos(\omega t - \theta - 120°)$

$I_c = \sqrt{3}\, I_c \cos(\omega t - \theta + 120°)$

$$P = P_1 + P_2 + P_3$$

$$P_1 = \sqrt{2}\,V_p \times \sqrt{2}\,I_p (\cos \omega t) \times (\cos(\omega t - \theta))$$

$$P = 2 V_p I_p \{ \cos(\omega t)\cos(\omega t - \theta) + \cos(\omega t - 120^\circ)\cos(\omega t - 120^\circ - \theta) + \cos(\omega t + 120^\circ)\cos(\omega t + 120^\circ - \theta) \}$$

$$P = 2 V_p I_p (\cancel{V_p I_p} \cos\theta + \cos(2\omega t - \theta) + \cos\theta + \cos(2\omega t - 240^\circ - \theta) + \cos\theta + \cos(2\omega t + 240^\circ - \theta) \}$$

if $\alpha = 2\omega t - \theta$

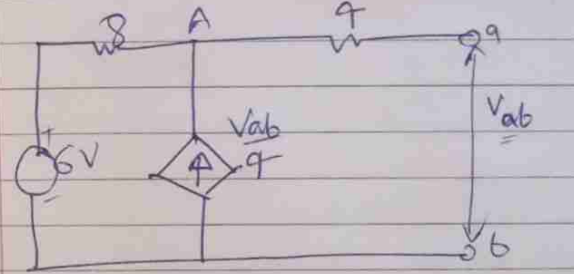
$$P = V_p I_p (3\cos\theta + \cos\alpha + \cos(\alpha - 240^\circ) + \cos(\alpha + 240^\circ) \}$$

$$P = V_p I_p (3\cos\theta + \cos\alpha + 2\cos\alpha \cdot \cos 240^\circ)$$

$$\boxed{P = 3 V_p I_p \cos\theta}$$

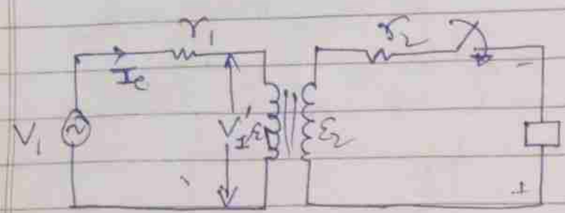
I_{bc}	Combination	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}	I_a	I_b	I_{ab}
I_b	Y – Y	$V\angle\theta$ (Ref)	$V\angle\theta-120^\circ$	$V\angle\theta-240^\circ$	$V\sqrt{3}\angle\theta+30^\circ$	$V\sqrt{3}\angle\theta-90^\circ$	$V\sqrt{3}\angle\theta-210^\circ$	$I\angle\theta$	$I\angle\theta-120^\circ$	I_a
$I\angle\theta-120^\circ$	Y – Δ	$\frac{V}{\sqrt{3}}\angle\theta-30^\circ$	$\frac{V}{\sqrt{3}}\angle\theta-150^\circ$	$\frac{V}{\sqrt{3}}\angle\theta-270^\circ$	$V\angle\theta$ (Ref)	$V\angle\theta-120^\circ$	$V\angle\theta+120^\circ$	$\sqrt{3}I\angle\theta-30^\circ$	$\sqrt{3}I\angle\theta-150^\circ$	$I\angle\theta$
$\theta-120^\circ$	Δ – Y	$\frac{V}{\sqrt{3}}\angle\theta-30^\circ$	$\frac{V}{\sqrt{3}}\angle\theta-150^\circ$	$\frac{V}{\sqrt{3}}\angle\theta-270^\circ$	$V\angle\theta$	$V\angle\theta-120^\circ$	$V\angle\theta+120^\circ$	$\frac{V_{an}}{Z}$	$\theta-120^\circ$	$\frac{V_{an}}{Z}$
$I\angle\theta-120^\circ$	Δ – Δ	$V\angle\theta$	$V\angle\theta-120^\circ$	$V\angle\theta-240^\circ$	V_{an}	V_{bn}	V_{cn}	$\sqrt{3}I\angle\theta-30^\circ$	$\theta-150^\circ$	$I\angle\theta$

Q.

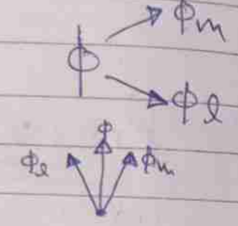


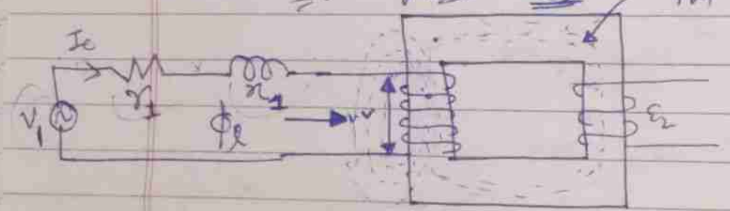
Thevenin eq. Circuit

(ii) Resistance effect



(iii) Leakage flux: (ϕ_l)





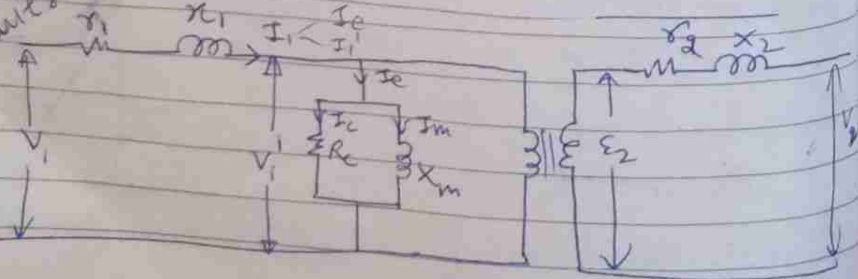
$E_l \Rightarrow \phi_l$ से generated emf

$E_l = -jI_e x_1$ → fictitious Reactance

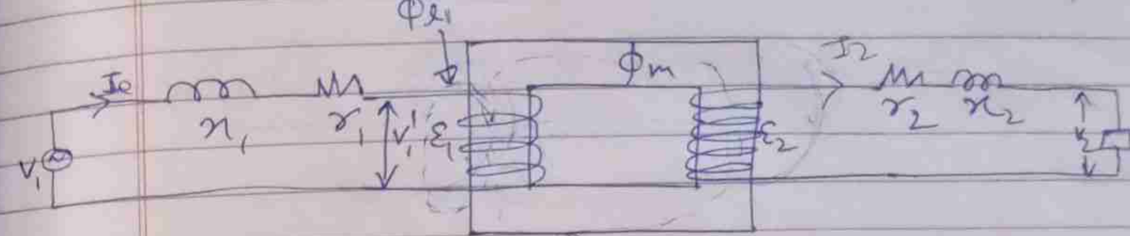
$V_1' = E_1$

$$V_1 = V_1' + I_e r_1 + jI_e x_1$$
$$= V_1' + I_e(r_1 + jx_1)$$
$$= E_1 + I_e(r_1 + jx_1)$$

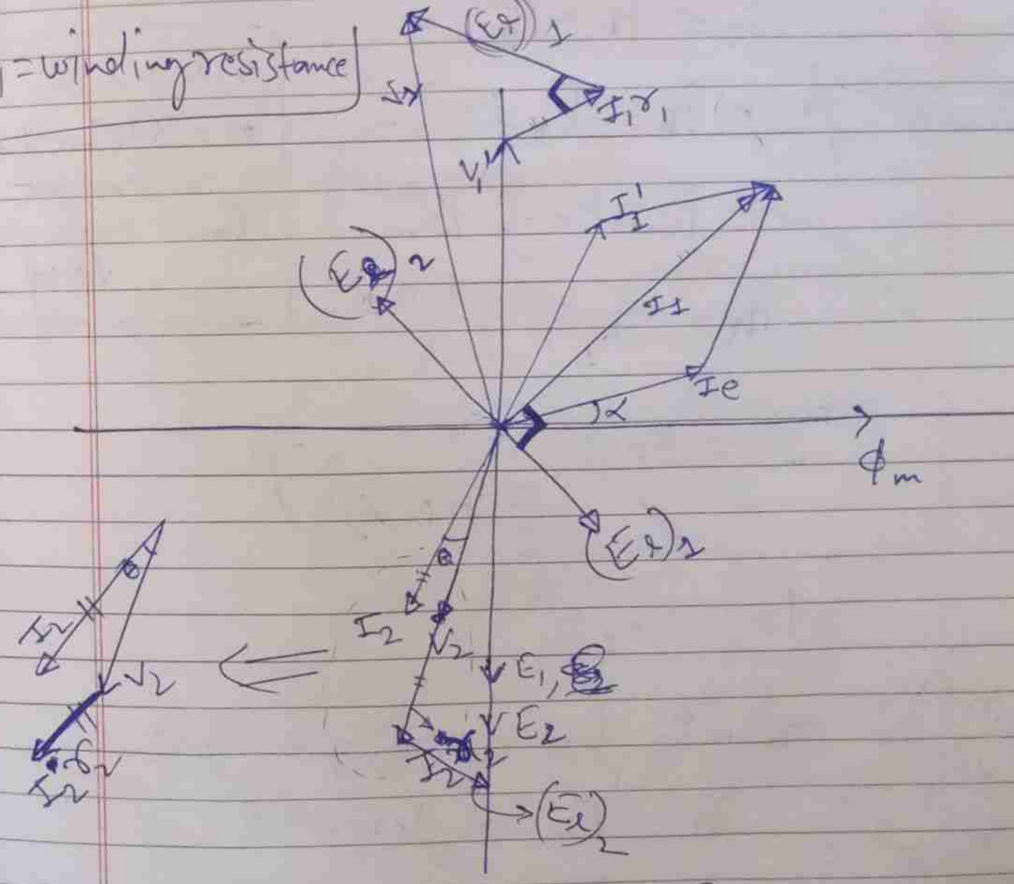
Electrical Equivalent Circuit:



⇒ Phasor diagram practical T/F at load



$r_2 r_1$ = winding resistance



$$E_2 = V_2 + I_2(r_2 + jx_2)$$

Below

$\rightarrow \phi_m = B_m A$

$V_1 \approx E_1 = \sqrt{2}\pi f N_1 \phi_m \Rightarrow B_m = \dfrac{V_1}{\sqrt{2}\pi N_1 A f}$

Losses of Transformer

Constant loss

1.) Hystressis & Eddy Current loss

$\underbrace{\text{Hystressis \& Eddy Current loss}}_{\text{Core loss}}$

$P_c = P_h + P_e$

$K_h f \dfrac{V_1^x}{(\sqrt{2}\pi N_1 A)^x} \cdot \dfrac{1}{f^x} = P_h = K_h f B_m^x$

$P_e = K_e f^2 B_m^2$

$P_h = K_{h_1} V_1^x f^{1-x}$

$P_e = K_e f^2 \dfrac{V_1^2}{(\sqrt{2}\pi N_1 A)^2} \times \dfrac{1}{f^2}$

$\boxed{P_e = K_{e_1} V_1^2}$

$x \approx 1.2$

x = Steinmetz Constant

B_m = Magnetic field

Variable loss

Load dependent loss

2) Ohmic loss or Copper loss.

r_1, r_2 से generated

$P_{cu} = P_W = I_1^2 r_1 + I_2^2 r_2$

$= I_1^2 r_{e_1} = I_2^2 r_{e_2}$

$= I_1^2 r_1 + I_1^2 \left(\dfrac{N_1}{N_2}\right)^2 r_2 \quad \because \dfrac{I_2}{I_1} = \dfrac{N_1}{N_2}$

$= I_1^2 \left(r_1 + \left(\dfrac{N_1}{N_2}\right)^2 r_2\right)$

$= I_1^2 r_{e_1}$

3) Stray loss

4) Dielectric loss

Efficiency of transformer

$\eta = \dfrac{\text{output Power}}{\text{Input Power}}$

$\cancel{\eta = \dfrac{V_2 I_2 \cos\theta_2}{V_2 I_2 \cos\theta_2 + P_c + P_W}}$

$\boxed{\eta = \dfrac{V_2 I_2 \cos\theta_2}{V_2 I_2 \cos\theta_2 + P_c + P_W}}$

$P_W \rightarrow I_2^2 r_{e_2}$

$\Rightarrow$ Condition for maximum efficiency

$$\frac{d\eta}{dI_2} = \frac{(V_2 I_2 \cos\theta_2 + P_c + I_2^2 r_{e_2}) V_2 \cos\theta_2 - (V_2 I_2 \cos\theta_2)(V_2 \cos\theta_2 + 2 I_2 r_{e_2})}{(V_2 I_2 \cos\theta_2 + P_c + I_2^2 r_{e_2})^2}$$

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$$\frac{d\eta}{dI_2} = 0$$

$$\cancel{V_2 I_2 \cos\theta_2} + P_c\, I_2^2 r_{e2} = \cancel{V_2 I_2 \cos\theta_2} + 2 I_2^2 r_{e2}$$

$$\boxed{P_c = I_2^2 r_{e2}}$$

if $\boxed{P_c = P_w}$

then maximum efficiency of trans.

$$\boxed{I_2 = \sqrt{\frac{P_c}{r_{e2}}}}$$

$$I_2 = I_{fl} \sqrt{\frac{P_c}{I_{fl}^2 \cdot r_{e2}}}$$

$$= I_{fl} \sqrt{\frac{P_c}{P_{full\ Load\ Copper\ loss}}}$$

In lab
2 KVA, 230V, 1:1

$I_{fl} = \frac{2000}{230} = 8.69$

$$\boxed{I_{fl} = \frac{\text{Rated KVA}}{V_2}}$$

$$x = \frac{I_{actual} = I_2}{I_{fl}}$$

if find $\frac{1}{4}$ fl eff.
then $x = \frac{1}{4}$

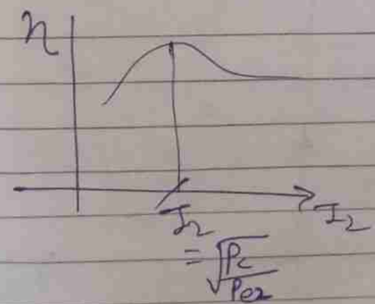
$$\eta = \frac{x\, \text{Rated KVA} \times \cos\theta}{x\, \text{Rated KVA} \cos\theta + P_c + x^2 P_{wc}}$$

$P_W = I_{Actual}^2 r_{e2}$

$P_{WC} = I_{fl}^2 r_{e2}$

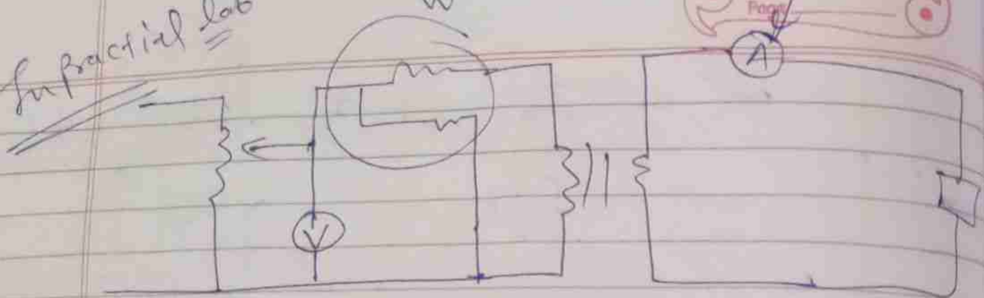
full Load Copper loss

$$\boxed{\frac{P_W}{P_{WC}} = \left(\frac{I_{Actual}}{I_{fl}}\right)^2 = x^2}$$



$I_2 = I_{actual}$

In practial lab



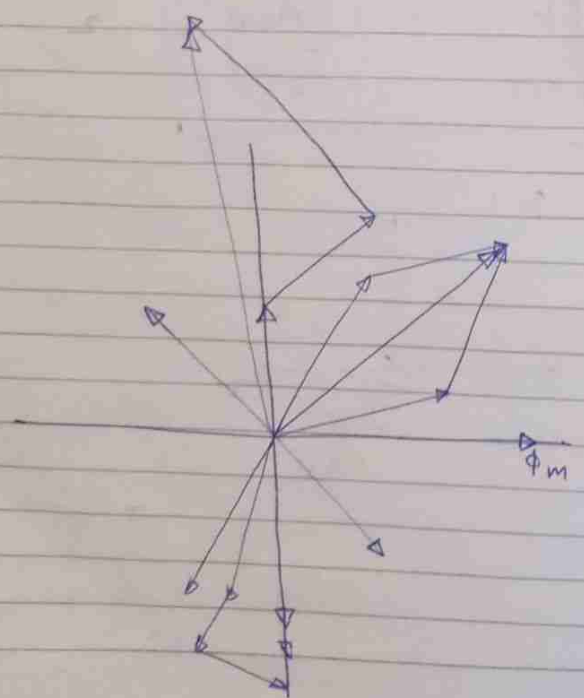
$$W_1 = P_{iron} + n^2 P_W$$

$I_{fl} = 8.69$

$$W_2 = P_{iron} + n^2 P_W$$

$$n = \frac{I_{actual}}{I_{fl}}$$

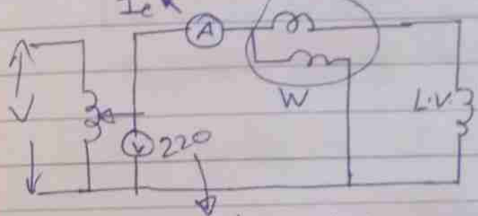
Phasor diagram of practial transformer



Test:

1. open ckt test
2. short ckt test

① open ckt test



2200/220

rated Voltage applied on Low Voltage

I_e = 2 to 5% of full load Current (I_{fl})

→ Watt meter reading giving only Core loss b/c I_e is very less then Cu loss is neglect.

$$W = V_1' I_e \cos\theta_1$$

$$R_C = \frac{V_1'}{I_C} = \frac{V_1'}{I_e \cos\theta_1}$$

$$X_m = \frac{V_1'}{I_m} = \frac{V_1'}{I_e \sin\theta_1}$$

in ckt then

$V_1 = E_1 + I_e(r_1 + jx_1)$

neglected

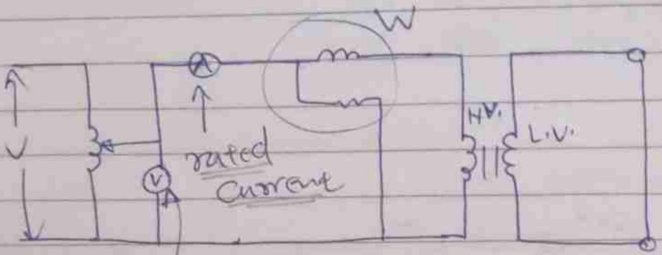
then

$V_1 = E_1$

T/F show only

CORE LOSS

(2) Short Ckt test 4KVA, 2200/220



2 to 9% of rated Voltage

Core loss is neglited

Cu loss

When I current flow in ckt the

$V = E_1 + I(r_1 + jx_1)$ ✓

+

$P_c = P_h + P_e$

$P_h = K_h V_1^x f^{1-x}$

$P_e = K_e V_1^2$

$\boxed{V_1 KC}$

then $P_h + P_e$ is neglected

then T/F show only Cu loss (from resistance & Inductance)

$W = I^2 R_{eq}$

$R_{eq} = r_1 + r_2'$

$r_2' = R_2 + \left(\frac{N_2}{N_1}\right)^2 R_1$

$R_{eqH} = \frac{W}{I^2}$

$Z_{eqH} = \frac{V_{sc}}{I}$

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

Q The emf per turn for a single phase 2310/220V, 50Hz transformer is approximately 13 volts/turn. Calculate

(a) the number of primary & secondary Turns

(b) net cross sectional area of the core for a maxi. flux density of 1.47T

Solⁿ Ideal trans (b/z no r/s. no react.)

$E_1 = V_1$

$E_2 = V_2$

$E_1 = \sqrt{2}\pi N_1 f \Phi_m$

$\frac{E_1}{N_1} = \text{emf/turns}$

$\frac{E_1}{N_1} = 13 = \frac{2310}{N_1}$ $\boxed{\text{or}}$ $\frac{E_2}{N_2} = 13 = \frac{220}{N_2}$

$N_2 = 16.9230$

$N_2 \approx 17$ turns

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

$\frac{2310}{220} = \frac{N_1}{17} \Rightarrow 178.5 = N_1$

b/z

$N_2 \approx 17 \xrightarrow{\text{inc.}} 18$

$\frac{2310}{220} = \frac{N_1}{18} \Rightarrow \boxed{N_1 = 189}$

$\phi_m = B_m \times A$

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

$E_1 = \sqrt{2}\pi N_1 f B_m A$

$2310 = \sqrt{2}\pi \times 189 \times 50 \times 1.47 \times A$

$A = 0.037428115\ m^2$

rated voltage

Q A 10kVA 2500/250V, Single phase t/f gave the following test result open ckt test 250V, 0.8A, 50W
Short ckt test 60V, 3A, 45W rated current
(a) Calculate the efficiency at 1/4 FL at 0.8 pf.
(b) Calculate the load kVA at which max. effeciency occurs.

Soln

$P_{core\,loss} = 50W, \quad P_{cu\,loss} = 45W$

$$\eta = \frac{x \times \text{Rated kVA} \times pf}{x \times \text{Rated kVA} \times pf + P_{core} + x^2 W_c}$$

We will check Pculoss is real

$$I_{fl} = \frac{10{,}000}{2500} = 4A$$

$$\frac{I_{actual}^2 R_{eq}}{I_{fl}^2 R_{eq}} = \frac{W_{actual}}{W_{culoss}}$$

$I_{actual} = 3A$ पर है

$I_{fl} = 4A$ होना चाहिए था

$$W_{culoss} = \left(\frac{I_{fl}}{I_{actual}}\right)^2 \times W_{actual}$$

$$= \left(\frac{4}{3}\right)^2 \times 45$$

$= 80W$

$$\eta = \frac{\frac{1}{4} \times 10{,}000 \times \cancel{1000} \times 0.8}{\frac{1}{4} \times 10{,}000 \times 0.8 + 50 + \left(\frac{1}{4}\right)^2 \times 80}$$

$$I_2 = \sqrt{\frac{P_c}{r_{eq}}} \qquad P_c = I^2 r_{eq}$$

$$I_2 = I_{fl}\sqrt{\frac{P_c}{I_{fl}^2 r_{eq}}} = I_{fl}\sqrt{\frac{P_c}{W_c}}$$

full load Cu

Rated kVA

$$E_2 \times I_2 \times 1000 = E_2 \cdot I_{fl} \times 1000 \sqrt{\frac{P_c}{W_c}}$$

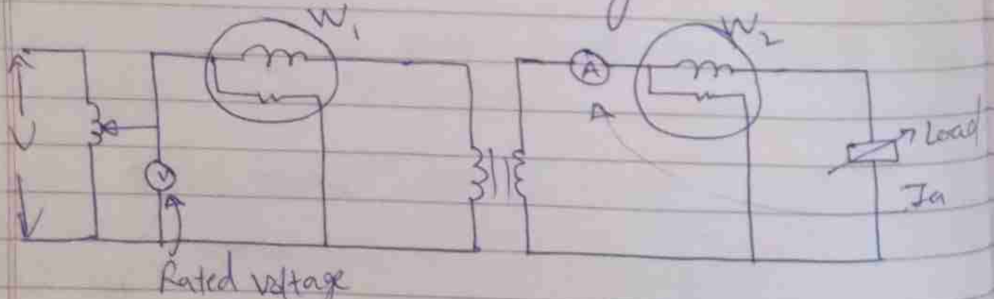
$$= 10 \times 1000 \sqrt{\frac{50}{80}}$$

Max. V.A

$$= 7905.69 \text{ V.A.}$$

$$\text{max. } \eta = \frac{7905}{2500} = 3.162$$

Determining the losses in a T/F using direct loading :-



$$I_{rated} = I_{full} = \frac{2000}{230} \left\{ \begin{matrix} 2\text{KVA} \\ 230/230 \\ \text{T/F} \end{matrix} \right.$$

→ $W_1 - W_2 = P_c + x^2 W_c$

$$x = \frac{I_{actual}}{I_{rated}}$$

→ Predetermine η at $\frac{1}{2}$ FL, $\frac{1}{4}$ FL, 1.25 FL at 0.8 pf lagging

→ $$\eta = \frac{x \cdot \text{Rated kVA} \times 1000 \times pf}{x \cdot \text{Rated kVA} \times 1000 \times pf + P_c + x^2 W_c}$$

find histress loss and eddy current loss Experimentaly

$P_c = P_h + P_e$

Separation of Core losses

$P_h = K_h f B_m^x$

$P_e = K_e f^2 B_m^2$

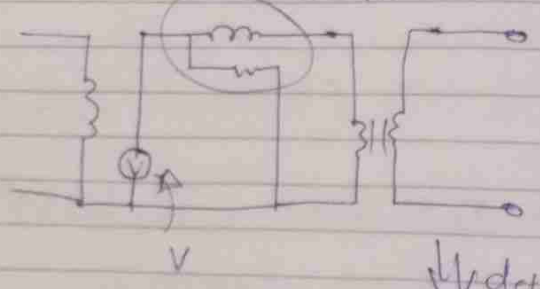
$P_c = K_h f B_m^x + K_e f^2 B_m^2 = K_1 f + K_2 f^2$

$$\left\{ \begin{matrix} V \simeq E = \sqrt{2}\pi N f \phi_m \\ \phi_m \propto \frac{V}{f} \end{matrix} \right.$$

$$\frac{P_c}{f} = K_1 + K_2 f$$

in open ckt.

$W = P_c$



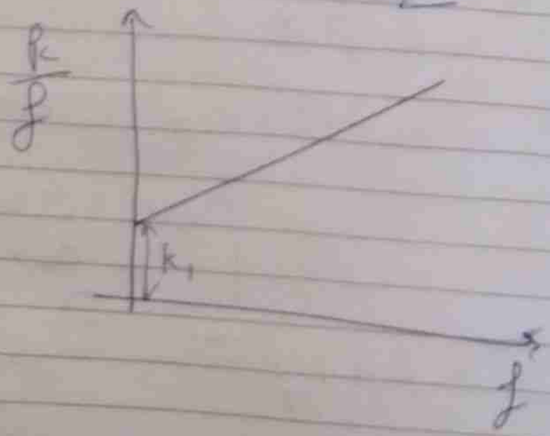
determ reading.

P_{c_1},	P_{c_2}
f_1,	f_2

$$\begin{cases} P_{c_1} = k_1 f_1 + k_2 f_1^2 \\ P_{c_2} = k_1 f_2 + k f_2^2 \end{cases}$$

Solve find

k_1 & k_2



Q In a transformer the Core loss is 100 W at 40Hz and 72 W at 30 Hz find the hysteresis and eddy current losses at 50Hz. Assume V/f was constant

Soln

$$\frac{P_c}{f} = k_1 + k_2 f$$

$$\frac{100}{40} = k_1 + k_2(40)$$

$$\frac{72}{30} = k_1 + k_2(30)$$

$$\frac{\left(\frac{10}{4} - \frac{72}{30}\right)}{10} = k_2 \Rightarrow \frac{2.5 - 2.4}{10}$$

$$= \frac{0.1}{10}$$

$$= \boxed{0.01 = k_2}$$

$$\boxed{k_1 = 2.1}$$

$P_h = k_1 \times f$

$P_h = 2.1 \times 50$

$P_e = k_2 f^2$

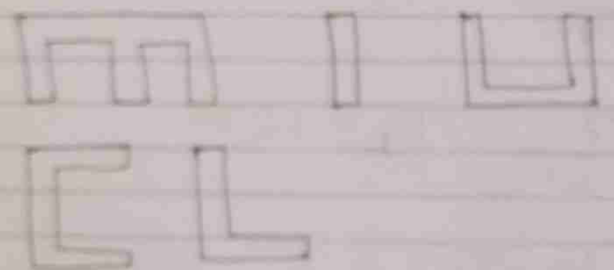
$= 0.01 \times 50 \times 50$

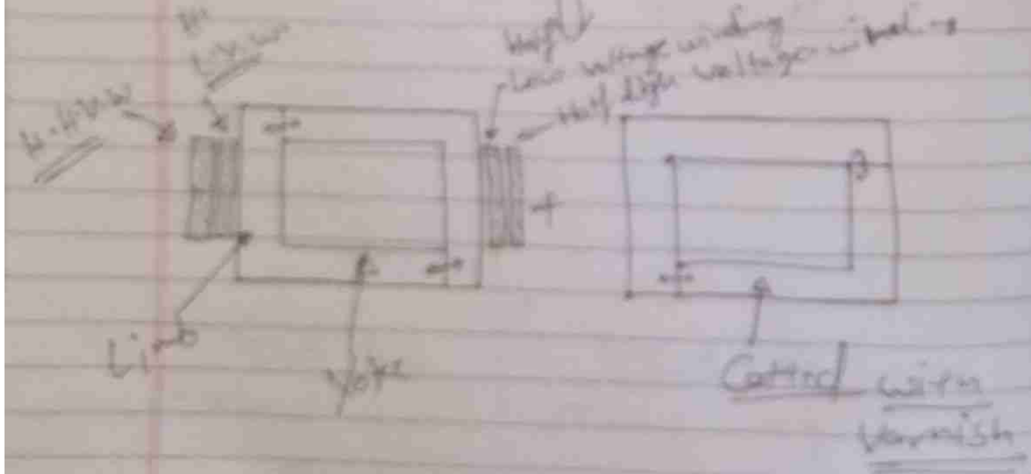
$= 25$

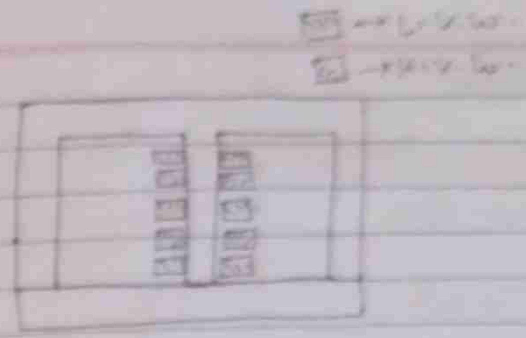
Construction of Transformer

(i) Core type → winding surrounding the core
(ii) Shell type → Core surrounds the winding

→ Stamping (thin Sheet of iron)
material:- CRGO (Cold rolled grain oriented)





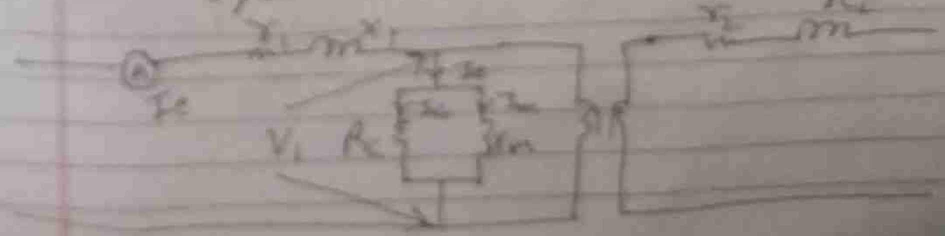


Q The following result were obtained on 50KVA 2400/120V transformer
open ckt test
Wattmeter reading 396W
Ammeter reading 9.65 A
Voltmeter reading 120V
Short ckt test
Wattmeter reading 810W
Ammeter reading 20.8A
voltmeter reading 92V

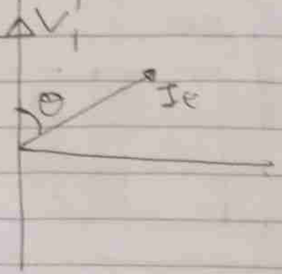
(a) determine Circuit Constant
(b) η at full load 0.8 pf lagging

Soln (a) $P_c = 396$ $W_c = 810W$

$I_{full} = 20.8A$



$P_c = V_1 I_e \cos\theta$



$396 = 120 \times 9.65 \cos\theta$

$\theta = 70.123$

$3.28 = I_c = I_e \cos\theta = 9.65 \cos 70.1$

$9.07 = I_m = I_e \sin\theta = 9.65 \sin 70.1$

$R_c = \frac{V_1}{I_c} = \frac{120}{3.28} = 36.58$

$X_m = \frac{V_1}{I_m} = \frac{120}{9.07} = 13.23$

$W_c = I^2 R_{eqH}$

$(Z_{eq})_H = \frac{V_{SC}}{I_{SC}}$

$(X_{eq})_H = \sqrt{Z_{eqH}^2 - R_{eqH}^2}$

$R_{eq} = 1.87\,\Omega$

$Z_{eq} = 4.42\,\Omega$

$X_{eq} = 4\,\Omega$

at full load $x = 1$

(b) $\%\eta = \frac{1 \times 50 \times 1000 \times 0.8}{1 \times 50 \times 1000 \times 0.8 + 396 + (1)^2 \cdot 810} \times 100$

$\%\eta =$

Q 2200/220V, 50Hz single phase T/F has exciting current of 0.6A and core loss of 361 W when its h.v. (high voltage) energised at rated voltage.

(a) Calculate the two components of exciting current

(b) If the T/F of part (a) supply a load current of 60A at 0.8 p.f. lag on its L.V. side then

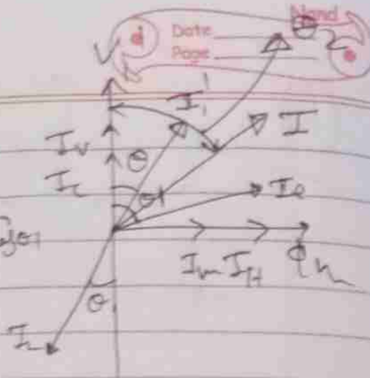
Calculate the primary current and its p.f.

Sol^n

$\frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{I_2}{I_1} \Rightarrow$

$\frac{2200}{220} = \frac{60}{I_1'} \Rightarrow I_1' = 6A$

$P_c = V I_c \cos\theta_1$



$361 = 2200 \times 0.6 \cos\theta_1$

$\cos\theta_1 = 0.27$

$\theta_1 = 74.33$

$\boxed{p.f. = \cos 0.8}$

$I_c = 0.6 \cos\theta_1 = 0.162$

$I_m = 0.6 \sin\theta_1 = 0.577$

$I = \sqrt{I_V^2 + I_H^2}$

$I_V = I_1' \cos\theta + I_c \cos\theta_1$

$I_H = I_1' \sin\theta + I_c \sin\theta_1$

$I_V = 6 \times 0.8 + 0.162$

$I_H = 6 \times 0.59 + 0.577$

$I_V = 4.8 + 0.162 = 4.962$

$I_H = 4.117$

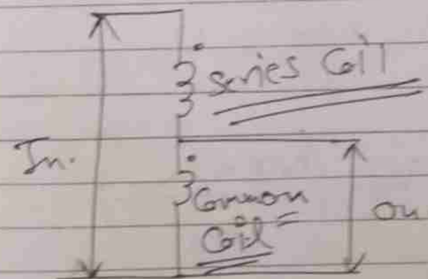
$I = \sqrt{(4.962)^2 + (4.117)^2} = 6.447$

$I \cos\theta_2 = I_V$

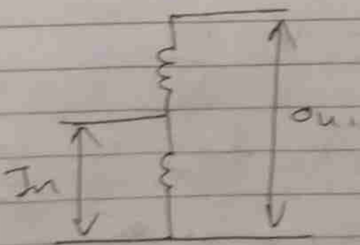
$\cos\theta_2 = \frac{I_V}{I_q} = \frac{4.962}{6.44}$

$\theta_2 = 39.60$

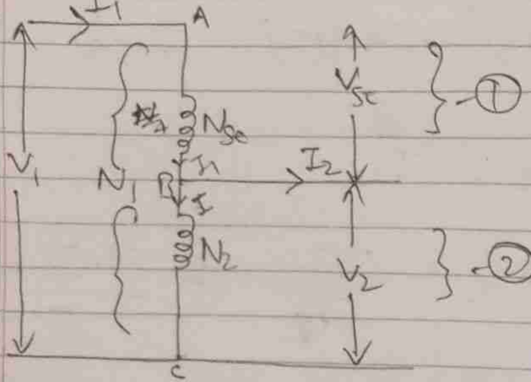
Auto Transformer



⇐ Step down



⇐ Step up.



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

$$\frac{V_{SE}}{V_2} = \frac{N_{SE}}{N_2}$$

$$N_1 = N_{SE} + N_2$$

$$V_1 = V_{SE} + V_2$$

$$V_1 = V_2 \frac{N_{SE}}{N_2} + V_2$$

$$V_1 = V_2 \left(\frac{N_{SE} + N_2}{N_2} \right)$$

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

when A.T/F has No loss ⇓ same

$$V_1 I_1 \cos\theta_1 = V_2 I_2 \cos\theta_2$$

$$V_1 I_1 = V_2 I_2$$

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}}$$

$$\text{Ratio} = \frac{N_2}{N_1} = K \ \text{(Transformation Ratio)}$$

for T/F Action:-

mmf winding ① = mmf of winding ②

$$(N_1 - N_2) I_1 = (I_2 - I_1) N_2$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$\Rightarrow N_1 I_1 - N_2 I_2$$

$$N_2 I_2 - N_2 I_1$$

$$N_2 (I_2 - I_1)$$

$\frac{\text{Transformed V.A}}{\text{Input V.A}} = \frac{(V_1 - V_2) I_1}{V_1 I_1}$

$$= 1 - K$$

Conduction V.A. = Input VA. − Transformed V.A

$$= V_1 I_1 - (V_1 - V_2) I_1$$

$$= V_2 I_1$$

$\frac{\text{Conduction V.A}}{\text{Input V.A}} = k$

2 winding transformer   m KVA

Auto T/F   m KVA

Weight $\propto N \cdot I$ $(\because I = neAV_d)$

$\Rightarrow$ Weight of Auto T/F

$\propto \cancel{N_1 I_1} \; (N_1 - N_2) I_1 + N_2 (I_2 - I_1)$

$(\because N_1 I_1 = N_2 I_2)$

$\propto 2 N_1 I_1 - 2 N_2 I_1$

$\Rightarrow$ ~~weight of 2 winding T/F. $\propto$~~

$\propto N_1 I_1 + N_2 I_2$

$\propto 2 N_1 I_1$

$\frac{\text{Weight of A T/F}}{\text{weight of 2W T/F}} = \cancel{2N_1I_1} (1 - k)$

Saving:—

Wt. of 2wdg T/F — Wt. of A T/F

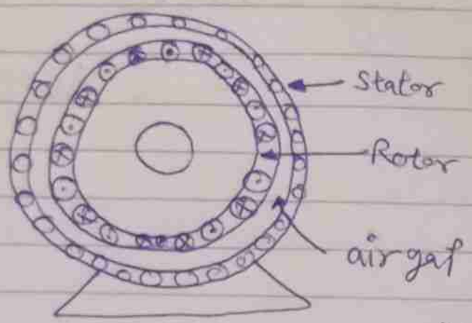
$= K \cdot$ Wt. of 2wdg T/F

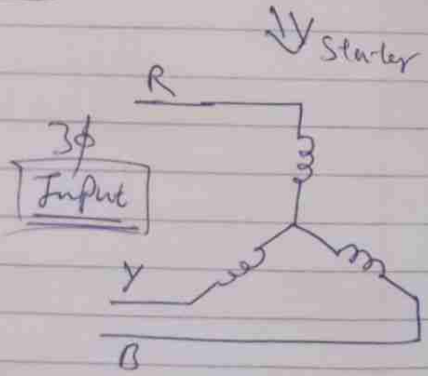
Three phase Induction Motor

Generalized transformer

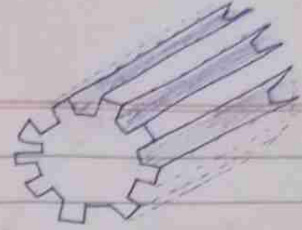
1. Stator
2. Rotor

Stator frame which houses the Stator wdg. mounted Core
↓
laminated (High grade alloy steel)
↳ responsible for producing rotating magnetic field

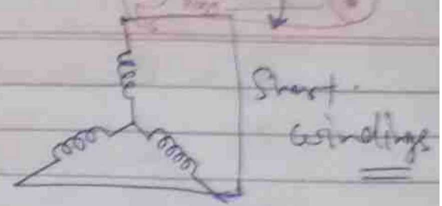




2. Rotor
   (a) Cage Rotor
   (b) Wound Rotor

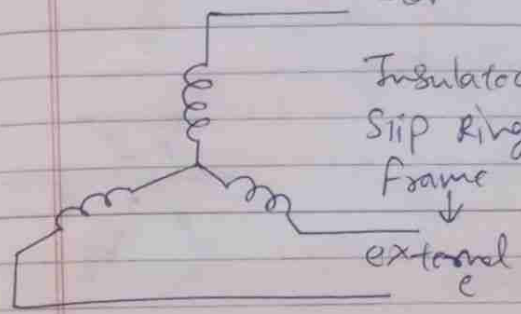


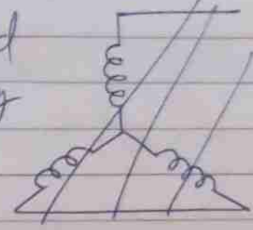
Cage Rotor

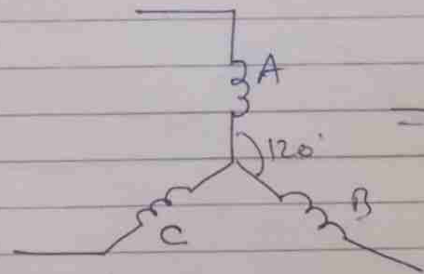


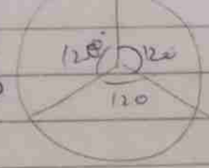
~~Wound Rotor~~

Wound Rotor

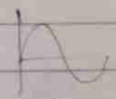








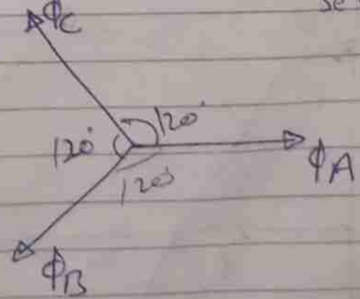
use it for set flux direct



$V_1 = V_m \sin \omega t$

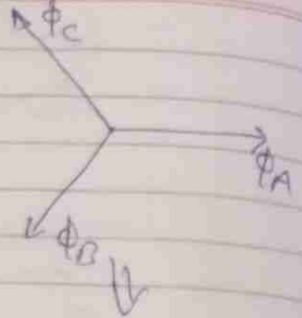
$V_2 = V_m \sin(\omega t - 120)$

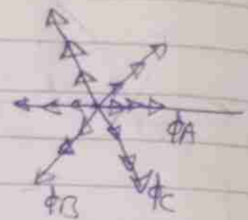
$V_3 = V_m \sin(\omega t - 240)$

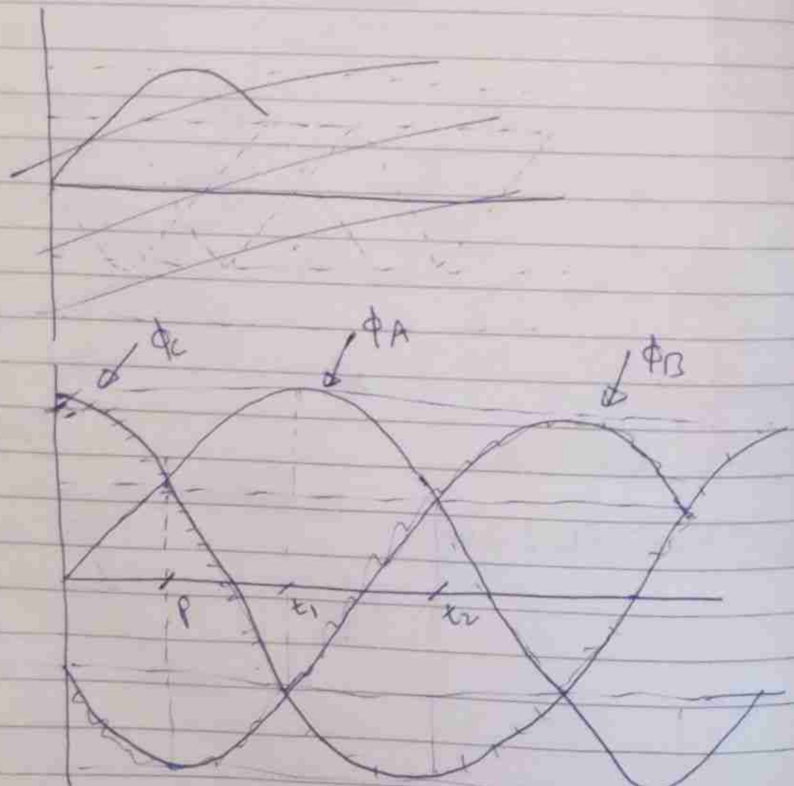


Rotating Flux:

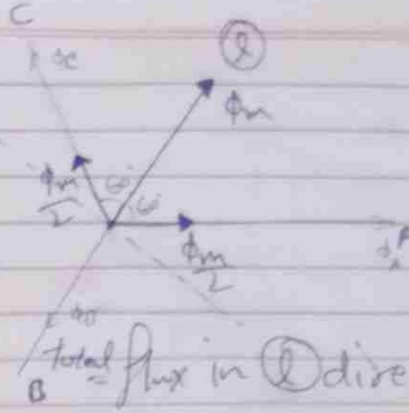
$$\phi_A = \phi_m \sin\omega t$$
$$\phi_B = \phi_m \sin(\omega t - 120^\circ)$$
$$\phi_C = \phi_m \sin(\omega t - 240^\circ)$$







at (P)

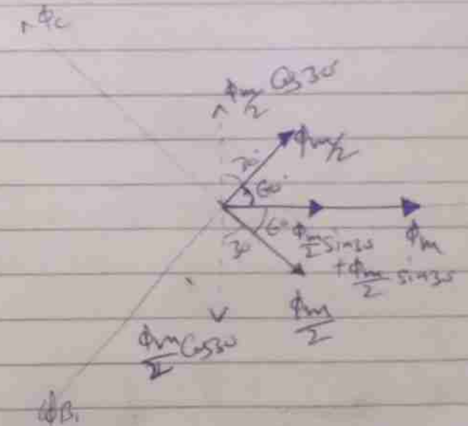


total flux in (P) direction ~~flux~~

$$\phi_{Resultant} = \phi_m + \frac{\phi_m}{2} \times \frac{1}{2} + \frac{\phi_m}{2} \times \frac{1}{2}$$

$$\phi_{Resultant} = \frac{3\phi_m}{2}$$

at (t_1)

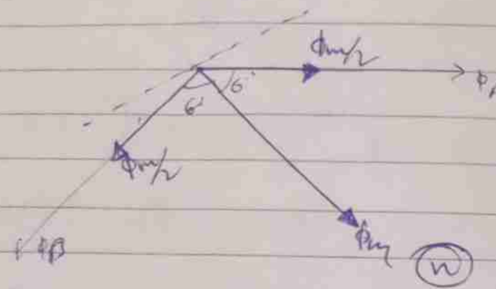


total flux in (m) direction

$$\phi_R = \phi_m + \frac{\phi_m}{2} \times \frac{1}{2} + \frac{\phi_m}{2} \times \frac{1}{2}$$

$$= \frac{3\phi_m}{2}$$

at t_2



Total flux Resultant in (w) direction.

$$\phi_R = \phi_m + \frac{\phi_m}{2}\times\frac{1}{2} + \frac{\phi_m}{2}\times\frac{1}{2}$$

$$= \frac{3}{2}\phi_m$$

Rotating flux

Reason

1. 120° space in winding
2. 3ϕ voltage in 120° phase

→ Resultant sum of ϕ_A, ϕ_B, ϕ_C is $\frac{3\phi_m}{2}$ at any time

in mathematical

$$(\phi_R)_{30^\circ} = |\phi_A| + |\phi_B| + |\phi_C|$$

$$= |\phi_m \sin 30| + |\phi_m \sin(30-120)| + |\phi_m \sin(30-240)|$$

$$= \frac{3}{2}\phi_m$$

flux Rotating speed/Synchronous speed

$$\boxed{N_s = \frac{120 f}{P}} \text{ rpm}$$

f → Supply frequency

P → No. of poles

N_s → Synchronous Speed

$$\boxed{N_s = \frac{2f}{P} \text{ rps}}$$

Rotor speed to no caught flux speed
↓
Synchronous & Asynchronous
↓
Rotor caught flux speed

⇒ Slip speed (S) = $n_s - n_r$

n_s → Synchronous speed of magnetic flux

n_r → Speed of rotor

Slip/unit slip or fractional slip

$$S = \frac{n_s - n_r}{n_s}$$

$$\% S = \frac{n_s - n_r}{n_s} \times 100$$

n_s = rps, N_s = rpm

#

rotor freq. $f_1 = \frac{(n_s - n_r)P}{2}$ } it is freq. of rotor emf.

$f_1 = \frac{(n_s - n_r)P\, n_s}{2\, n_s}$

$f_1 = Sf$

Q A 3ϕ, 6 pole, 50 Hz induction motor has a slip 1% at no load and 3% at full load Determine

(a) Synchronous speed

(b) no load speed

(c) full load speed

(d) frequency of rotor current at Stand still

(e) frequency of rotor current at full load

Soln (a) $N_s = \frac{120 f}{P}$ rpm

$= \frac{120 \times 50}{6} = 1000$ rpm

(b) $\% S = \frac{n_s - n_r}{n_s} \times 100$

$\% S = \frac{N_s - N_r}{N_s} \times 100 = 1$

$\frac{1000 - N_r}{1000} = \frac{1}{100}$

$990 = N_r$

$N_r = 990$ rpm

(c) $\% S = 3 = \frac{N_s - N_r}{N_s} \times 100$

$3 = \frac{1000 - N_r}{1000} \times 100$

$N_r = 970$ rpm

(d) 50 Hz

(e) $f_1 = \frac{3}{100} \times 50 = 1.5$ Hz

3φ Induction Motor

↳ Generalized T/F

T/F.	3φ IM.
(1) Primary	(1) Stator
(2) Concentrated	(2) Distributed
(3) Stationary flux	(3) Rotating flux (N_s)
(4) $E_1 = \sqrt{2}\pi f N_1 \phi_m$	(4) $E_s = \sqrt{2}\pi f N_1 K w_1 \phi_m$
(5) Low Reluctance Path for mutual flux	(5) high reluctance path for mutual flux
(6) 2 to 5% of full load Current	No load Current (6) 40 to 50% of full load Current
(7) Rotor emf $E_2 = \sqrt{2}\pi f N_2 \phi_m$	(7) $E_R = \sqrt{2}\pi f_1 N_2 K w_2 \phi_m$ ⇓ $f_1 = Sf$

$S = 1$ (stand still)
$S = 0$ (when ~~Rotor~~ Synchronous speed of rotor)
$S = -ve$ (when rotor Rotate in oposit direc

E_2 (at Stand Still Rotor)

$$\boxed{E_{2r} = SE_2}$$

X_2 (at stand still)

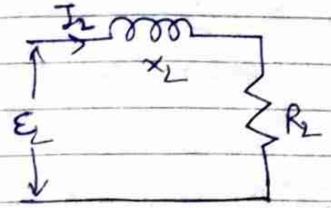
X_{2r} (rotor rotating)

$X_{2r} = SX_2$

⇓

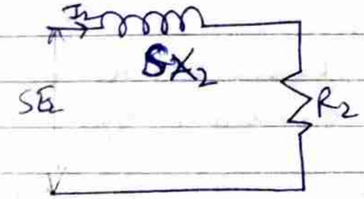
$2\pi f L$

Circuit at Stand still



$$I_2 = \frac{E_2}{\sqrt{R^2 + X_2^2}}$$

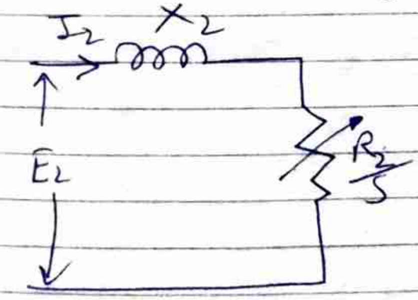
at Rotating.



$$I_2 = \frac{SE_2}{\sqrt{R_2^2 + (SX_2)^2}}$$

$$= \frac{E_2}{\sqrt{\left(\frac{R_2}{S}\right)^2 + X_2^2}}$$

⇓



⇒ Power transfer to Rotor $P_g = E_2 I_2 \cos\theta$

$$\cos\theta = \frac{R}{Z}$$

$$P_g = E_2 I_2 \cdot \frac{R_2/S}{\sqrt{(R_2/S)^2 + X_2^2}} = \frac{I_2^2 R_2}{S}$$

$$P_g = \underbrace{I_2^2R_2}_{\text{Loss of Rotor}} + \underbrace{\frac{I_2^2 R_2}{S} - I_2^2R_2}_{\text{Mechanical Power of Rotor}}$$

$$P_g = \frac{SI_2^2R_2}{S} + \frac{I_2^2R_2}{S}(1-S)$$

$$P_g = SP_g + (1-S)P_g$$

Torque $T_e = \frac{\text{Mechanical Power}}{\text{angular Speed}}$

$$T_e = \frac{P_m}{\omega_r} = \frac{(1-S)P_g}{\omega_r}$$

$$S = \left(\frac{N_s - N_r}{N_s}\right) = \frac{2\pi N_s - 2\pi N_r}{2\pi N_s}$$

$$S = \frac{\omega_s - \omega_r}{\omega_s}$$

$$\omega_r = (1-S)\omega_s$$

$$\boxed{T_e = \frac{P_g}{\omega_s}}$$

Angular speed of

Stator

T_e

$$T_e = \frac{I_2^2R_2}{S(2\pi N_s)}$$

RPM

$\therefore \frac{N_s}{60} = n_s$??

$$T_e = \frac{I_2^2R_2}{S(2\pi n_s)}$$

Starting of Inducting motor :-

depend on :-

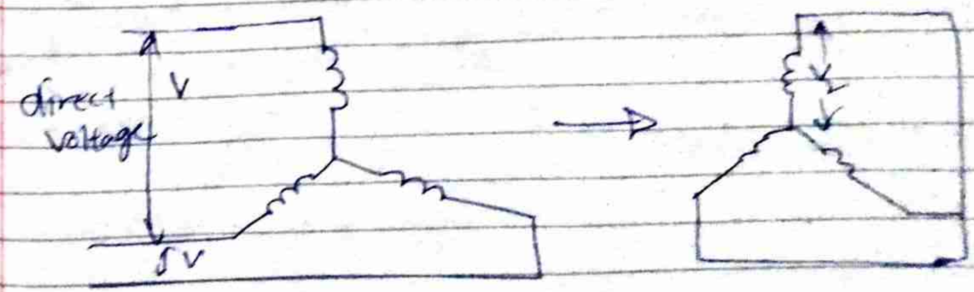
1. Size & design of motor
2. Capacity of Transmission line
3. Driven load

Start :-

(a) Rated voltage (when size is low)

(b) Reduced voltage (size is big)

(A) DOL (Direct online starting) :-



$$\frac{T_{st}}{T_{fl}} = \frac{\text{Starting torque}}{\text{full load Torque}} = \frac{I_{2s}^2 R_2 \cdot 1}{s} \left(\frac{1}{2\pi n_s}\right)$$

$$\frac{I_{2fl}^2 \cdot R_2 \times 1}{2\pi n_s} \cdot \frac{1}{S_{fl}}$$

(S=1 at Starting)

$$\frac{T_{st}}{T_{fl}} = \left(\frac{I_{2s}}{I_{2fl}}\right)^2 \cdot S_{fl}$$

$I_{1sc} \times$ Effective no. of turns in Stator

$= I_{2sc} \times$ Effective No. of turns in Rotor,

$$\boxed{I_1 \times N_1 = I_2 \times N_2}$$

$I_{1fl} \times$ Eff. No of turns in Stator $= I_{2fl} \times$ Eff. No of turns in Rotor

$$\boxed{\frac{I_{1st}}{I_{1fl}} = \frac{I_{2st}}{I_{2fl}}}$$

$Z_1 \Rightarrow$ Total Per phase Impedance of motor

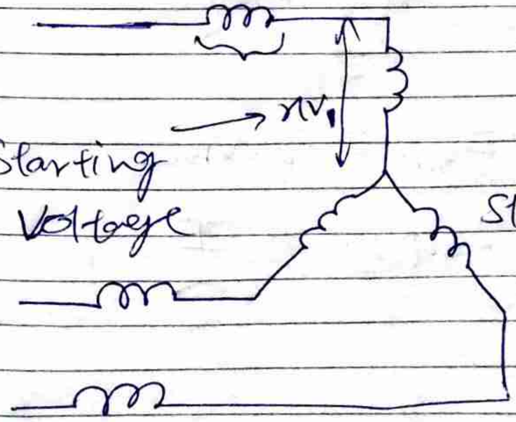
$$I_{sc} = \frac{V_1}{Z_1}$$

Rotor in Short | $I_1 = I_{sc}$

Sc = Short Current

(B) Series Reactor :- Reduce Starting Current we use Series Reactor

$x < 1$



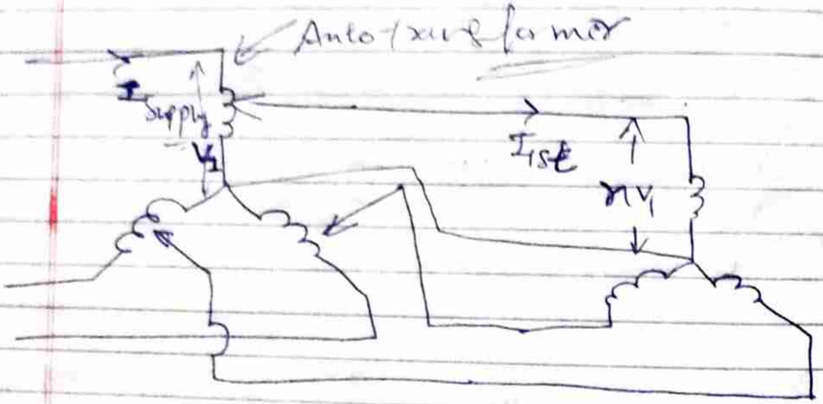
$I_{st} \Rightarrow \frac{xV_1}{Z_1}$

Starting Current

$$\boxed{I_{st} = x\, I_{sc}}$$

$$\frac{T_{st}}{T_{fl}} = x^2\left(\frac{I_{sc}}{I_{fl}}\right)^2 \cdot S_{fl}$$

(c) Auto transformer:-



$$I_{st} = \frac{xV_1}{Z_1} = I_{sc}$$

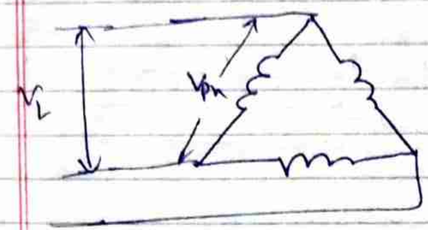
$$V I_{supply} = xV_1 \cdot \cancel{I_{sc}} = xV_1 \cdot I_{st}$$

$$\boxed{I_{supply} = x^2 I_{sc}}$$

$$\frac{T_{st}}{T_{fl}} = \left(\frac{x I_{sc}}{I_{fl}}\right)^2 \cdot S_{fl}$$

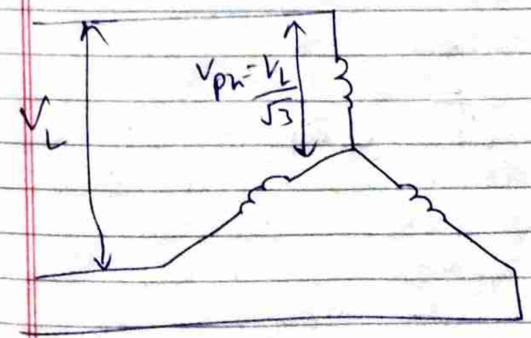
$$= \frac{1}{x^2}\left(\frac{I_{supply}}{I_{fl}}\right)^2 S_{fl}$$

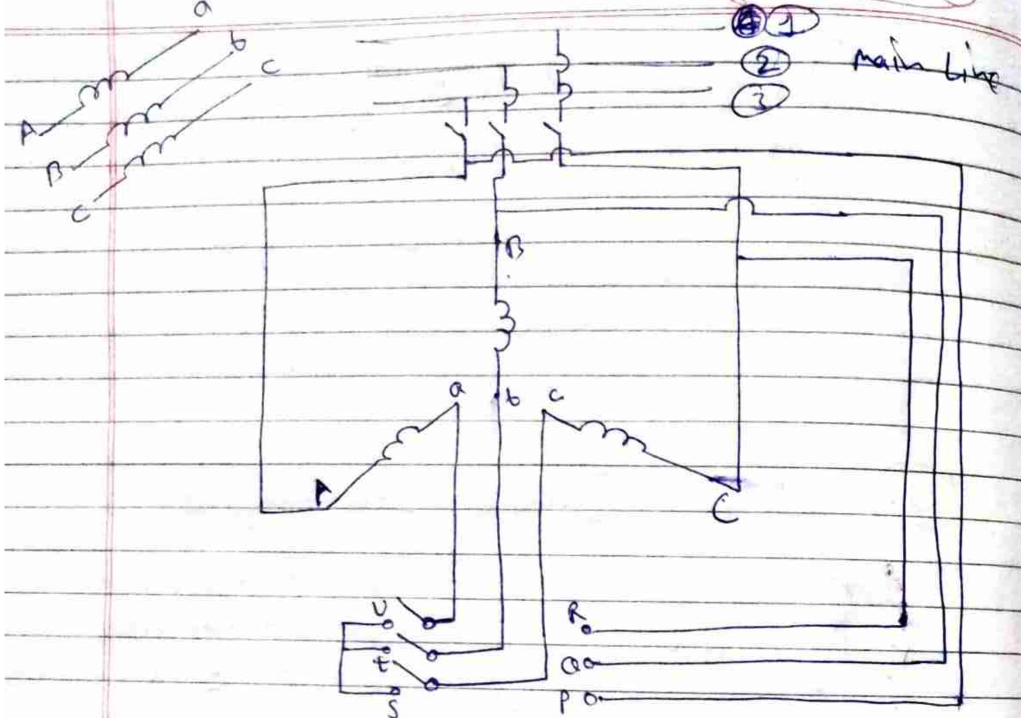
(d) Star Delta Starting:-



When motor is large size then his ~~stator~~ winding connected in Δ

use it for rating growth





In Star

$$I_{\lambda} = \frac{V_L}{\sqrt{3}} \times \frac{1}{Z_1}$$

$$I_{SC} = \frac{V_L}{Z_1}$$

$$\boxed{I_{\lambda} = \frac{I_{SC}}{\sqrt{3}}}$$

In delta

$$I_{\Delta} = \frac{V_L}{Z_1} = I_{SC}$$

$$I_{\Delta} = \sqrt{3}\, I_{SC}$$

$$\frac{I_{\lambda}}{I_{\Delta}} = \frac{1}{3}$$

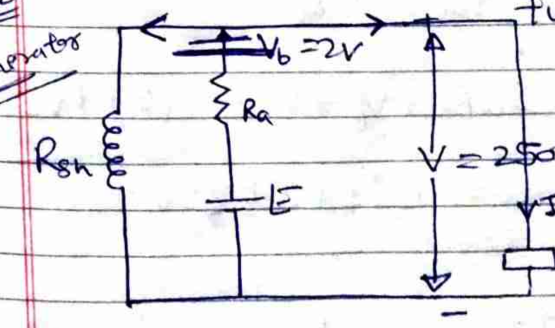
Q A Shunt generator delivers 50kw at 250V when running at 400 rpm. The armature and field resistance are 0.02Ω and 50Ω respectively. Calculate the speed of machine when running as a Shunt motor and taking 50kw input at 250V allow 1V per brush for contact drop.

Soln

in nothing given about brush then assume two brush is taken

$V_b = 1 \times 2 = 2V$

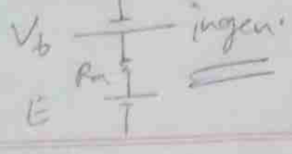
In generator



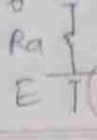
$P = VI$

$$I = \frac{50000}{250}$$

$= 200A$



in gen.



in Mo.

Speed $N = 400 = \frac{120f}{P}$

$R_a = 0.02\,\Omega$

$R_{sh} = 50\,\Omega$

$I_{sh} = \frac{250}{50} = 5$

$I_a = 200 + 5 = 205A$

in gen $E_1 = \phi_1 n_1 Z \frac{P}{A}$

in Mo. $E_2 = \phi_2 Z n_2 \frac{P}{A}$

$\frac{E_{gen}}{E_{mo}} = \frac{\phi_g}{\phi_m} \times \frac{n_g}{n_m}$

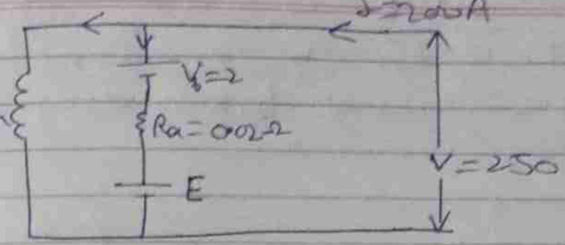
$E_{gen} = I_a R_a + V_b + V$ (by KVL)

$= 205 \times 0.02 + 2 + 250$

$= 256.1V$

252
4.10
256.1

if generator working as shunt motor



$R_{sh} = 50\,\Omega$

$I_{sh} = \frac{250}{50} = 5A$

$I_a = \cancel{195}\ 200 - 5 = 195A$

$E_{Mo} = V - I_a R_a - V_b$

$= 250 - 195 \times 0.02 - 2$

$= 244.1\,V$

250
5.90
244.10

$\frac{E_g}{E_M} = \frac{I_{shg}}{I_{shm}} \times \frac{n_g}{n_m}$

b/z $I_{shg} \propto \phi_g$

$\frac{E_g}{E_M} = \frac{\phi_g}{\phi_m} \times \frac{n_g}{n_m}$

$\phi_g = \phi_m$

b/z R_{sh} की Current same h

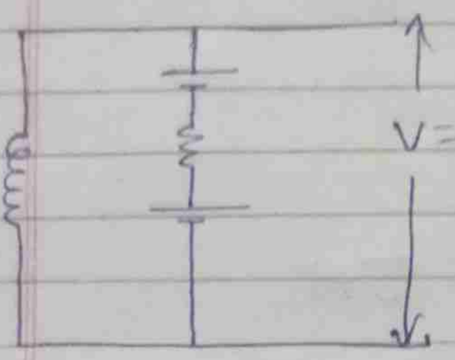
$\frac{E_g}{E_m} = \frac{n_g}{n_m}$

$\frac{256.1}{244.1} = \frac{400}{n_m} = \frac{400}{N_m}$

$= N_m = \frac{400 \times 244.1}{256.1} = 381.25$ rpm

Q2. A 4 Pole, 500V d.c. Shunt motor has 700 Wave Connected Conductor on its armature. The full load armature Current is 60A and flux per pole is 30mWb. Calculate the full load speed if the motor armature resistance is 0.2 Ω and brush drop is 1V/brush.

Soln



P=4
Z=700
Ia=60A
Φ=30mWb
Ra=0.2 Ω
n=?
A=2 (wave Connected)
Vb=2V

$$E = V - I_a R_a - V_b$$
$$= 500 - 60 \times 0.2 - 2$$
$$= 486V$$

12
500
486

$$E = \frac{\phi Z n P}{A}$$

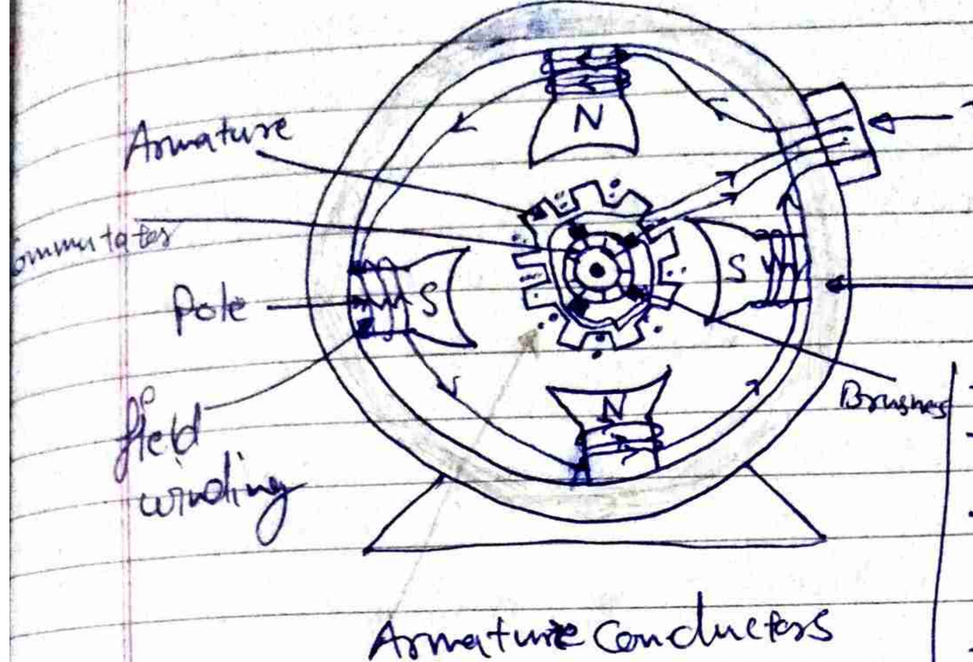
$$E = 486 = \frac{30 \times 10^{-3} \times 700 \times 4 \times n}{2}$$

$$n = 11.$$

$$N = n \times 60$$
$$= 694.2857143$$

Construction of DC Machines :-

initial cond AC/DC (M)



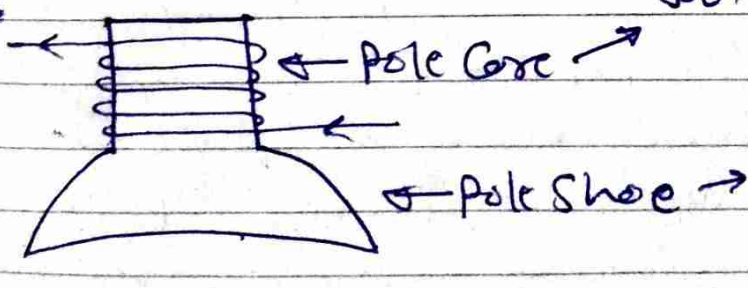
Yoke
↓
→ protactive Cover
→ protact all Compunents
→ It's give mechanical support to the poles
→ it's make from Cast iron

Pole !- two parts:-

① Pole Core ② Pole shoe

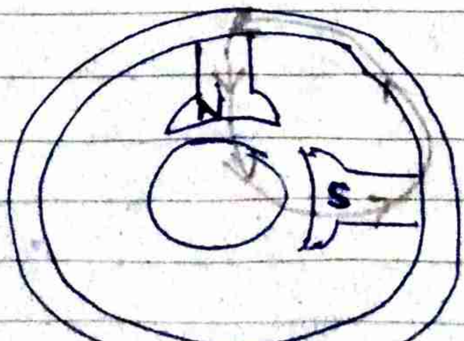
Cast iron/ Cast Steel

Job:- To Carry field winding



it's Covers max. Area of armature

direction of flux in DC Machine

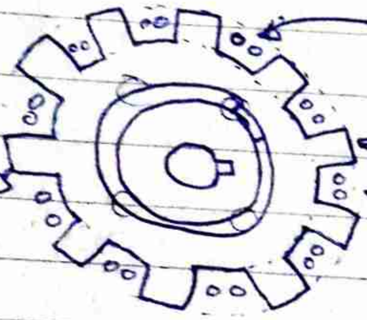


→ Pole make by thin sheets

field winding :- → It is a coil wire
→ it's responsible for flux
→ all windings are connecting in series
→ it's making from Copper

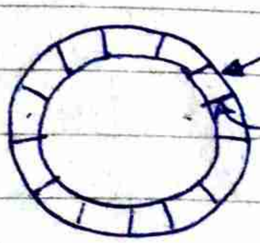
Armature
Emf. induced in ← made up of Copper

→ Cast iron
→ thin leminations



Armature Conductor
Armature
Armature Slots

Commutator :-
→ it is mechanical rectifier
→ it is made up from Copper segments



mica insulation

work :- Take voltage and current from out side and give it armature

Brushes:-
→ it is made up from Carbon

→

DC Generator Principle:-

Principle of operation of DC Generator is faraday's law of electromagnetic induction.

→ Dynamically induced emf, $e = \frac{d\phi}{dt}$
→ Relative Motion b/w Conductor and flux.

ways:-
① Flux is stationary, Conductor is moving.
② Conductor is Stationary, flux is moving.

(in DC generator)

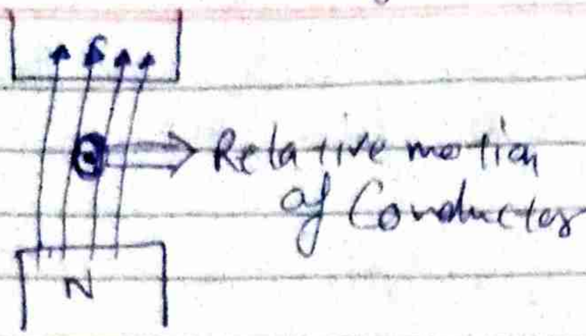
(in AC generator)

→ Conductor can be rotated with the help of prime mover
ex:- Diesel Engine, Steam turbine, Diesel turbine etc.

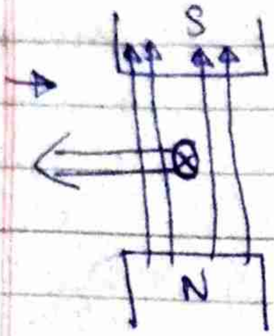
→ fleming's right hand rule is use to check direction of induced e.m.f. in Coil

⇒ Direction of induced emf.

→ Current Coming out



→ Current going inside plane



→ magnitude of induced E.M.f.

$e = Blv\sin\theta = E_m\sin\theta$ Volts

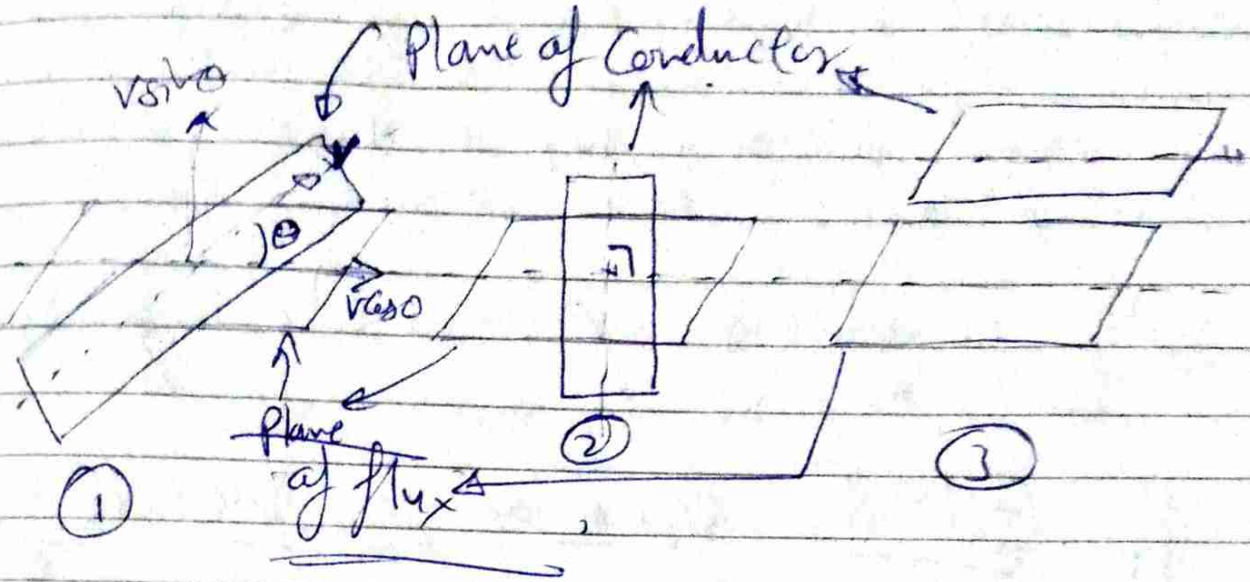
B = flux density (wb/m^2)

l = active length of Conductor (m)

v = relative velocity of Conductor w.r.t. Magnetic flux (m/s)

θ = angle b/w two Planes (Plane of Rotation & Plane of magnetic flux measured from axis of plane of flux)

→ magnitude of emf. depends on ⊥ar compont of relative velocity of conductor



1

$E \propto v \sin\theta$

⇓

⊥ar component of V

2

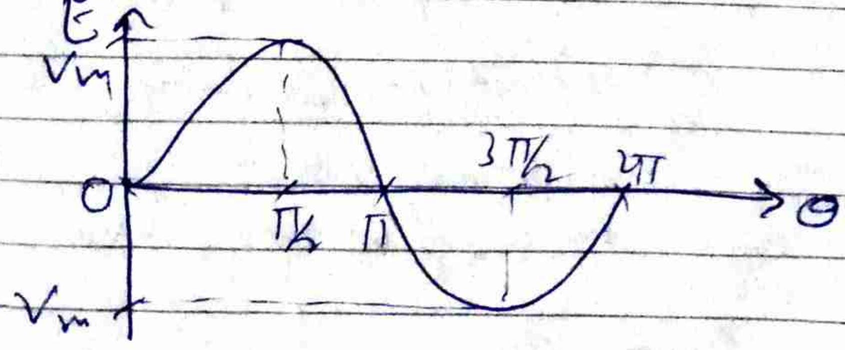
$\theta = 90°$

E is max.

3

$\theta = 0°$

E is zero



⇒ Commutator :- a device is used in dc generator to convert ~~ac~~ alternating induced emf. to unidirectional d.c. e.m.f. (Mechanical Rectifier)

→ The Commutator is the essential part of a dc. machine used for reversing the direction of current. It is made up of wedge-shaped hard drawn copper wires

→ it Convert AC ⟶ dc in dc machine

E.M.F. equation for D.C. Generator

let. P = Number of poles of the generator
ϕ = flux produced by each pole (wb)
N = speed of armature of generator (rpm)
Z = total no. of Conductors in armature.
A = No. of ll^{al} path in which armature Conductor's are distributed.
e = Rate of cutting flux.

$$e = \frac{d\phi}{dt} \quad \text{--- (1)}$$

as per Faraday's law of Electromagnetic induction

Total flux = flux produced by eachpole X No of Poles

$\Rightarrow$ total $(\phi) = \phi \times P$

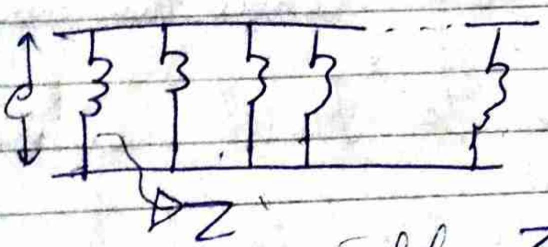
$\Rightarrow$ Time required for a Conductor to complete 1 revolution.

$T = \frac{1}{f}$

$f = \frac{N}{60}$

$$T = \frac{60}{N} \text{ (sec)}$$

$$e = \frac{\phi P}{\left(\frac{60}{N}\right)} = \frac{\phi P N}{60} \quad \text{(only for one Conductor)}$$



Eff. $\frac{Z}{A}$ Conductor need to multiplied with emf induced in one Conductor

$$E = e \times \frac{Z}{A} = \frac{\phi P N Z}{A 60}$$

DC Machine :-

⇒ Electromechanical Conversion

(1) Mechanical Energy $\xrightarrow{\text{generator}}$ Electrical energy

Motor

⇒ Type

(1) A.C. machine :- works on A.C. Current

(2) D.C. Machine :- works on DC Current

Types of D.C. generator :-

→ Types depend on Connection on field winding.

→ Excitation to field winding

Type :- (1) Separately Excited

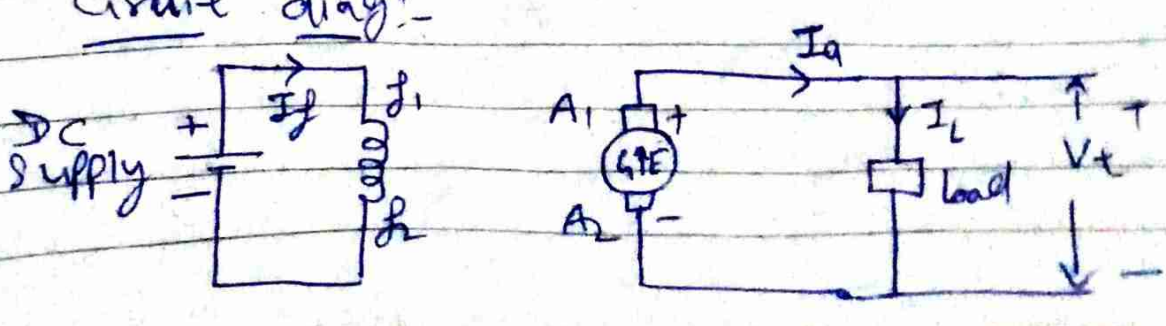
(2) Self Excited

(a) Shunt generator

(b) Series generator

(1) Separately Excited generator :-

Circuit diag :-



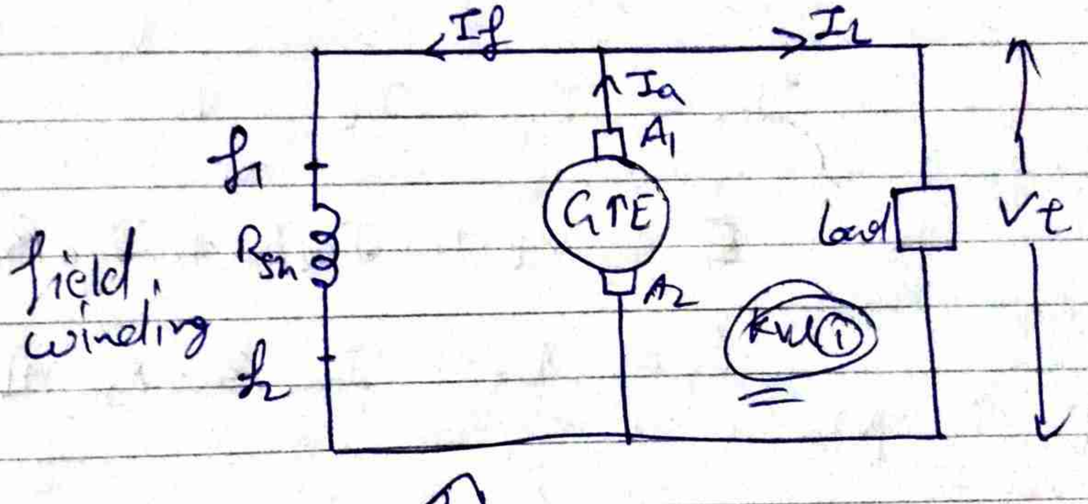
Voltage & Current Relation

$I_a = I_l$ — I_a = Armature Cur.

$E = V_t + I_a R_a + V_{brush}$ — R_a = armature Risis.

Brushs se hone bala drope

② (a) Shunt generator :-



field winding Shunt with armature so it's Called Shunt generator.

Voltage V/s Current

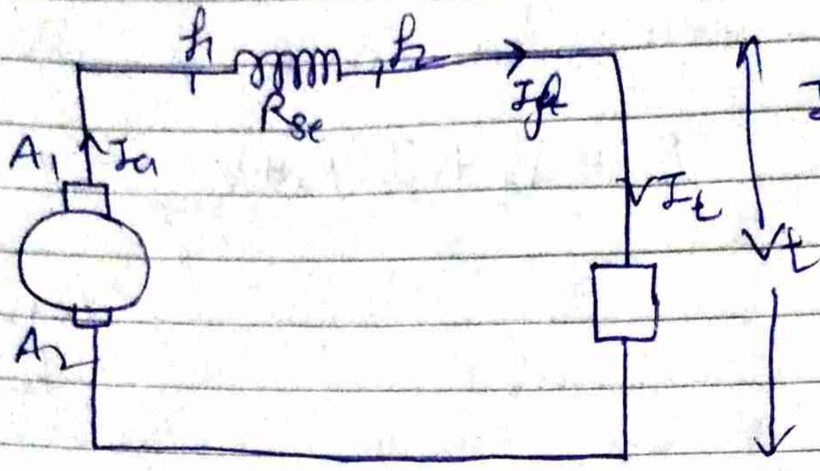
$I_a = I_f + I_l$

$I_f = \frac{V_t}{R_{sh}}$

KVL① $E = V_t + I_a R_a + V_{brush}$

Page

(3) Series Generator :-



$I_a = I_f = I_L$

Voltage V/s Current

$I_a = I_f = I_L$

$E = V_t + I_a R_a + I_a R_{se} + V_{brush}$

$E = V_t + I_a(R_a + R_{se}) + V_{brush}$

(2) D.C. Motor :-

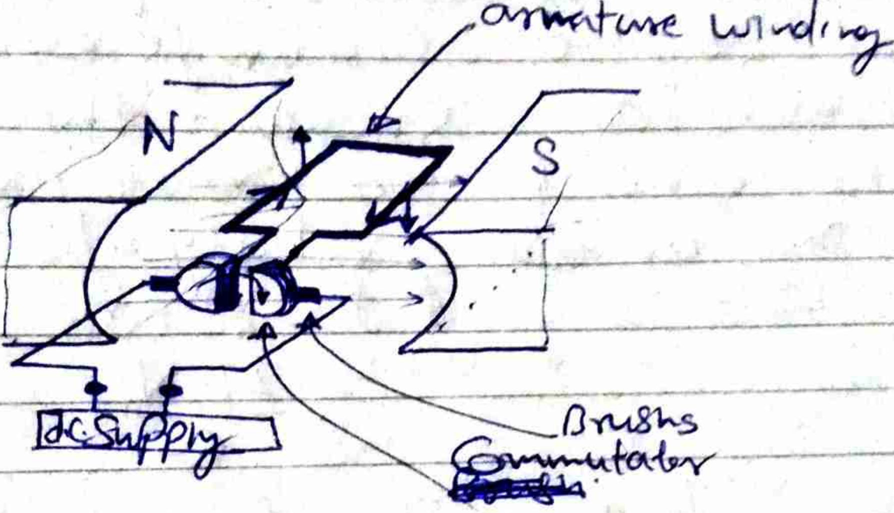
Working principle of D.C. Motor

When a current carrying conductor is placed in a magnetic field; it experiences a mechanical force.

→ Convert it Electrical Energy to mechanical Energy

Parts:-

1. Stator
2. Rotor
3. field winding
4. Armature winding
5. Commutator
6. Brushes

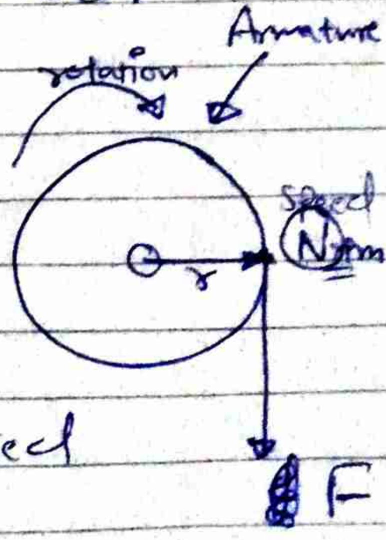


Torque Equation for d.c. motor

~~Consider~~ ~~a~~

$f = N/60 = n$

$\omega = \frac{2\pi N}{60}$



$\text{Torque}(T) = F \times r \quad N.m$

$W = F \times \text{distance moved}$

$W = F \times 2\pi r$

$\text{Power} = \frac{W}{t} = \frac{2\pi r \times F}{(60/N)}$

Nand
Date
Page

$$\cancel{P = (F\times r)\,\frac{2\pi N}{60}}$$

$$\cancel{P = \tau \times \frac{2\pi N}{60}}$$

Consider a wheel of radius r(m) acted on by a circumferential force F (Newton) as shown. the force F causes the wheel to rotate at N rpm.

The angular velocity of wheel is

$$f = \frac{N}{60} = n$$

$$\omega = \frac{2\pi N}{60}$$

Torque $T = F \times r$

W = F × distance moved

$W = F \times 2\pi r$ Joules

Power developed $P_1 = \frac{\text{work done}}{\text{time}}$

$$= \frac{F \times 2\pi r}{60/N}$$

$\left(\because \text{rpm} = 60,\ \text{rps} = \frac{N}{60} \because 1 \text{ rev } \frac{60}{N}\right)$

$$P_1 = (F\times r)\cdot\frac{2\pi N}{60}$$

$$= T \times \frac{2\pi N}{60}$$

The torque developed by a dc motor is obtaines by looking at the Electrical power supply to it and mechanical power produced by it. It's also called armature torque. the gross mechanical power developed is $E_b \cdot I_a$, then

Power developed in armature = Power at outpt

$$E_b \times I_a = T \times \frac{2\pi N}{60}$$

when $E_b = \frac{\phi Z N P}{A 60}$

$$\frac{\phi Z N P}{60 A} \times I_a = T \times \frac{2\pi N}{60}$$

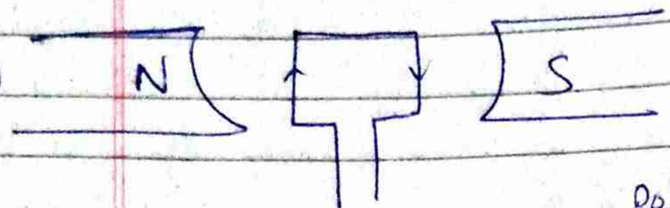
$$T = \frac{P Z \phi I_a}{2\pi A} \ (N \cdot m)$$

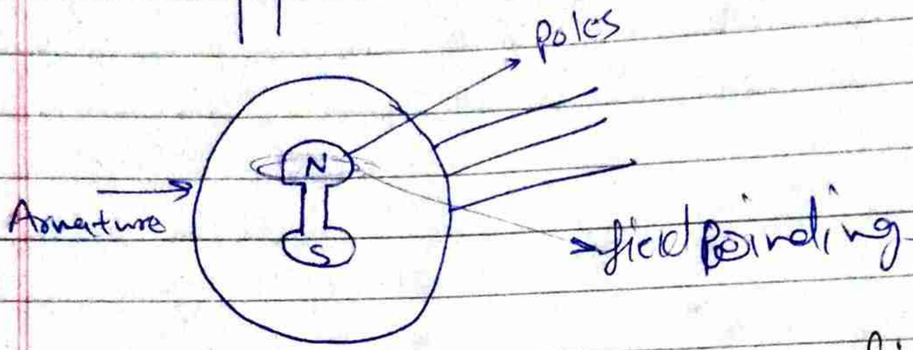
$$\boxed{T = 0.159 \phi I_a Z \left(\frac{P}{A}\right)} \ Nm$$

Hence the torque developed by a d.c motor is directly proportional to the flux per pol and armature current

$$\boxed{T \propto I_a \phi}$$

Alternator (Synchronous Generator / A.C. Generator)

① 

② 

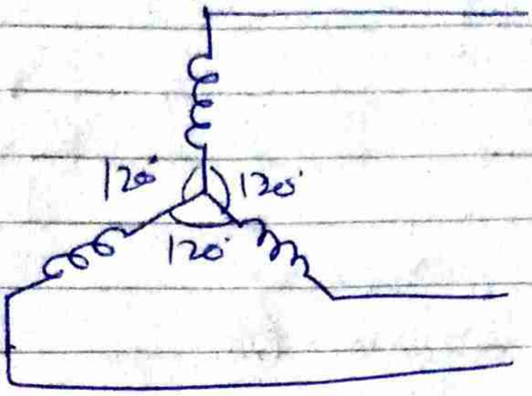
Advantages of Rotating field Alternator

→ Insulation Easy on armature winding
→ No vibration & other dis~~tur~~turbanes
→ O/P, No slip Rings and brushes in armature
→ Two slip Rings are Required for dc input
→ Size of machine is reduced (Arm. winding > field winding in machines)
→ High speed rotation (depend on weight)
→ Cooling is Easy. (Arm. heat)

⇒ use prime mover in rotating field winding
⇓
hydro turbines, steam turbines

⇒ Excitation System is use ~~to give~~ ∈ in AC generator. It gives current from field winding.

⇒ Arm. winding :-



Excitation System type:-

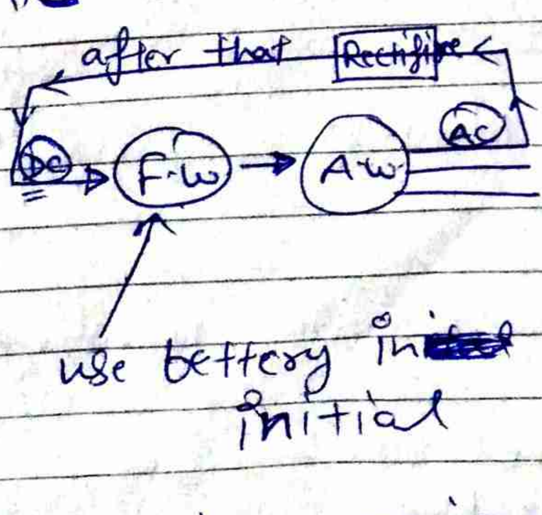
① DC Excitation :-

⇒ Pilot Exiter → Main Exitor $\xrightarrow{DC}$ Alternator field winding

(Smalest) → has permanent megnets

(middle)

② AC- Excitation:-

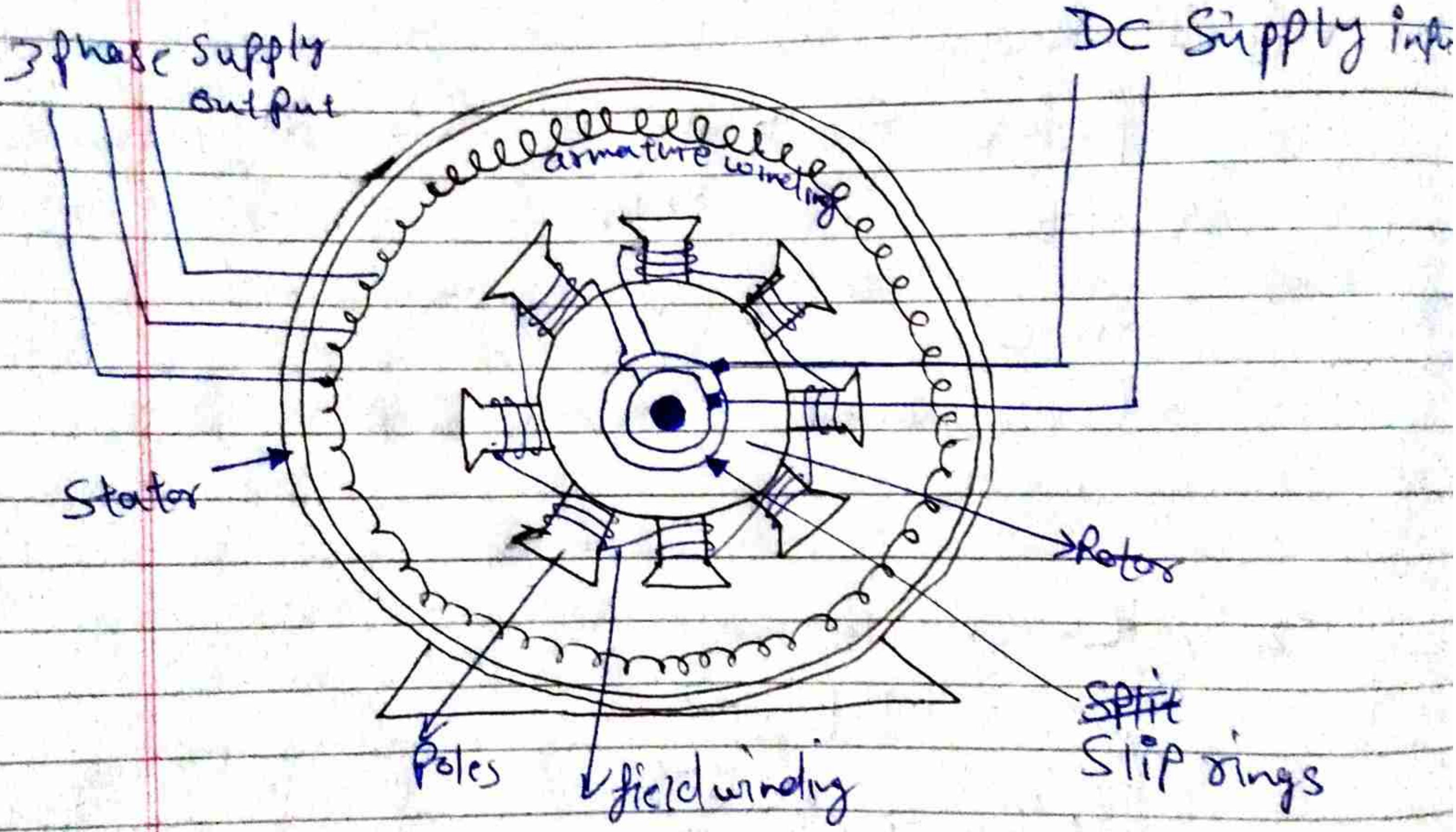


use bettery in initial

③ Brush less excitation System use in big generators

Parts of Generator :-

- Stator
- Rotor
  - Salient-Pole Rotor
  - Cylindrical Rotor (non Salient Pole Rotor)



① Stator :-

Parts :- Frame, Core, windings, Cooling arrangement

Frame :- Small size machine → ~~Size~~ Cast Iron

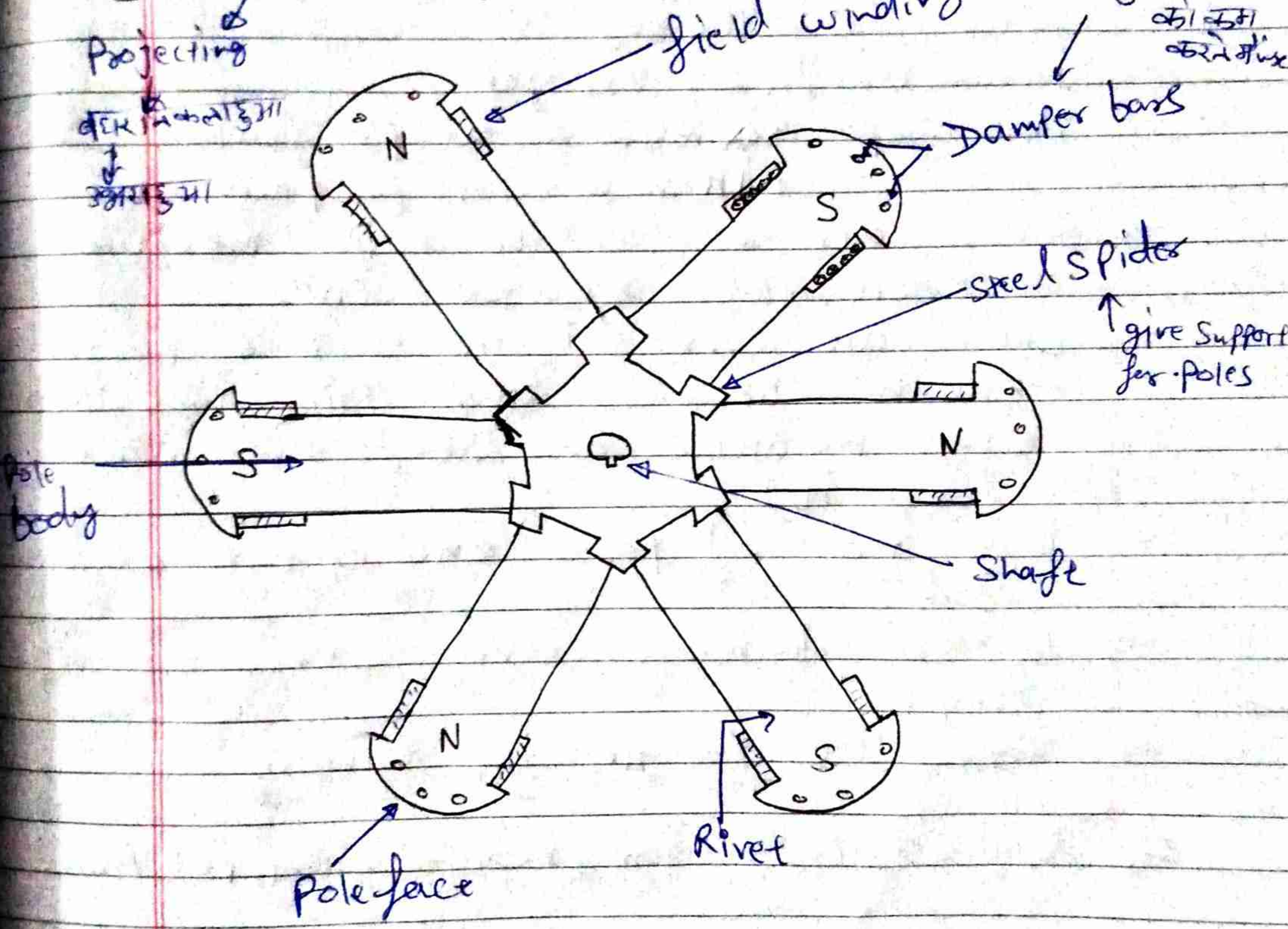
large size machine → welded steel type

turns $\xrightarrow{\text{series}}$ coil $\xrightarrow{\text{Series}}$ winding

→ Armature winding are Connected in Star

① Salient-Pole Rotor:-

Projecting



→ Max. Poles use

→ it do not gives high speed

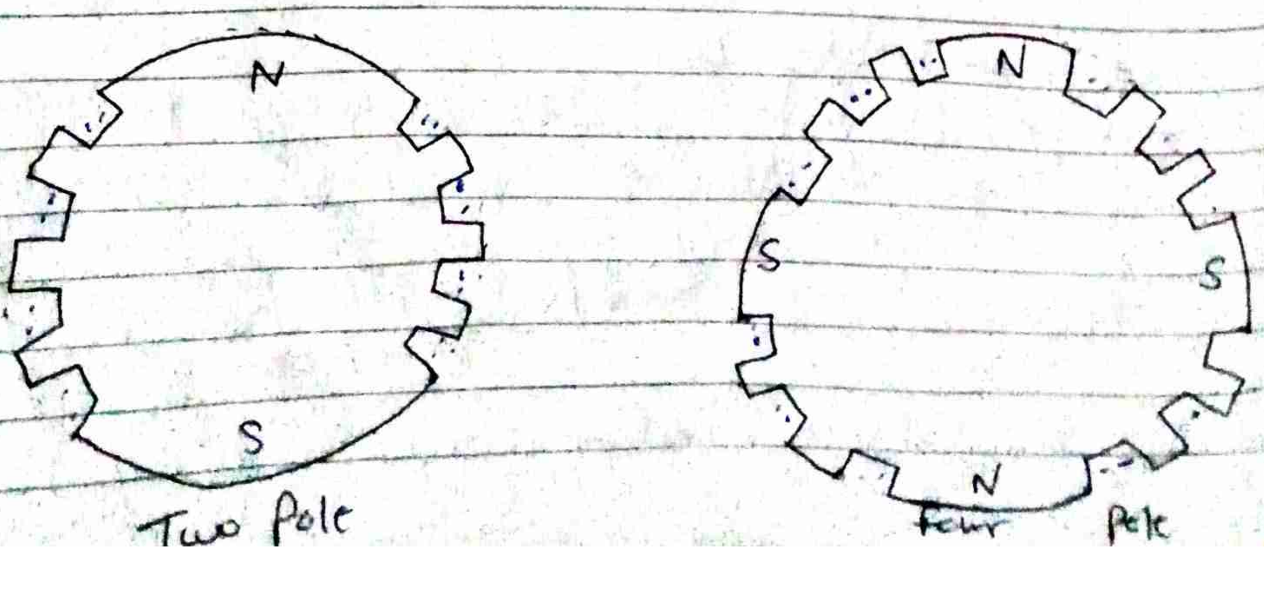
→ No. of Poles ↑ speed ↓

$$\downarrow N_s = \frac{120f}{P\uparrow}$$

→ use hydro turbine in Salien-Pole Rotor

→ To Reduce eddy Currents, thin steel laminations are used
→ Concentrated winding are used
→ Damper bars are used to damp out the rotor oscillations
→ Non-uniform air-gap
→ Air gap maximum – at pole centres
minimum – at pole faces
→ Radial air gap length helps machine to generate sinusoidal emf
→ Ends are connected to a DC source through brushes and slip rings (metal rings mounted on shaft and insulated from it)
→ large no. of poles and operate at lower speed
→ larger diameter and short axial length
→ ~~dense~~ use Concentrated winding

Cylindrical or non-Salient Pole Rotor



Two Pole

Four Pole

→ use distributed winding.
→ high grade nickel - Chrome Molybdenum
→ used in hig speed machine.
→ Greater machanical strength and more accurate dynamic balancing.

→ Steam turbines used

E.M.F. Equation of an Alternator

ϕ = useful flux per pole
P = total No. of poles
f = frequency of generated voltage (Hz)
n = speed of rotor in (rps)
Z_p = Total No. of Conductors per phase
T_p = Total No. of Coils

$n = \frac{N}{60}$

$\boxed{Z_P = 2T_P}$ in A.C. generator

~~Eav : Emf. in per Conductor~~

⇒ total flux = $P\phi$, time taken in 1 rev. = $\frac{1}{n}$ sec

$$E_{av/\text{conductor}} = \frac{P\phi}{1/n} \quad \frac{d\phi}{dt}$$

$$= Pn\phi$$

$N = \frac{120f}{P}$

$$f = \frac{PN}{120} = \frac{Pn}{2}$$

$$Pn = 2f$$

$$E_{av/\text{Conductor}} = 2f\phi$$

$$E_{av}/_{phase} = 2fZp\phi$$

$$Zp = 2Tp$$

$$E_{av}/_{phase} = 4\phi f Tp$$

form factor $= K_f = \dfrac{\text{r.m.s value}}{\text{average value}}$

Value of K_f for sine wave $= 1.11$

$$E_{rms} = K_f \times E_{av}/_{phase}$$

$$E_{rms} = 1.11 \times 4\phi f Tp$$

$$= 4.44 f Tp \phi$$

Voltage Regulation:-

The voltage regulation of a synchronous generator is the rise in voltage at the terminals when the load is reduced from full-load rated value to zero, speed and field current remaining constant

Per unit voltage Regulation

$$\triangleq \frac{|E_a| - |V|}{|V|}$$

E_a = No loaded voltage
V = terminal voltage (full load voltage)

Percente voltage Regulation

$$\triangleq \frac{|E_a| - |V|}{|V|} \times 100$$

→ it is a one type of disadvantage