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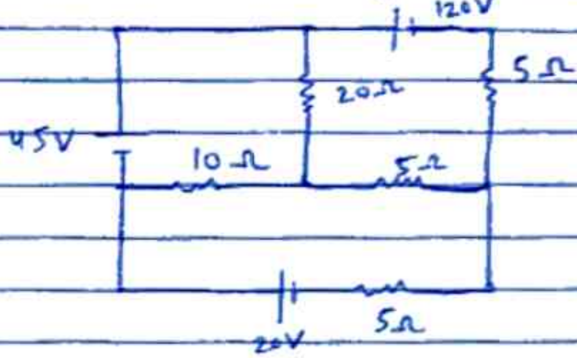
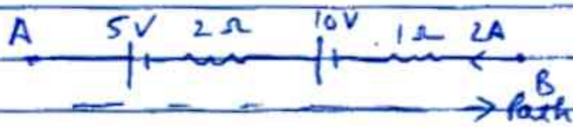
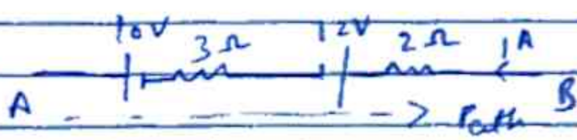
Q Determine Current through 20 Ω resistor in the circuit shown



Q Find potential diff. b/w 2 points

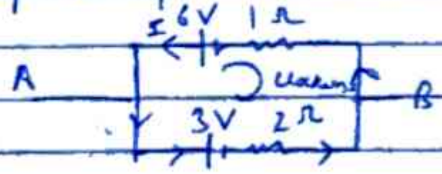


$$V_A - 5 + 2\times 2 - 10 + 2\times 1 = V_B$$
$$V_A - 8 = V_B$$
$$V_A - V_B = 8$$



$$V_A - 10 + 3\times 1 + 12 + 2\times 1 = V_B$$
$$V_A - V_B = -7$$

Q Find p.d b/w A & B



$-6 + I + 2I + 3 = 0$, $3I = 3$, $I = 1A$

$$V_A - 6 + 1\times 1 = V_B$$
$$V_A - V_B = 5$$
$$V_A - 3 - 2\times 1 = V_B$$
$$V_A - V_B = 5V$$

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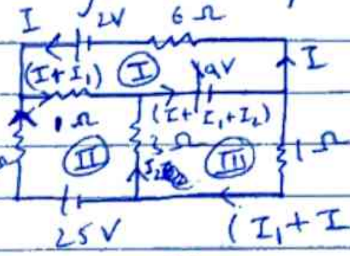
Applying KVL to loop (II)

$$-2.5I_1 - 5I_1 + 3(I - I_1) = 0$$
$$-7.5I_1 + 3I - 3I_1 = 0$$
$$3I = 10.5I_1$$
$$I = 3.5I_1$$
$$6(3.5)I_1 - 3I_1 = 12.5$$
$$18I_1 = 12.5$$
$$I_1 = \frac{125}{180}$$

$$I = 3.5 \times \frac{125}{180} = 2.43\text{ A}$$

$$\begin{array}{r} 21 \\ \times 19 \\ \hline 189 \\ 21\times \\ \hline 399 \end{array}$$

Q Find current through all loops



Clockwise

Apply KVL in Mesh (I)
$$-2 + 6I + 19 + I + I_1 = 0$$
$$7I + I_1 = 17. \quad -(1)$$

Mesh (II)
$$-2I_1 - I - I_1 - 3I_2 + 25 = 0$$
$$25 = 3I_1 + I + 3I_2$$

Mesh (III)
$$-19 - I_1 - I_2 - 3I_2 = 0$$
$$-I_1 - 4I_2 = -19$$

$$21I_1 + 21I_2 = 8$$
$$I_1 + 4I_2 = 19 \times 21$$
$$21I_1 + 21I_2 = 8$$
$$21I_1 + 84I_2 = 399$$
$$-63I_2 = -391$$
$$I_2 = \frac{391}{63} = 6.2\text{ A}$$

$7I + I_1 = 17 \quad \times 3 \quad 21I + 3I_1 = 51$

$3I_2 + I + 3I_1 = 25 \quad \times 7 \quad 3I_2 + I + 3I_1 = 25$

$7I + I_1 = 17 \qquad 21I_1 + 21I_2 = 8$

$21I_2 + 7I + 21I_1 = 25$

$-21I_2 - 21I_1 = -8$

Supermesh is when there is current source b/w 2 loops

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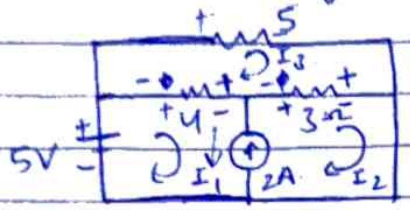
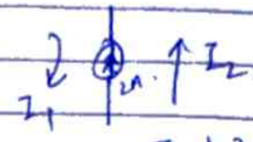
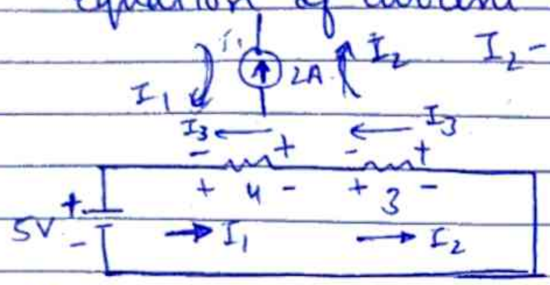
Q Find current through 5Ω using mesh analysis





$I_2 + 2 = I_1 = 0$.
$I_2 - I_1 = -2$.

Ans Equation of current source



$I_2 - I_1 = -2$ — ①

$I_2 + 2 = I_1$

$I_2 - I_1 = 2$.

Applying KVL to Supermesh

$-4I_1 + 4I_3 - 3I_2 + 3I_3 + 5 = 0$

$\therefore 7I_3 - 3I_2 - 4I_1 = -5$ — ②

Applying KVL to Loop ③

$-5I_3 - 3I_3 + 3I_2 - 4I_3 + 4I_1 = 0$

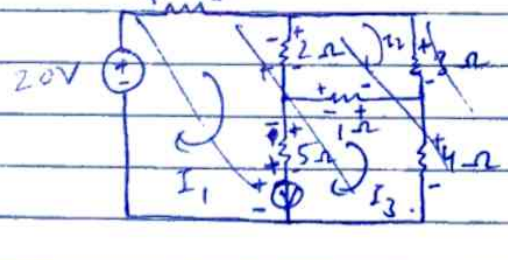
$-12I_3 + 3I_2 + 4I_1 = 0$ — ③

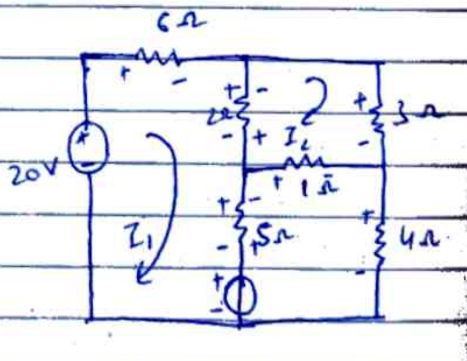
Solving eq. ①, ②, ③.

$I_1 = 0.8571A$, $I_2 = 2.8571A$, $I_3 = 1A$

$I_{5\Omega} = 1A$

Q Find V so that $I_1 = 0A$.





Current Source $\xrightarrow{\text{series}}$ R
Voltage source $\xrightarrow{\text{parallel}}$ R
Redantant (reduce)

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Nodal analysis

Ans ~~Applying KVL to mesh 1~~

$$20 - 6I_1 + 2I_1 - 2I_2 + 5I_1 - 5I_3 - V = 0$$
$$I_1 = 0A$$
$$20 - 2I_2 - 5I_3 - V = 0$$
$$20 = V + 2I_2 + 5I_3$$

Applying KVL to mesh 2

$$-2I_1 + 2I_2 - 3I_2 + I_2 + I_3 = 0$$
$$I_1 = 0 \qquad I_3 = 0$$
$$3I_2 = 3I_2$$

Applying KVL to mesh 1

$$20 - 6I_1 - 2I_1 + 2I_2 - 5I_1 + 5I_3 - V = 0$$
$$I_1 = 0$$
$$2I_2 + 5I_3 - V = -20 \quad - (1)$$

Apply KVL to mesh 2

$$-3I_2 - I_2 + I_3 - 2I_2 + 2I_1 = 0$$
$$2I_1 - 6I_2 + I_3 = 0$$
$$-6I_2 + I_3 = 0 \quad - (2)$$

Mesh 3

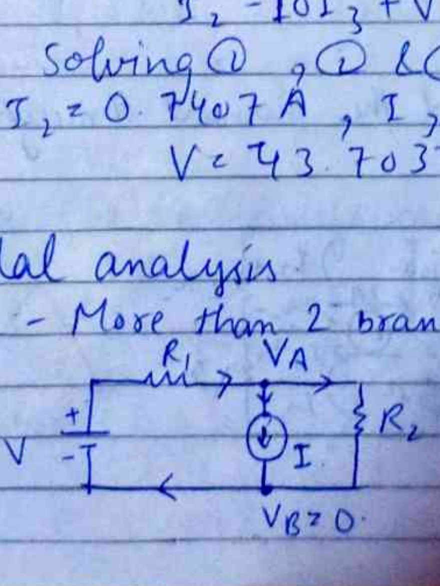
$$-I_3 + I_2 - 4I_3 + V - 5I_3 + 5I_1 = 0$$
$$I_1 = 0$$
$$I_2 - 10I_3 + V = 0 \quad - (3)$$

Solving (1), (2) & (3)

$$I_2 = 0.7407\ A, \quad I_3 = 4.44\ A$$
$$V = 43.7037\ V$$

★ Nodal analysis

Node - More than 2 branches are connected



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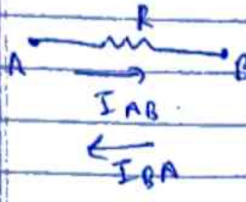
1. Identification of nodes
2. One node is a reference (V of a node is zero)

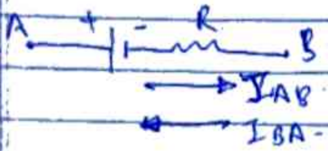
- 

$\Rightarrow I_{AB} = I$

- 

$\Rightarrow I_{AB} = \frac{V_A - V_B}{R}$

$I_{BA} = \frac{V_B - V_A}{R}$

- 

$\Rightarrow I_{AB} = \frac{V_A - V_B - V}{R}$

$I_{BA} = \frac{V_B - V_A + V}{R}$

Applying KCL at Node A

$$\frac{0 - V_A + V}{R_1} = I + \frac{V_A - 0}{R_2}$$

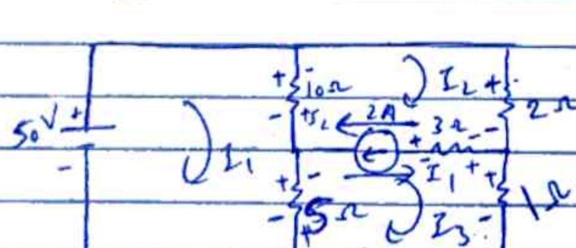
$$\frac{V}{R_1} - I = \frac{V_A}{R_2} + \frac{V_A}{R_1}$$

$$\frac{V}{R_1} - I = V_A\left(\frac{1}{R_2} + \frac{1}{R_1}\right)$$

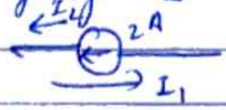
$$I_{R_1} = \frac{0 - V_A + V}{R_1}, \quad I_{R_2} = \frac{V_A - 0}{R_2}$$

Q Supermesh

By mesh analysis, Find the current through $5\,\Omega$ resistor in the circuit

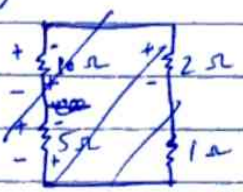


As 3 Ω resistor is in series with current source of 2A
∴ 3 Ω resistor becomes redundant
∴ Applying KCL to current loop



$I_2 - I_3 = 2$ — (1)

Applying KVL in Supermesh



Applying KVL to loop (1).

$50 - 10I_1 + 10I_2 - 5I_1 + 5I_3 = 0$

$-15I_1 + 10I_2 + 5I_3 = -50$ — (2).

Applying KVL to Supermesh

$-2I_2 - I_3 - 5I_3 + 5I_1 - 10I_2 + 10I_1 = 0$

$15I_1 - 12I_2 - 6I_3 = 0$ — (3)

$$\begin{array}{c|cccc} & a & b & c & d \\ \hline 1 & 0 & 1 & -1 & 2 \\ 2 & -15 & 10 & 5 & -50 \\ 3 & 15 & -12 & -6 & 0 \end{array}$$

$a_1x + b_1y + c_1z = d_1$

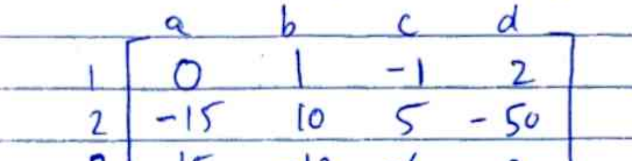
$I_1 = 20A$, $I_2 = 17.33A$, $I_3 = 15.33A$

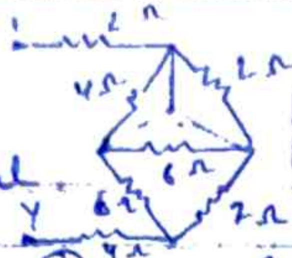
Current through 5 Ω resistor $= I_1 - I_3$

$= 20 - 15.33A$

$= 4.67A$

★ Star - Delta Transformation:





D.S is more useful.

- Delta to Star Conversion

(1) $R_1 = \dfrac{R_{12} \times R_{31}}{R_{12} + R_{23} + R_{31}}$

(2) $R_2 = \dfrac{R_{12} \times R_{23}}{R_{12} + R_{23} + R_{31}}$

(3) $R_3 = \dfrac{R_{23} \times R_{31}}{R_{12} + R_{23} + R_{31}}$

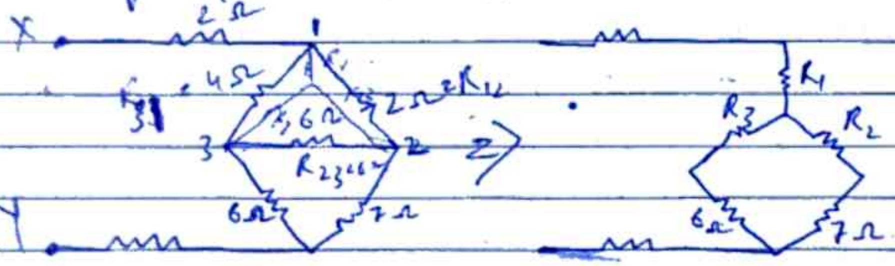
- Star to Delta Conversion :-

(1) $R_{12} = R_1 + R_2 + \dfrac{R_1 R_2}{R_3}$

(2) $R_{23} = R_2 + R_3 + \dfrac{R_2 R_3}{R_1}$

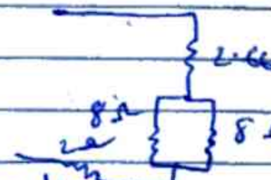
(3) $R_{31} = R_3 + R_1 + \dfrac{R_3 R_1}{R_2}$

Q Find R_{eq} b/w terminals X and Y in the network,

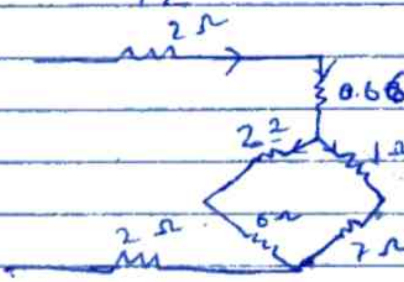


Ans Delta to Star Conversion

$R_1 = \dfrac{2 \times 4}{2+4+6} = \dfrac{8}{12} = \dfrac{2}{3} = 0.66\,\Omega$



$R_2 = \dfrac{2 \times 6}{12} = \dfrac{12}{12} = 1\,\Omega$, $R_3 = \dfrac{4 \times 6}{12} = 2\,\Omega$



~~2+0.66~~

~~(2+0.66)~~

$\Rightarrow$ $2\,\Omega$ & $0.66\,\Omega$ are in series

$2 + 0.66 = 2.66\,\Omega$

$2 + 6 = 8\,\Omega$.

$1 + 7 = 8\,\Omega$

~~2.66 || 8 || 8~~

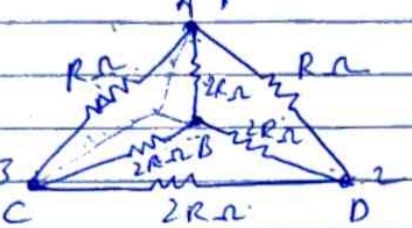
8 || 8


$$R_{eq} = \frac{2.66 \times 8 \times 8}{8 + 2.66 + 8} = \frac{170.24}{18.66} = 9.12$$

$$R_{eq} = \frac{8 \times 8}{8+8} = \frac{64}{16} = 4$$

$$R_{final} = 2 + 0.66 + 4 + 2 = 8.66$$

Q Find Req b/w terminals A & B in the network



Ans Delta to Star Conversion

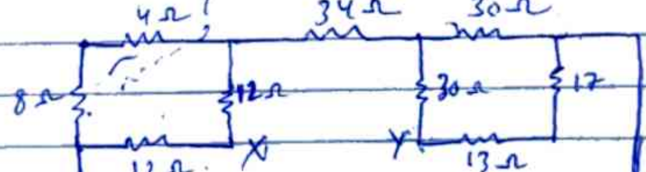
$R_1 = \frac{R \times R}{R + 2R + R} = \frac{R^2}{4R} = \frac{R}{4}$, $R_3 = \frac{R \times 2R}{4R} = \frac{R}{2}$

$R_2 = \frac{R \times 2R}{4R} = \frac{R}{2}$

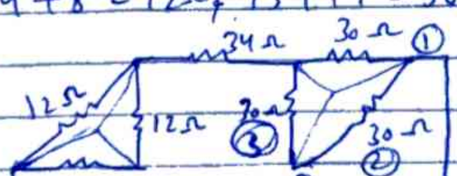
$2R = 2\frac{R}{4}$,

Q Find equivalent resistance b/w terminals X and Y in the n/w shown

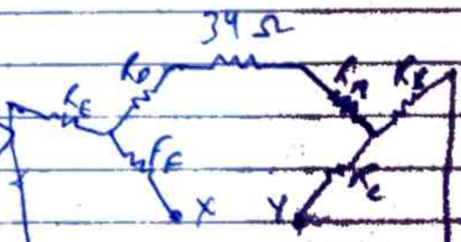
Ans

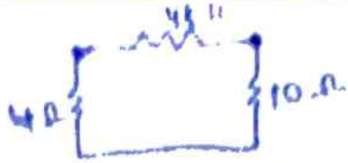


$4 + 8 = 12\Omega$, $13 + 17 = 30\Omega$



$\Rightarrow$





$R_A = \frac{30 \times 30}{30+30+30} = \frac{900}{90} = 10\,\Omega$, $R_C = 10\,\Omega$

$R_B = \frac{30 \times 30}{90} = 10\,\Omega$

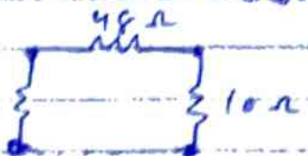
$R_D = \frac{12 \times 12}{12+12+12} = \frac{144}{36} = 4\,\Omega$, $R_D = R_E = R_F = 4\,\Omega$

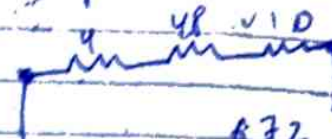
$4\,\Omega$ & $34\,\Omega$ & $10\,\Omega$ are in series

$4 + 34 + 10 = 48\,\Omega$

$4\,\Omega$

$\because$ 4 & $10\,\Omega$ will short





$(48 \| 14)\,\Omega$

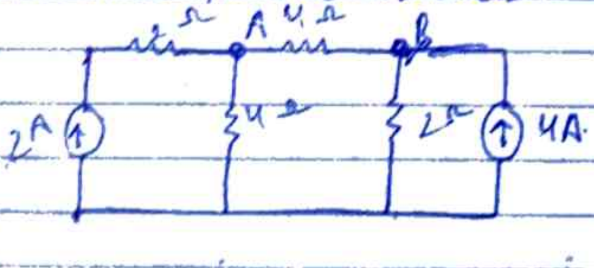
$R_{eq} = \frac{48 \times 14}{48+14} = 10.84\,\Omega$ $\quad \frac{672}{62}$

$R_{eq} = 10.84 + 4 + 10 = 24.84\,\Omega$

Nodal analysis (KCL) no. of Node branches = no. of equations

$V = IR$, $I = \frac{V}{R} = \frac{V_2 - V_1}{R}$

Q. By Nodal analysis, determine Voltages at nodes A and B in the circuit.



Agar I node ke paas aa raha to +ve
Agar I node se ja raha to −ve

Applying KCL to node A,

$$2 = \frac{V_A}{4} + \frac{V_A - V_B}{4}$$

$$8 = 2V_A - V_B, \quad 2V_A - V_B = 4$$

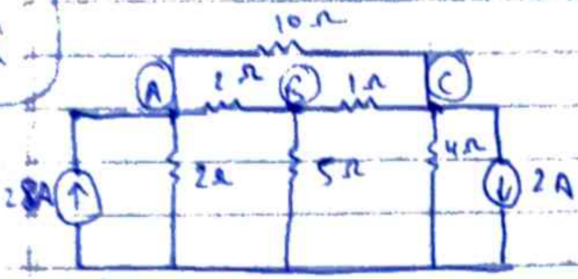
Apply KCL to node B

$$4 = \frac{V_B}{2} + \frac{V_B - V_A}{4}$$

$$16 = V_A + 3V_B$$

$$V_B = 8V, \quad V_A = 8V$$

Q. Find the currents in various resistors of circuit shown in fig.



According to KCL to node A

$$28 = \frac{V_A}{2} + \frac{V_A - V_B}{2} + \frac{V_A - V_C}{10}$$

$$1.1V_A - 0.5V_B - 0.1V_C = 28 \quad - (1)$$

According to KCL to node B

$$0 = \frac{V_B}{5} + \frac{V_B - V_A}{2} + \frac{V_B - V_C}{1}$$

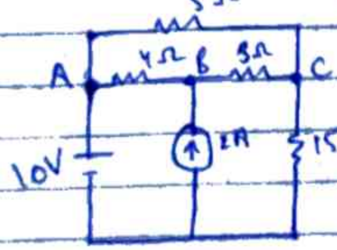
$$-0.5V_A + 1.7V_B - V_C = 0 \quad - (2)$$

According to KCL to node C

$$-2 = \frac{V_C}{4} + \frac{V_C - V_B}{1} + \frac{V_C - V_A}{10}$$

$$-0.1V_A - V_B + 1.35V_C = -2 \quad - (3)$$

Q Find node voltage across all nodes



Applying KCL to node A

$$0 = \frac{V_A - V_B}{4} + \frac{V_A - V_C}{5}$$

Applying KCL to node B

$$2 = \frac{V_B - V_A}{4} + \frac{V_B - V_C}{3}$$

Applying KCL to node 3

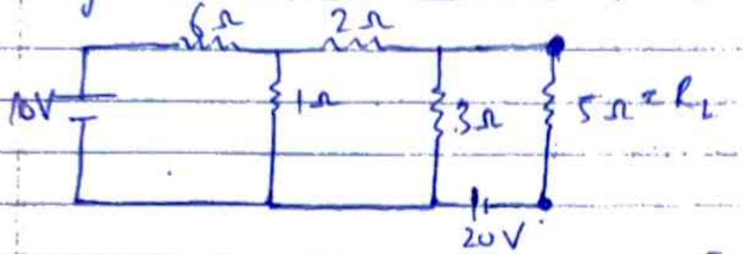
$$0 = \frac{V_c}{15} + \frac{V_c - V_B}{3} + \frac{V_c - V_A}{5}$$

* Thevenin's Theorem

• $I = \frac{V}{R}$

• For thevenin's circuit, $I_L = \frac{V_{Th}}{R_{Th}+R_L}$

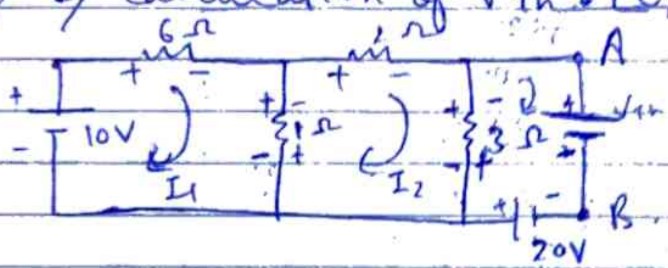
Q Determine current through $5\,\Omega$ resistor in network by thevenin's theorem



R_L is resistance near the voltage

V_{Th} nikalne ke liye parallel branch ke resistance ko I se multiply + agar voltage di hai to add karo

step-1) Calculation of V_{Th}: [Open circuit R_L]



V_{Th} ke liye Jo voltage di hai uske series wale resistance se nikalte hai

Applying KVL in Loop 1

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

$$10 = 7I_1 - I_2 \quad \text{--- (1)}$$

$V_{Th} = 20 + 3I_2$

Applying KVL in Loop 2

$$-2I_2 - 3I_2 - I_2 + I_1 = 0$$

$$6I_2 = I_1$$

$$10 = 42I_2 - I_2 \quad \text{(2)}$$

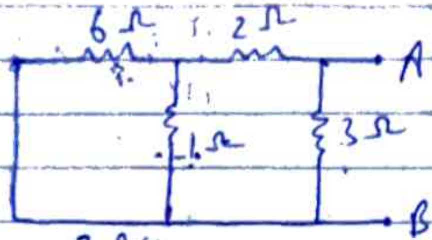
$$I_2 = \frac{10}{41} = 0.24A$$

V_{Th} ke liye fold hue page pr jao

$V_{Th} = (I_2 \times 3) + 20V = (0.24 \times 3) + 20V = 0.72V + 20V = 20.72V$

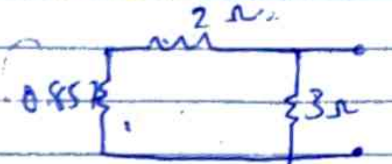
$$V_{Th} = V_{AB} = 20 + 3I_2 = 20 + 3(0.244) = 20.732V$$

Step-② Calculation for R_{Th} = V → Short circuit
I → Open circuit



6 ∥ 1

$R_A = \frac{6 \times 1}{6+1} = \frac{6}{7} = 0.85\Omega$



0.857 ∥ 2Ω

0.857 ∥ 2Ω & 3Ω are in series

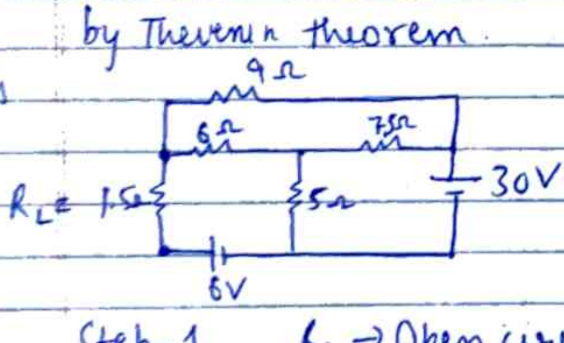
$R_{Th} = 1.46\Omega$

Step ③ $I_L = \frac{V_{Th}}{R_{Th} + R_L} = \frac{20.73}{1.46+5} = \frac{20.73}{6.46}$

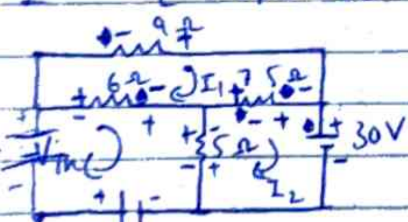
$I_L = 3.21\Omega$

Q Determine the current through 1.5Ω resistor in network by Thevenin theorem.

Ans



Step-1 R_L → Open circuit.



Applying KVL in Loop 1

$7.5I_1 - 7.5I_2 + 6I_1 + 9I_1 = 0$

$22.5I_1 = 7.5I_2$

$3I_1 = I_2, \; I_1 = \frac{I_2}{3}$

Loop ②

$-7.5I_1 + 7.5I_2 - 30 + 5I_2 = 0$

$-8.5I_2 + 7.5I_2 - 25 = 0$

$5I_2 = 25$

$I_2 = 5A$

$I_1 = \frac{5}{3} = 1.66A$

$5I_2 + 6 - 6I_1$
$-6 + 6I_1$

$12.5I_2 - 7.5I_1 = 30$

$12.5I_2 - 2.5I_2 = 30$

$10I_2 = 30$

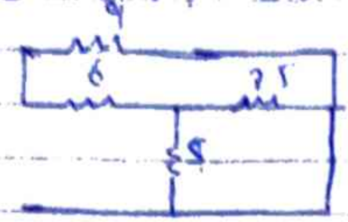
$I_2 = 3, \; I_1 = 1A$

$-6I_1 - 5I_2 + 6 + V_{Th} = 0$

$6 + 15 \quad V_{Th} = -6 + 6 + 15$

$V_{Th} = 15V$

Step-② V → Short circuit, Current → Open Circuit



$7.5 \parallel 5 = \frac{7.5 \times 5}{7.5+5} = 3\Omega$

$6 + 3 = 9\Omega$

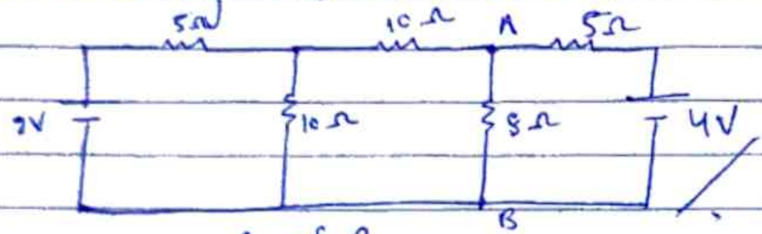
$9 \parallel 9 = \frac{9 \times 9}{9+9} = \frac{81}{18} = 4.5\Omega$

~~$V_{Th} = I_1 \times 5 = 3 \times 5 = 15\Omega$~~

Step③ $I_L = \frac{V_{Th}}{R_{Th}+R_L} = \frac{15}{4.5+1.5} = \frac{15}{6} = 2.5\,A$

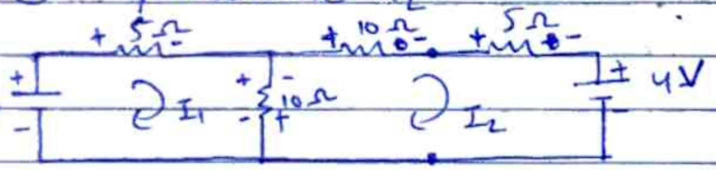
Q Determine the current through 8Ω resistor in the circuit by Thevenin's theorem

Ans



$R_L = 8\Omega$

Step ① Open circuit R_L



Applying KVL to Loop ①

$2 - 5I_1 - 10I_1 + 10I_2 = 0$

$2 = 15I_1 - 10I_2$ — ①

Applying KVL to loop ②

$-4 - 10I_2 + 10I_1 + \cancel{10I_2} + 5I_2 = 0$

$10I_1 + 5I_2 = 4$ — ②

$15I_1 - 10I_2 = 2$

$20I_1 + 10I_2 = 8$

$15I_1 - 10I_2 = 2 \times 10$

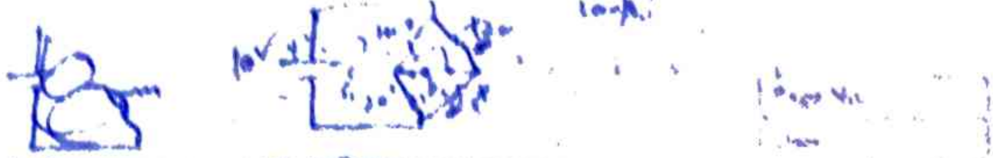
$10I_1 + 5I_2 = 4 \times 15$

$150I_1 - 100I_2 = 20$

$150I_1 + 75I_2 = 60$

$-175I_2 = -40$

$I_2 = 0.228\,A$



$10I_1 + 5(0.11) = 4$

$10I_1 = 4 - 1.15$, $I_1 = \frac{3.15}{10} = 0.315$

Applying KVL to Loop 1

$2 - 5I_1 - 10I_1 + 10I_2 = 0$

$2 = 15I_1 - 10I_2$ — ①

Applying KVL to loop 2

$-10I_2 + 10I_1 - 10I_2 - 5I_2 = 4$

$10I_1 - 25I_2 = 4$ — ②

$\left.\begin{matrix} 15I_1 - 10I_2 = 2 \\ 10I_1 - 25I_2 = 4 \end{matrix}\right\} \begin{matrix} \times 10 \\ \times 15 \end{matrix}$

$150I_1 - 100I_2 = 20$

$150I_1 - 375I_2 = 60$

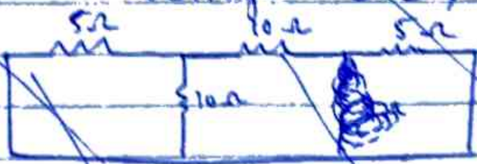
$\underline{- \quad\quad + \quad\quad -}$

$275I_2 = -40$

$I_2 = -0.145A$

$V_{Th} = 4 + 5I_2 = 4 + 5(-0.145) = 4 - 0.725 = 3.275V$

Step ② Voltage → SC, Current → OC



$5 \parallel 10\Omega$

$R_{eqA} = \frac{5 \times 10}{5+10} = \frac{50}{15} = 3.33$

$5 \parallel 8$

$R_B = \frac{5 \times 8}{5+8} = \frac{40}{13} = 3.07$

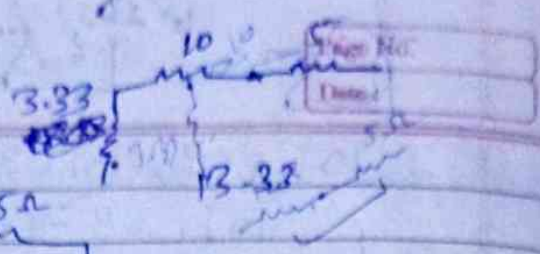
$5 \parallel 10$

$R_A = \frac{5 \times 10}{5+10} = \frac{50}{15} = 3.33$

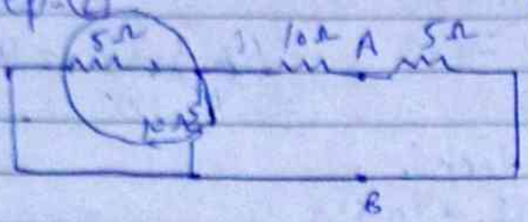
$R_{eqA} = \frac{15 \times 10}{15+10} = \frac{150}{25} = 6$

$R_{eq} = \frac{6 \times 5}{6+5} = \frac{30}{11} =$

Series
Left to Right



Step-②



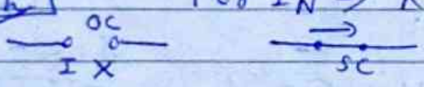
$R_A = \frac{5\times10}{5+10} = \frac{50}{15} = 3.33$, $3.33 + 10 = 13.33$

$R_{Th} = \frac{13.33\times5}{13.33+5} = \frac{66.65}{18.33} = 3.63\Omega$

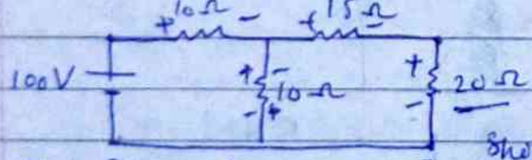
Step ③ $I_L = \frac{V_{th}}{R_{Th}+R_L} = \frac{3.275}{3.63+8} = 0.281A$

* Norton's Theorem:- $I_L = \frac{I_N R_N}{R_N + R_L}$

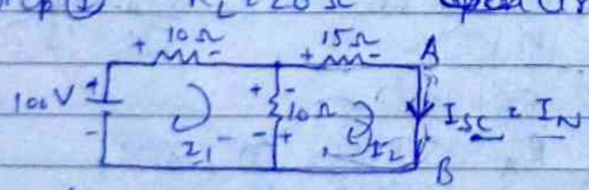
where $\boxed{R_N = R_{Th}}$ For $I_N \Rightarrow R_L \rightarrow$ Short Circuit



Q ① By Norton's theorem, Find current in 20Ω in the network.



Step ① $R_L = 20\Omega$ Short Circuit $\rightarrow R_L$



$V I_N$

Applying KVL to Loop 1

$100 - 10I_1 - 10I_1 + 10I_2 = 0$

$100 = 20I_1 - 10I_2$ - ①

$50 = 2I_1 - I_2$

Applying KVL to Loop 2

$-15I_2 - 10I_2 + 10I_1 = 0$

$10I_1 = 25I_2$

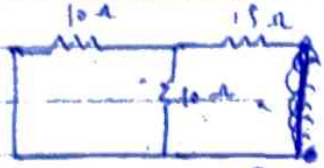
$I_1 = 2.5I_2$ $I_1 = 6.25A$

$5I_2 - I_2 = 50$

$I_2 = \frac{50}{4} = 12.5A$

$I_2 = I_N = 2.5\ A$

Step ② Calculation of R_N $V \to SC$, $I \to OC$



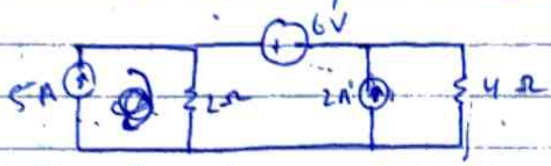
$10 \parallel 10$.

$R_A = \frac{10 \times 10}{10+10} = \frac{100}{20} = 5$

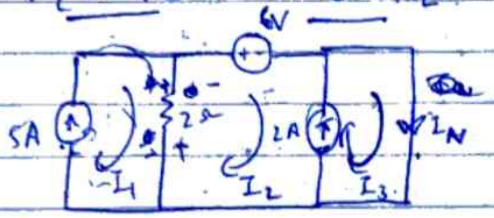
$R_N = R_{Th} = 5 + 15 = 20\ \Omega$

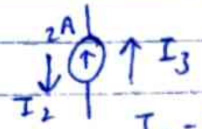
Step ③ $I_L = \frac{I_N R_N}{R_N + R_L} = \frac{2.5 \times 20}{20 + 20} = \frac{50}{40} = 1.25\ A$

Q By Norton's theorem, Find current in 4 Ω in network



Ans Step ① $R_L = 4\ \Omega$ $S.C \to R_L$





$I_3 - I_2 = 2$

Current through mesh 1

$I_1 = 5A$

For 2A source (supermesh)

$I_3 - I_2 = 2$

$I_2 = 2 + I_3$.

$I_2 - I_3 = 2$.

Equation for supermesh

$\cancel{-6 + 2I_2 - 2I_1 = 0}$.

$-6 - 2I_2 + 2I_1 = 0$.

$I_1 - I_2 = 3$

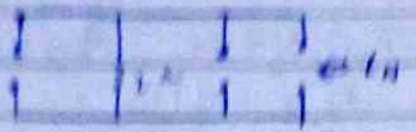
$5 - 3 = I_2,\ I_2 = 2A$

$I_3 - 2 = 2,\ I_3 = 4A$.

$I_N = 4A$

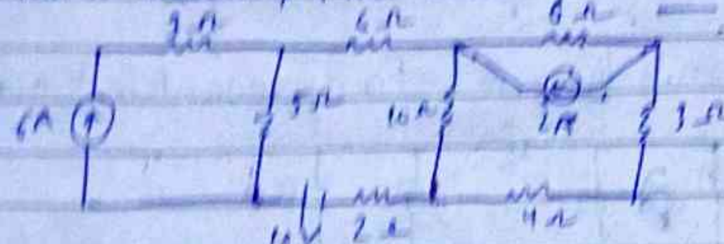
Step ② Calculation for R_N $V - SC$, $I \to OC$

$R_N = R_{th} = 2\Omega$

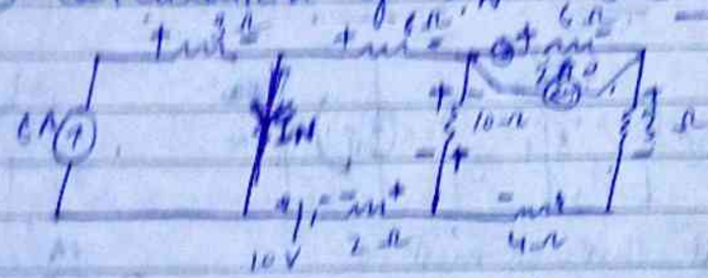


Step (3) Calculation of $I_L = \frac{I_N R_N}{R_N + R_L} = \frac{4 \times 2}{2+4} = \frac{8^4}{6_3} = 1.33A$

Q By Norton's theorem, Find current in 5Ω resistor.

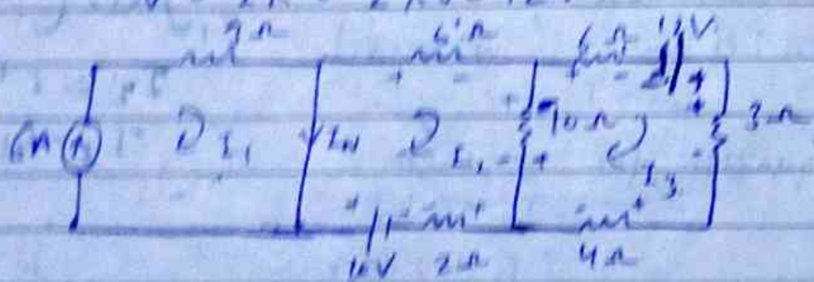


Step (1) Calculation of I_N S.C → $R_L = 5\Omega$



$I_T R = 2 \times 6 = 12$

$V = IR = 2 \times 6 = 12V$



Applying KVL to Loop 2

$$-6I_2 - 10I_2 + 10I_3 - 2I_2 + 10 = 0$$

$$18I_2 - 10I_3 = 0$$

Applying KVL to Loop 3

$$-6I_3 - 12 - 3I_3 - 4I_3 - 10I_3 + 10I_2 = 0$$

$$-23I_3 + 10I_2 = 12$$

Current Division Rule

$$I_L = I_T \times \frac{R_L}{R_P + R_L}$$

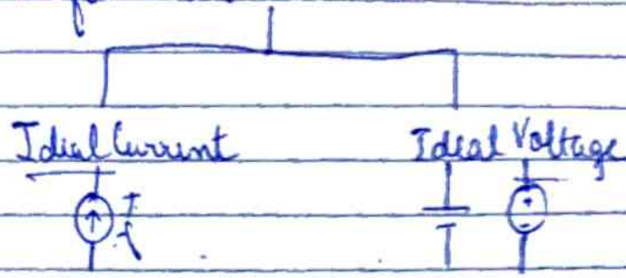
$$I_L = I_T \times \frac{R_P}{R_P + R_L}$$

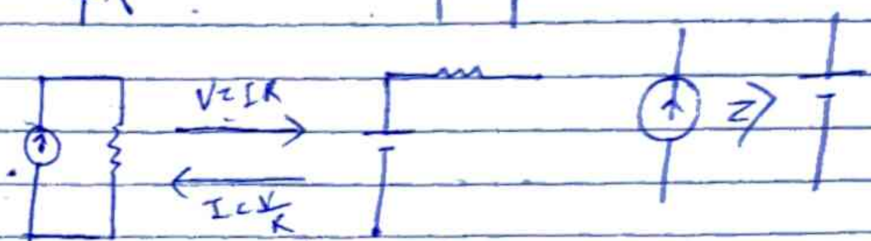
R_L = Load Resistance

R_P = Resistance parallel to R_L / opposite

Opposite branch means jo current 2 branches me divide hota hai to R_P dusri branch ka hota hai

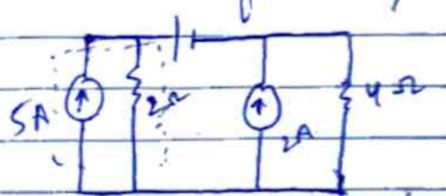
* Source Transformation:



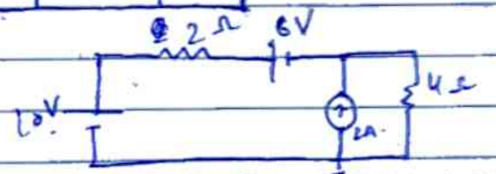


When current source is parallel with resister, then voltage source will be in series with resister & vice versa

Q By source transformation, Find current in 4 Ω resister

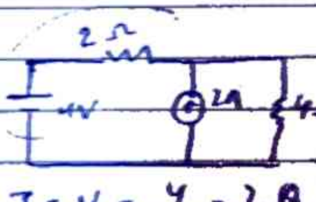


$R_L = 4\Omega$

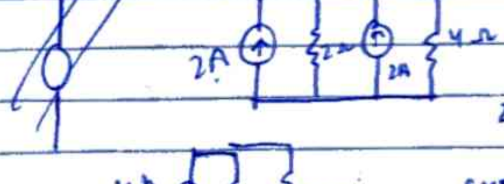


$V = IR = 5 \times 2 = 10V$

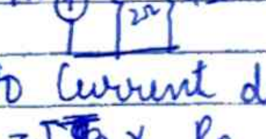
According to $+10V - 6V = 4V$

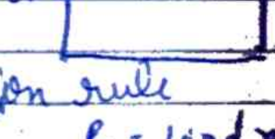


$I = \frac{V}{R} = \frac{4}{2} = 2A$



$2A + 2A = 4A$





$I = \frac{8}{6}$

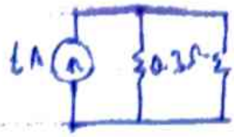
According to Current division rule

$$I_L = I_T \times \frac{R_P}{R_P + R_L}$$

R_L = Load resistance

R_P = Resist. parallel to Load resistance

Ohm's law, Limitations
All definitions



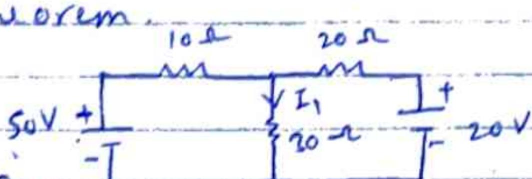
$$I_L = I_T \times \frac{R_P}{R_P + R_L} = 6 \times \frac{0.3}{0.3+3}$$

$$= \frac{1.8}{3.3} = 0.54$$

* Superposition theorem - In any linear and bilateral network or circuit having multiple independent sources, the response of an element will be equal to algebraic sum of responses of that element by considering one source at a time

Q Find current I_1 for circuit shown using superposition theorem.

Ans



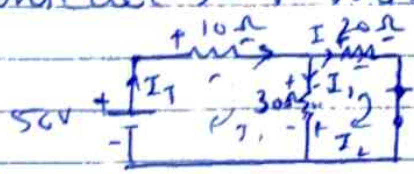
$-20I_2 - 30I_2 + 30I_1 = 0$

$30I_1 = 50I_2$

$I_1 = 1.6 I_2$

$I_1 = 3.2$

Step ① Consider 50 V voltage source & S.C. 20 V



$$R_1 = \frac{20 \times 30}{20+30} = \frac{600}{50} = 12$$

$R_{eq} = 12 + 10 = 22\,\Omega$

$$I_T = \frac{50}{22} = 2.272A$$

$50 - 10I_1 - 30I_1 + 30I_2 = 0$

$50 - 40I_1 + 30I_2 = 0$

$4I_1 - 3I_2 = 5$

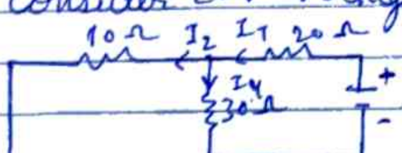
$4I_1$ ~~$4.8I_2 = 5$~~

$-0.8I_2 = 5$

$$I_1 = 2.272A \times \frac{20}{20+30} = 0.908A \downarrow$$

$$I_2 = \frac{50}{8I_1} = 6$$

Step ② Consider 20V voltage source



$6.4I_2 - 3I_2 = 5$

$$I_2 = \frac{50}{34} = 2.0$$

$$R_1 = \frac{10 \times 30}{10+30} = \frac{300}{40} = 7.5\,\Omega$$

$R_{eq} = 7.5\,\Omega + 20 = 27.5\,\Omega$

$$I_T = \frac{20}{27.5} = 0.727A = 0.73A$$

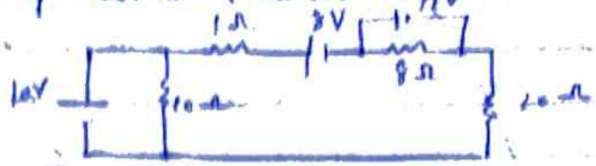
$$I_4 = I_T \times \frac{R_P}{R_P + R_L} = 0.73 \times \frac{10}{10+30} = \frac{7.3}{40} = 0.1825A \downarrow$$

If resistor is connected with ...
If a short circuit is connected across resistor then it becomes redundant

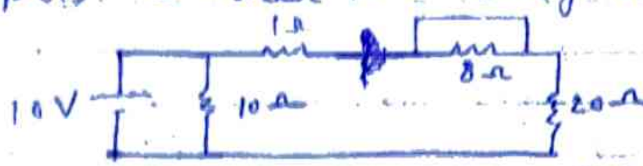
Total I through 50Ω = $I + I_4 = 0.908 + 0.181A$
$= 1.089$

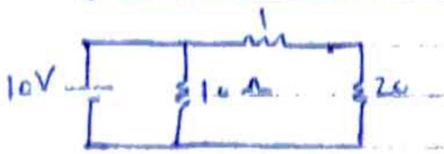
Q Determine the current in 20Ω resistor in network by superposition theorem.

Ans



Step (1) consider 10V voltage only & short circuit other





∵ 8Ω resistor becomes redundant

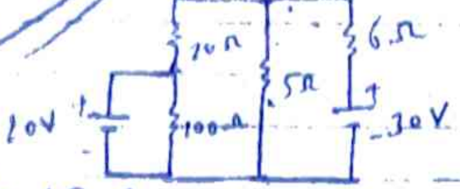
21Ω || 10Ω

$R_{eqT} = \frac{21 \times 10}{21+10} = 6.774\Omega$

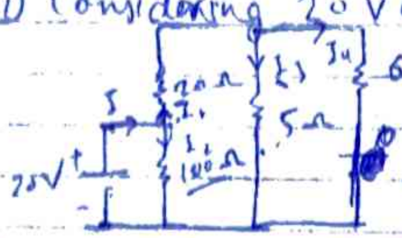
$I = \frac{V_T}{R_T} = \frac{10}{6.77} = 1.477A$

Step (2)

Q Find current through 5Ω resistance by superposition.

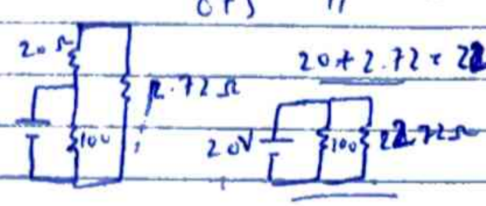


Step (1) Considering 20V as single source



$R_1 = \frac{6 \times 5}{6+5} = \frac{30}{11} = 2.72\Omega$

$20 + 2.72 = 22.72\Omega$



$R_T = \frac{100 \times 22.72}{100 + 22.72} = 18.51\Omega$

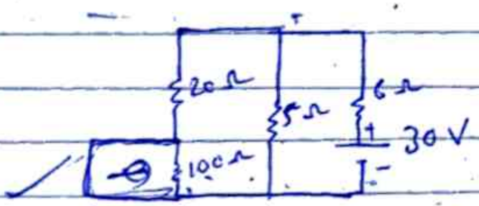
$I_T = \frac{20}{18.5} = 1.08A$

$I_1 = I_T \times \frac{R_P}{R_P + R_L} = 1.08 \times \frac{100}{100+20}$

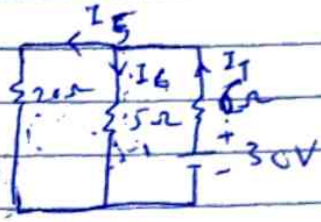
$I_1 = 0.88\ A$

$I_3 = 0.88 \times \frac{6}{5+6} = 0.48\ A$

Step(2) Consider 30V voltage source



$\Rightarrow$



$R = \frac{V}{I} = \frac{V}{\infty}$ $\quad R_T = \frac{20 \times 5 \times 6}{20+5+6} = 19.35\ \Omega$

$I_T = \frac{V_T}{R_T} = \frac{30}{19.35} = 1.53\ A$

$V = IR$

$R = \frac{V}{I}$ $\quad I_6 = I_T \times \frac{R_P}{R_P + R_L} = 1.53 \times \frac{20}{30+20} = 0.612$

$= \frac{1}{\infty}$ $\quad R_1 = \frac{20 \times 5}{20+5} = 4$, $R_T = 4 + 6 = 10\ \Omega$

$I_T = \frac{V_T}{R_T} = \frac{30}{10} = 3A$

$I_6 = I_T \times \frac{R_P}{R_P + R_L} = 3 \times \frac{20}{20+5} = \frac{60}{25} = 2.4A$

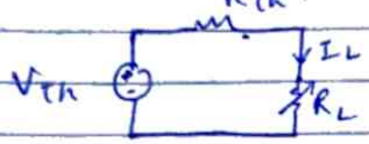
Total current through $5\ \Omega = I_3 + I_6 = 0.48 + 2.4$

$= 2.88A$

All steps same as thevenin, only conditions are diff

* **Max Power Transfer theorem:**

According to this, the condition for max power flow through load resistor R_L can be achieved when load resistor equals thevenin equivalent resistance of the circuit.



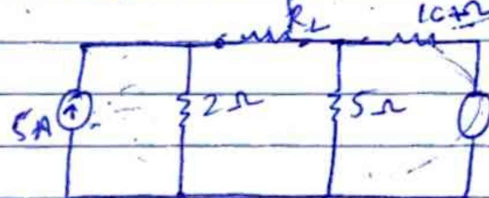
$$P = I_L^2 R_L \quad - (1)$$

$$P = \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2 R_L$$

$\boxed{R_L = R_{Th}}$ This is required condition for max Power flow

$$\boxed{P_{max} = \frac{V_{Th}^2}{4R_{Th}}}$$

Q In given network find the value of R_L which will absorb max Power from source. Find P_{max}.



$V = 5 \times 2 = 10$

Ans step (1) Removing R_L

$I_1 = 5A$

$\frac{24}{10}$

3.33

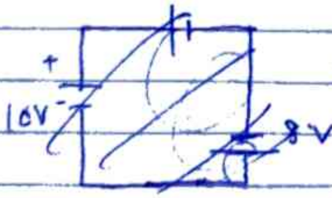
$I_1 = 5A$

Applying KVL in mesh 2

$$-24 + 5I_2 + 10I_2 = 0$$

$$15I_2 = 24$$

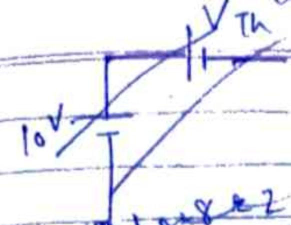
$$I_2 = \frac{24}{15} = 1.6A$$



$V_{Th} =$

$-V_{Th} - 8 + 10 = 0$

$V_{Th} = 2V$



$V_{Th} = -24 + 5(1.6) + 10(1.6)$

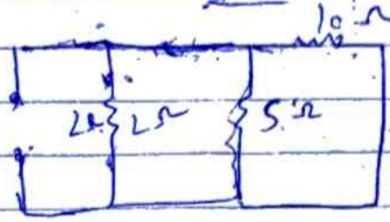
$= -24 + 8 + 16$

$= 0$

$V_{Th} = 10 + 8 = 2$

$V_{Th} = -24 + 10 \times 1.6 = -24 + 16 = -8V$

Step ② R_{Th} V → SC, Current = O.C



$2\Omega \parallel 5\Omega$, $R_1 = \frac{2 \times 5}{2+5} = \frac{10}{7} = 1.$

$10\Omega \parallel 5\Omega$, $R_1 = \frac{10 \times 5}{10+5} = \frac{50}{15} = 3.33$

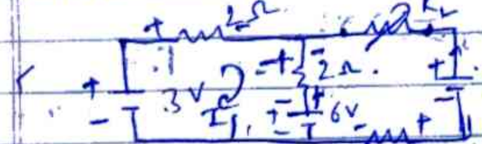
$3.33 + 2\Omega = 5.33\Omega$

$R_L = R_{Th} = 5.33\Omega$

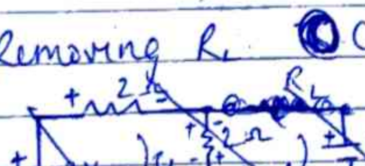
$P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \frac{64}{21.32} = 3W \quad \frac{4}{21.32} = 0.187$

Q. Find the value of resistance R_L for max Power transfer. Also calculate Maximum Power

Ans



Removing R_L OC → R_L For V_{Th}



Apply KVL to loop 1

$3 - 2I_1 - 2I_1 + 2I_2 - 6 = 0$

$2I_2 - 4I_1 = 3$ — ①

Apply KVL to loop 2

$-2I_2 + 2I_1 - 10 - 2I_2 + 6 = 0$

$2I_1 - 4I_2 = 4$

$I_1 - 2I_2 = 2$ — ②

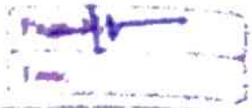
$I_1 = 2 + 2I_2$

$2I_2 - 8 - 8I_2 = 3$

$-6I_2 = 11$

$I_2 = -1.83A$

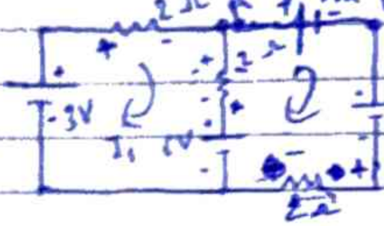
V_{Th}



$V_{Th}' = -10 - 2I_2 - 2I_1 + 6$

$V_{Th}' = -10 - 2I_2 + 6 = -4 +$

$V_{Th} = -10 - 2I_2 = -10 - (2\times -1.83) = -6.34$



Applying KVL to loop 1

$3 - 2I_1 - 2I_1 - 6 = 0$

$4I_1 = -3$

$I_1 = -\frac{3}{4} = \underline{-0.75A}$

V_{Th} ②.

$V_{Th} = -10 - 2I_1 = -10 -$

$-V_{Th} - 10V + 2I_1 = 0$ $\quad V_{Th} = -10 - 2I_1 + 6 - 2I_1$

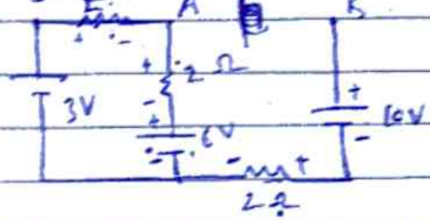
$V_{Th} = 2I_1 - 10$ $\quad V_{Th} = -10 - 2I_1 + 6 - 2I_1$

$= -1.5 - 10$ $\quad = -10 - 2(0.75) + 6 - (-0.75)$

$= -11.5V + 6$ $\quad = -10 + 1.5 + 6 + 1.5$

$= -5.5V$

$\sqrt{V_{Th}}$



$-V_{Th} - 10V + 6V + 2I_1 = 0$

$V_{Th} = -4 + 2(-0.75)$

$= -4 - 1.5$

$= -5.5V$

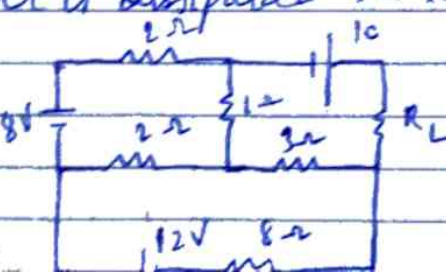
$R_L = R_{Th} = 3\Omega$

$\frac{2\times 2}{2+2} = \frac{4}{4} = 1$ $\quad P_{max} = \frac{V_{Th}^2}{4R_{Th}} = \underline{2.52W}$

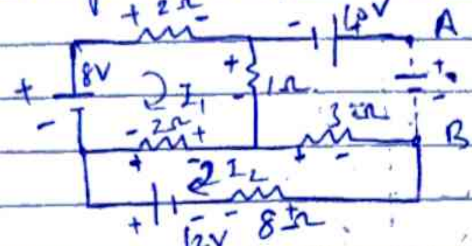
$\frac{3025}{12}$

Q For given circuit find the value of R_L so that max power is dissipated in it. Also find P_{max}

Ans



Removing R_L & open circuit for V_{Th}



Applying KVL in mesh 1

$$8-2I_1-\cancel{1}I_1-2I_1+2I_2=0$$

$$5I_1-2I_2=8 \quad \times 2$$

Applying KVL in mesh 2

$$2I_1-2I_2-3I_2-8I_2+12=0$$

$$-13I_2+2I_1=-12 \quad \times 5$$

$$10\cancel{I_1}-4I_2=16$$

$$1\cancel{0}I_1-65I_2=-60$$

$$- \quad + \quad +$$

$$61I_2=76, \quad I_2=1.24A$$

$$5I_1-2.48=8$$

$$I_1=\frac{10.48}{5}=2.096\,A$$

For V_{Th}, $-V_{Th}+3I_2+I_1+10=0$

$$V_{Th}=10+2.096+3.72=15.816$$

Max Power Transfer Theorem

* Time-Domain Analysis of RC & LC
  - R → Energy dissipated
  - L & C → Energy stored
  - Circuit having one energy storage element is called first order (RL, RC)
  - Circuit having 2 energy storage elements :- second order

Charging of Capacitor

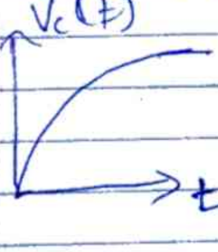
At $t = 0$.

$V(t) = Ae^{-Pt}$, $Q = 0, V = 0, P = \frac{1}{RC}$

$P = \frac{1}{RC}$

$$\boxed{V_c(t) = Ae^{-t/RC}}$$

At $t = \infty$. $Q = \max$, $I = 0$.



$V_c = Ae^{-t/RC} + V$

$V_c = -Ve^{t/RC} + V$

$$\boxed{V_c(t) = V(1 - e^{-t/RC})}$$

(time constant) $\tau = RC$

$t = 5RC = 0.99V$ Capacitor is fully charged.

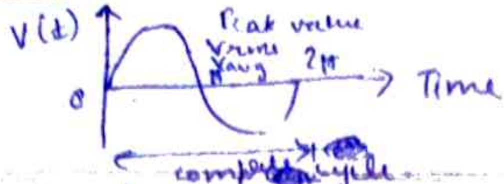
Time constant of RC is defined as time in which it charges upto 63% of its final value

Discharging Of Capacitor.

At $t = 0$

$V_c(t) = V_0 e^{-t/RC}$

Time constant of RC circuit is defined as time required to discharge the capacitor by 36% of its initial value



DC :- Current which remains constant in magnitude wrt time.

AC :- Current which changes periodically wrt time in both magnitude & direction.

Instantaneous Value :- Value of alternating quantity at a particular instant

Amplitude :- Max. Value attained by an alternating quantity during +ve or -ve half cycle.

Cycle :- Each repetition of a set of +ve and -ve instantaneous values of alternating quantity is called a cycl

Time period :- Time taken by alternating quantity (AQ) to complete 1 cycle

Frequency :- No of cycles completed by AQ per sec

$$f = \frac{1}{T}$$

$$A = A_0 \sin \omega t$$

RMS :- The square root of means of squares of instantaneous values gives rms value

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0 , \quad V_{rms} = 0.707 V_0$$

Average value :- Avg of all instantaneous values of an alternating voltage and currents over 1 complete cycle gives avg value

$$I_{avg} = \frac{2 I_0}{\pi} = 0.637 I_0$$

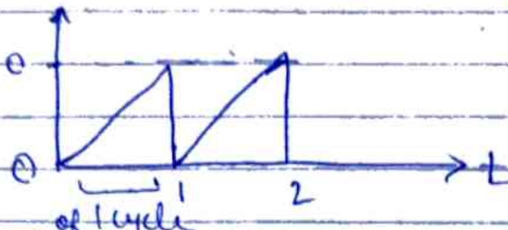
$$I_{rms} = \sqrt{\frac{1}{T_2-T_1}\int_{T_1}^{T_2} (I)^2\,dt}$$

$$I_{avg} = \frac{1}{T_2-T_1}\int_{T_1}^{T_2} I\,dt$$

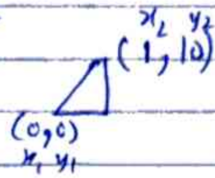
Peak Value :- Max value reached by AC in 1 cycle

$$V_{peak} = \sqrt{2}\,V_{rms}$$

Q $I(t)$



Find I_{avg}, I_{rms}



$T = 1$ sec.

$$\boxed{\frac{y_2-y_1}{x_2-x_1} = \frac{y_1-y}{x_1-x}}$$

$$\frac{10}{1} = \frac{0-i(t)}{-t}$$

$$\boxed{i(t) = 10t} \quad 0 < t < 1$$

$$I_{avg} = \frac{1}{T}\int_0^1 i\,dt$$

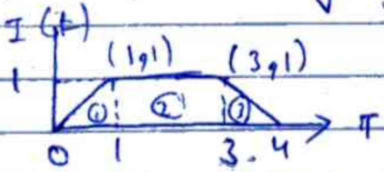
$$I_{avg} = \frac{10}{2} \times 1 = 5A.$$

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

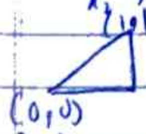
$$= \sqrt{1\int (10t)^2\,dt}$$

$$= \sqrt{\frac{100}{3}} = 5.77A.$$

Q



I_{avg} & I_{rms}.



~~$T_1 = 1$ sec, $T_2 = 2$ sec~~ Time = 4 sec

$$\frac{1}{1} = \frac{-I(t)}{-t}, \quad I(t) = t \text{ for } 0 < t < 1$$

$$I(t) = 1 \quad \text{for } 1 < t < 3$$

$i(t) = 4 - t$ for $3 < t < 4$

$$I_{avg} = \frac{1}{T}\int_0^T i(t)\,dt$$

$$= \frac{1}{4}\left[\int_0^1 t\,dt + \int_1^3 1\,dt + \int_3^4 4-t\,dt\right]$$

$$= 0.75\,A$$

$$I_{rms} = \sqrt{\frac{1}{T}\left[\int_0^1 t^2 dt + \int_1^3 dt + \int_3^4 (4-t)^2 dt\right.}$$

$$= 0.66\,A$$

* Power :- Rate of doing work / Work per unit time
  $P = VI$ SI unit = W (J/S)
  $$P = \frac{dW}{dt}$$
* Energy :- Ability to do work
  $$E = \frac{1}{2} m V^2 \text{ Joules}$$
* KCL :- Acc to KCL, total current entering the junction is equal to total current leaving junction
* KVL :- Algebric sum of all voltages in a loop must be equal zero.
* Thevenin's theorem :- Any 2 terminal linear & bilateral network or circuit having multiple sources can be represented in a simplified equivalent circuit consisting of V_{Th} in series with R_{Th}.

Step ① Remove R_L and Calculate V_{Th}

Step ② Calculation of R_{Th} ⇒ V → Short, I = Open

$$I_L = \frac{V_{Th}}{R_{Th} + R_L}$$

Thevenin :- Any linear circuit can be simplified into equivalent circuit consisting of one voltage source and series resistance connected to load.

* Norton :- Any linear circuit can be simplified to an equivalent circuit consisting of single current source and parallel resistance connected to a load.

Step ① Short R_L (Plain wire) Find I_N

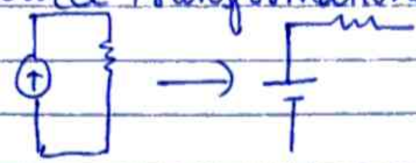
I_N = Current through shorted R_L

Step ② Calculation of R_N/R_{Th} :- $V \to SC$, $I \to OC$

Step ③ $I_L = \frac{I_N R_N}{R_N + R_L}$

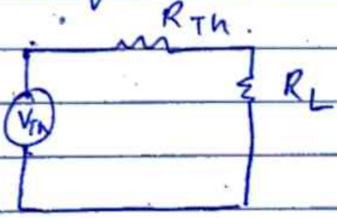
* $I_L = I_T \times \frac{R_P}{R_P + R_L}$

Source transformation



* Superposition theorem :- In any linear and bilateral network or circuit having multiple independent sources, the response of an element will be equal to algebric sum of responses of that element by considering one source at a time.

* Max Power Transfer :- Explains that to generate max external power through a finite resistance, R_L must be equal to R_{Th}.



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

We know, $P = I^2 R_L$

$$P = \frac{V_{Th}^2 R_L}{(R_{Th} + R_L)^2}$$

Differentiating wrt R_L

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$$\frac{dP}{dR_L} = V_{Th}^2 \left(\frac{1 \times (R_{Th}+R_L)^2 - 2R_L(R_{Th}+R_L)}{(R_{Th}+R_L)^4} \right)$$

$$= V_{Th}^2 \left(\frac{R_{Th}^2 + \cancel{2R_{Th}R_L} + R_L^2 - \cancel{2R_L R_{Th}} - 2R_L^2}{(R_{Th}+R_L)^4} \right)$$

$$= V_{Th}^2 \frac{(R_{Th}^2 - R_L^2)}{(R_{Th}+R_L)^4}$$

Putting $\frac{dP}{dR_L} = 0.$

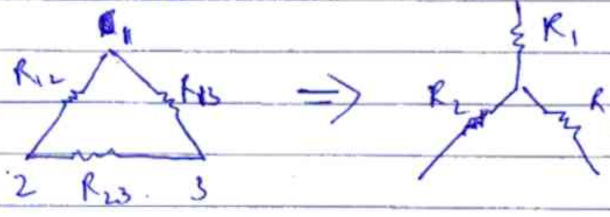
$$(R_{Th}^2 - R_L^2) V_{Th}^2 = 0.$$

$$\boxed{R_{Th} = R_L}$$

$$P = \frac{V_{Th}^2 R_L}{(2R_L)^2} = \frac{V_{Th}^2}{4R_L}$$

★ Delta to Star

③ − ① ⇒ Result ④
④ Result + ② = ⑤, ⑥
⑦
⑤ × ⑥ + ⑥ × ⑦ + ⑦ × ⑤



For branch R_{23}

$$(R_{12} + R_{13}) \parallel R_{23}$$

$$R_{23} = \frac{(R_{12}+R_{13})R_{23}}{R_{12}+R_{23}+R_{31}} \quad - ① \qquad R_{23} = R_2 + R_3$$

Similarly; for R_{13}

$$(R_{12} + R_{23}) \parallel R_{13}$$

$$R_{13} = \frac{(R_{12}+R_{23})R_{13}}{R_{12}+R_{23}+R_{31}} \quad - ② \qquad R_{13} = R_1 + R_3$$

For R_{12} $$R_{12} = \frac{(R_{13}+R_{23})R_{12}}{R_{12}+R_{23}+R_{31}} \quad - ③ \qquad R_{12} = R_1 + R_2$$

Now, subtracting ① from ③

$$\cancel{R_1} + \cancel{R_2} - \cancel{R_2} - R_3 = \frac{(R_{13}+R_{23})R_{12} - R_{23}(R_{12}+R_{13})}{R_{12}+R_{23}+R_{31}}$$

$$= \frac{R_{13}R_{12} + R_{23}R_{12} - R_{12}R_{23} - R_{13}R_{23}}{R_{12}+R_{23}+R_{31}}$$

$$R_1 - R_3 = \frac{R_{13}(R_{12}-R_{23})}{R_{12}+R_{23}+R_{31}} \quad - (4)$$

Add (2) + (4)

$$R_1 + \cancel{R_3} + R_1 - \cancel{R_3} = \frac{R_{13}R_{12} - \cancel{R_{13}R_{23}} + R_{13}R_{12} + \cancel{R_{13}R_{23}}}{R_{12}+R_{23}+R_{31}}$$

$$\cancel{2}R_1 = \frac{\cancel{2}R_{13}R_{12}}{R_{12}+R_{23}+R_{31}} \quad - (5)$$

Similarly :- $R_2 = \dfrac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}}$ - (6), $R_3 = \dfrac{R_{13}R_{23}}{R_{12}+R_{23}+R_{31}}$ - (7)

Star → Delta

Multiply (5) × (6), (6) × (7), (7) × (8)

$$R_1R_2 = \frac{R_{12}^2R_{13}R_{23}}{(R_{12}+R_{23}+R_{31})^2} - (9), \quad R_2R_3 = \frac{R_{23}^2R_{12}R_{13}}{(R_{12}+R_{23}+R_{31})^2} - (10)$$

$$R_3R_1 = \frac{R_{13}^2R_{12}R_{23}}{(R_{12}+R_{23}+R_{31})^2} - (11)$$

Add (9), (10), (11)

$$R_1R_2 + R_2R_3 + R_1R_3 = \frac{R_{12}^2R_{13}R_{23} + R_{23}^2R_{12}R_{13} + R_{13}^2 + R_{23} + R_{31}}{(R_{12}+R_{23}+R_{31})^2}$$

$$= \frac{R_{12}R_{23}R_{13}(\cancel{R_{12}+R_{23}+R_{13}})}{(R_{12}+R_{23}+R_{13})^{\cancel{2}}}$$

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

$$R_{12} = \frac{R_1R_2}{R_3} + R_2 + R_1, \quad R_{23} = \frac{R_2R_3}{R_1} + R_2 + R_3.$$

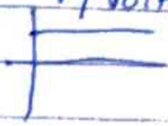
$$R_{31} = R_3 + R_1 + \frac{R_3R_1}{R_1}$$

Unit - 2

* AC circuits

Current

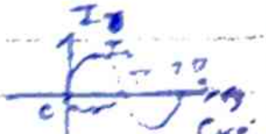
DC → R/Voltage



A.C → R/L/C

* Average Value

Avg Value = $\dfrac{\text{Area of half cycle}}{\text{Base length of half cycle}}$



$$I_{avg} = \frac{\int_0^{\pi} I \, d\theta}{\pi} \qquad I = I_0 \sin\theta$$

$$= \frac{\int_0^{\pi} I_0 \sin\theta \, d\theta}{\pi}$$

$$= \frac{I_0}{\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{I_0}{\pi}[1+1] = \frac{2I_0}{\pi} = 0.637I_0$$

$$I_{avg} = \frac{2I_0}{\pi} = 0.637 I_0$$

* RMS value (Root Mean Square)

$$I_{RMS} = \sqrt{\frac{\int_0^{\pi} I^2 d\theta}{\pi}} = \sqrt{\frac{I_0^2 \int_0^{\pi} \sin^2\theta \, d\theta}{\pi}}$$

$$= \sqrt{\frac{I_0^2}{\pi}\int_0^{\pi}\left(\frac{1-\cos 2\theta}{2}\right)d\theta} \qquad \cos 2\theta = 1 - 2\sin^2\theta$$

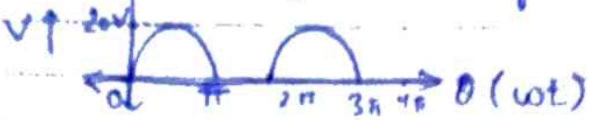
$$\sin^2\theta = \frac{1-\cos 2\theta}{2}$$

$$= \sqrt{\frac{I_0^2}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}}$$

$$= \sqrt{\frac{I_0^2 \cancel{\pi}}{2\cancel{\pi}}}$$

$$I_{RMS} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

Q1 . Find the avg value of waveform.



$V = V_0 \sin\theta$

$= 20 \sin\theta$

Ans . Given waveform is continuous

Equation	Interval
(1) $V = 20\sin\theta$	$0 < \theta < \pi$
(2) $V = 0$	$\pi < \theta < 2\pi$

$$V_{avg} = \frac{\text{Area of full cycle}}{\text{Base length of full cycle}}$$

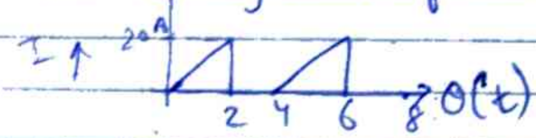
$$= \frac{\int_0^{2\pi} V\,d\theta}{2\pi}$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} 20\sin\theta\,d\theta + \int_{\pi}^{2\pi} 0\,d\theta\right.$$

$$= \frac{20}{2\pi}[-\cos\theta]_0^{\pi}$$

$$= \frac{10}{\pi}[2] = \frac{20}{\pi} = 6.3666\,V$$

Q2 Find the avg value of the waveform.



Ans . Given waveform is continuous

Equation	Interval
(1) $I = 20\sin\theta$	$0 < \theta < 2$
(2) $I = 0$	$2 < \theta < 4$

$$I_{avg} = \frac{\int_0^4 I\,d\theta}{4} = \frac{1}{4}\left[\int_0^2 20\sin\theta\,d\theta + \int_2 0\,d\theta\right]$$

$= \frac{d_0}{4}[-\cos\theta]_0^2$

$= 5$

~~Area of triangle~~

~~$\frac{1}{2} \times b \times h$~~

~~$\frac{1}{2} \times 2 \times 20$~~

Given waveform is continuous.

Equation	Interval
(1) $I = 10t$	$0 < t < 2$
(2) $I = 0$	$2 < t < 4$

$m(\text{slope}) = \frac{y_2 - y_1}{x_2 - x_1} = \frac{20-0}{2-0}$

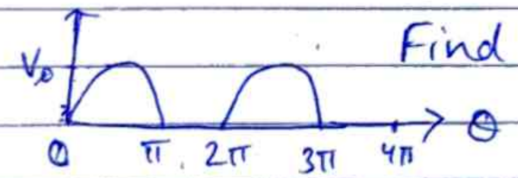
$= 10$

$$I_{avg} = \frac{\int_0^4 I\,dt}{4}$$

$$= \frac{1}{4}\left[\int_0^2 10t\,dt + \int_2^4 0\,dt\right]$$

$$= \frac{10}{4}\left[\frac{t^2}{2}\right]_0^2$$

$$= \frac{10}{8} \times 4 = 5A$$

Q3 

Find V_{rms}.

Ans Given waveform is continuous.

(1) $V = V_0 \sin\theta$	$0 < \theta < \pi$
(2) $V = 0$	$\pi < \theta < 2\pi$

$$V_{rms} = \sqrt{\frac{\int_0^{2\pi} V^2\,d\theta}{2\pi}}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} (V_0 \sin\theta)^2 + \int_\pi^{2\pi} 0\,d\theta\right]}$$

$$= \cancel{\sqrt{\frac{V_0}{2\pi}[-\cos\theta]_0^{\pi}}} \qquad \sqrt{\frac{V_0^2}{2\pi}\int_0^{\pi}\left(\frac{1-\cos 2\theta}{2}\right)d\theta}$$

$$= \cancel{\sqrt{\frac{V_0}{\pi}}} \qquad = \frac{V_0^2}{4\pi}\left[\int_0^{\pi}(1-\cos 2\theta)\,d\theta\right]$$

$$= \frac{V_0^2}{4\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi}$$

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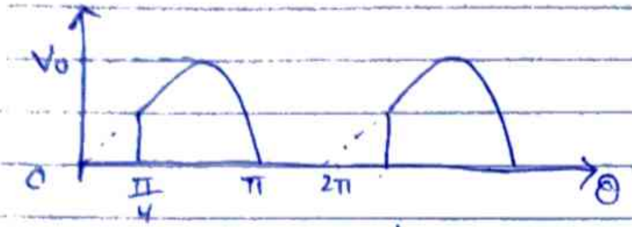
$$V_{rms}^2 = \frac{V_0^2}{4\pi} \times \pi = \frac{V_0^2}{4}$$

$$\therefore V_{rms} = \frac{V_0}{2} = 0.5 V_0$$

Q4.



Find V_{rms}.

Ans

	Equation	Interval
①	$V = 0$	$0 < \theta < \frac{\pi}{4}$
②	$V = V_0 \sin\theta$	$\frac{\pi}{4} < \theta < \pi$
③	$V = 0$	$\pi < \theta < 2\pi$

$$V_{rms}^2 = \frac{\int_0^{2\pi} V^2 d\theta}{2\pi} = \frac{\int_0^{\pi/4} 0\, d\theta + \int_{\pi/4}^{\pi} V_0^2 \sin^2\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\theta}{2\pi}$$

$$= \frac{V_0^2}{2\pi} \int_{\pi/4}^{\pi} \frac{1 - \cos 2\theta}{2}$$

$$= \frac{V_0^2}{4} \left[\theta - \frac{\sin 2\theta}{2} \right]_{\pi/4}^{\pi}$$

$$= \frac{V_0^2}{4} \left[\pi - \frac{\sin 2\pi}{2} - \frac{\pi}{4} + \frac{\sin \frac{\pi}{2}}{2} \right]$$

$$= \frac{V_0^2}{4} \left[\frac{3\pi}{4} + \frac{1}{2} \right]$$

$$V_{rms}^2 = V_0^2 (0.227)$$

$$V_{rms} = V_0 (0.476)$$

* Some Important formulas.

① $\omega = 2\pi f = \frac{2\pi}{T}$, ② $I_{rms} = \frac{I_0}{\sqrt{2}}$, $V_{rms} = \frac{V_0}{\sqrt{2}}$

(3) $I_{avg} = 0.637 I_0$
(4) Form factor $= \frac{I_{rms}}{I_{avg}}$

Q5. The equation of an A.C is $I = 62.35 \sin 323t$. Determine (1) max value (2) frequency (3) RMS value (4) Avg Value (5) Form factor

Ans5) $I = 62.35 \sin 323t$ Amperes

Comparing with $I = I_0 \sin \omega t$

$I_0 = 62.35A, \quad \omega = 323$

$\omega = 2\pi f, \quad f = \frac{323}{2\pi} = 51.403$ Hz

$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{62.35}{\sqrt{2}} = 44.08$ A

$I_{avg} = 0.637 \times 62.35 = 39.71$ A

Form factor $= \frac{I_{rms}}{I_{avg}} = 1.11$

★ Phasor Algebra

(1) Length of phasor : $V = \frac{V_0}{\sqrt{2}}$

(2) Rectangular form / Cartesian form : $x + iy = x + jy$
(3) Polar form : $r \angle \theta = r(\cos\theta + i \sin\theta)$

* Rectangular form

$z_1 = x_1 + jy_1, \quad z_2 = x_2 + jy_2$

$z_1 + z_2 = (x_1 + x_2) + j(y_1 + y_2)$ (Addition)

$z_1 - z_2 = (x_1 + jy_1) - (x_2 + jy_2)$

$= (x_1 - x_2) + j(y_1 - y_2)$ ... (Subtraction)

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★ Polar form

$z_1 = r_1 \angle \theta_1$, & $z_2 = r_2 \angle \theta_2$

$(z_1 . z_2) = (r_1 \angle \theta_1) . (r_2 \angle \theta_2)$

$= (r_1 . r_2) \angle (\theta_1 + \theta_2)$ ..... ~~Mult~~ (Multi)

$\frac{z_1}{z_2} = \frac{r_1 \angle \theta_1}{r_2 \angle \theta_2} = \frac{r_1}{r_2} \angle (\theta_1 - \theta_2)$ ..... (Division)

Q6 (1) $V_1 = 42.43 \angle 0°$, $V_2 = 28.28 \angle 60°$

Calculate $V_1 + V_2$ in polar form

Ans $V_1 + V_2 = (42.43 \angle 0°) + (28.28 \angle 60°)$ then press alpha F increase → In calci

$= Rec(42.43, 0) + Rec(28.28, 60)^n$

$= [42.43 + 0\hat{j}] + (14.14 + 24.49j)$

$= 56.57 + 24.49j$

$V_1 + V_2 = Pol(56.57, 24.49)$ → In calci

$= 61.64 \angle 23.41$ → Polar Form

Q7 Find the resultant of the following voltages

$V_1 = 25 \sin \omega t$, $V_2 = 10 \sin(\omega t + \frac{\pi}{6})$, $V_3 = 30 \cos \omega t$

$V_4 = 20 \sin(\omega t - \frac{\pi}{4})$

Ans $V_3 = 30 \cos \omega t = 30 \sin(\omega t + \frac{\pi}{2})$

Imp $\boxed{\cos \theta = \sin(\frac{\pi}{2} + \theta)}$

~~$V_1 + V_2 + V_3 + V_4 =$~~

Converting the standard sine waveform

$\bar{V_1} = \frac{V_0}{\sqrt{2}} \angle \theta = \frac{25}{\sqrt{2}} \angle 0 = 17.68 \angle 0°$

$\bar{V_2} = \frac{10}{\sqrt{2}} \angle 30° = 7.07 \angle 30°$, $\bar{V_3} = 21.21 \angle 90°$

$\bar{V_4} = 14.14 \angle -45°$

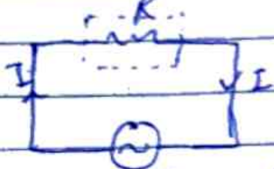
∴ For resultant voltage

$V = \bar{V_1} + \bar{V_2} + \bar{V_3} + \bar{V_4}$

Add^n & Sub^n → Rectangular form
Mult & Div → Polar

$V = (17.68 \angle 0) + (7.07 \angle 30°) + (21.21 \angle 90) + (14.14 \angle -45)$
$V = Rec(17.68, 0) + Rec(7.07, 30) + Rec(21.21, 90) + Rec(14.14, 45)$
$= 17.68 + 0j + 6.12 + 3.5j + 0 + 21.21j + 10 - 10j$
$V = 33.80 + 14.75j$ → Rectangular
$= Pol(33.80, 14.75)$
$V = (36.88 \angle 23.58)\ V$ → Polar

★ Resistive Circuit
According to Ohm's law,



$V = V_0 \sin \omega t$

$$I = \frac{V}{R} = \frac{V_0 \sin \omega t}{R}$$

For maximum, $\sin \omega t = 1$

$$\boxed{I_0 = \frac{V_0}{R}}$$

Instantaneous power $P = VI = V_0 \sin \omega t \, I_0 \sin \omega t$
$$= V_0 I_0 \sin^2 \omega t$$
$$= V_0 I_0 \left(\frac{1 - \cos 2\omega t}{2}\right)$$

Imp. $\boxed{P_{inst} = \frac{V_0 I_0}{2} - \frac{V_0 I_0 \cos 2\omega t}{2}}$

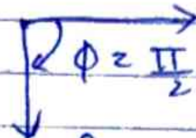
Power consumed $(P) = \frac{1}{2\pi} \int_0^{2\pi} P \, d\omega t$
$$= \frac{1}{2\pi} \int_0^{2\pi} \left[\frac{V_0 I_0}{2} - \frac{V_0 I_0}{2} \cos 2\omega t\right] d\omega t$$
$$= \frac{1}{2\pi} \left\{ \frac{V_0 I_0}{2} \left[\int_0^{2\pi} d\omega t - \int_0^{2\pi} \cos 2\omega t \, d\omega t \right] \right\}$$
$$= \frac{V_0 I_0}{4\pi} \left[(\omega t)_0^{2\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{2\pi} \right]$$
$$= \frac{V_0 I_0}{4\pi} \times 2\pi$$

Imp $\boxed{P_{consumed} = \frac{V_0 I_0}{2} = \frac{V_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} = V_{rms} I_{rms}}$

★ Pure Inductive Circuit

$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

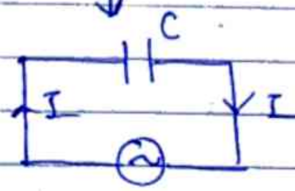
Current lagging behind the voltage by 90°



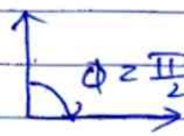
Phasor diagram

★ Pure Capacitive Circuit

$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$



Current leading Voltage by 90°



★ Pure L circuit

- Opposition to current (Z):

$I_0 = \frac{V_0}{\omega L}$, $\frac{V_0}{I_0} = \omega L$

Multiplying & Dividing by $\sqrt{2}$

$\frac{V_0/\sqrt{2}}{I_0/\sqrt{2}} = \omega L$

$\frac{V}{I} = \omega L$

$\boxed{X_L = \omega L = 2\pi f L}$ Inductive Reactance

★ Pure C circuit

$\boxed{X_C = \frac{1}{\omega C}} = \frac{1}{2\pi f C}$ ~~Capac~~ Capacitive Reactance

Inductive → lag → $\frac{\pi}{2}$
Capacitive → lead → $\frac{\pi}{2}$

AC circuits

Q8 A 318 μF capacitor is connected across a 230V, 50Hz supply. Determine ① Capacitive reactance ② RMS value of current ③ Equation for V & I

Ans) $C = 318 \times 10^{-6}$ F , $V = 230$ V

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times 3.14 \times 50 \times 318 \times 10^{-6}}$$

$$X_C = 10\ \Omega$$

$$I_{RMS} = \frac{V}{X_C} = \frac{230}{10} = 23$$

$$V = \frac{V_0}{\sqrt{2}},\quad V_0 = \sqrt{2}\,V = \sqrt{2} \times 230 = 325.27\ V$$

$$I_0 = \sqrt{2}\,I = \sqrt{2} \times 23 = 32.53\ A$$

Equation for V and I

$$V = V_0 \sin \omega t = 325.27 \sin(2\pi \times 50)t$$

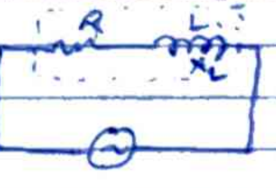
$$V = 325.27 \sin(314)t$$

$$I = I_0 \sin \omega t = 32.53 \sin\left(314t + \frac{\pi}{2}\right)$$

* A.C ~~serie~~ series circuit.

① R-L circuit ② R-C circuit ③ R-L-C circuit

* Series R-L circuit:



✓ $V_R = IR$

✓ $V_L = I X_L$

✓ Power factor $= \cos\phi$

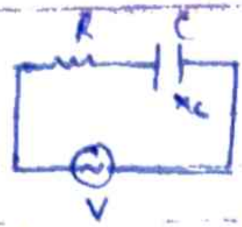
✓ $\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right)$ = Phase angle

✓ $Z = \sqrt{R^2 + X_L^2}$

✓ $\bar{Z} = R + X_L j = Z\angle\phi$

$P_{consumed} = VI\cos\phi$

* Series R C circuit.



$V_R = IR$

$V_C = IX_C$

Power factor = $\cos\phi$

$\phi = \tan^{-1}\left(\frac{V_C}{V_R}\right) = \tan^{-1}\left(\frac{X_C}{R}\right)$

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

$\bar{Z} = R - X_C j = Z\angle -\phi$

Q9. A coil having resistance of 7 Ω and inductance of 31.8 mH is connected to 230V, 50Hz. Calculate ① circuit current ② Phase angle ③ Power factor ④ Power consumed

Ans 9) ① $X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 31.8 \times 10^{-3}$

$\boxed{X_L = 10\ \Omega}$

② $Z = \sqrt{R^2 + X_L^2} = \sqrt{7^2 + 10^2} = 12.21\ \Omega$

③ $I = \frac{V}{Z} = \frac{230}{12.21} = 18.84\,A$

④ $\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{10}{7}\right)$

$\phi = 55^\circ$

⑤ Power factor = $\cos 55^\circ = 0.574$ (Lagging)

⑥ $P_{consumed} = VI\cos\phi$

$= 230 \times 18.84 \times 0.574$

$\boxed{P_{consumed} = 2487.26\,W}$

* series R-L-C circuit

① Phase angle (ϕ) = $\tan^{-1}\left(\frac{V_L - V_C}{V_R}\right) = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

② $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$\bar{Z} = R + (X_L - X_C)j$ .... Rectangular.

$Z = \bar{Z}\angle\phi$ ... Polar

Q10 For given circuit, Determine (1) Circuit Impedance (2) Circuit Current (3) Power factor (4) Active power

$R = 20\Omega$, $L = 0.1H$, $C = 50\mu F$, $V = 200V$, $f = 50Hz$

Ans 10)
$X_L = \cancel{2\pi\omega\phi}\ 2\pi f L = 2\times3.14\times50\times0.1$

$X_L = 31.4\ \Omega$

$X_C = \cancel{}\ \dfrac{1}{2\pi f C} = \dfrac{1}{2\times3.14\times50\times50\times10^{-6}}$

$X_C = 63.69\ \Omega$

$Z = \sqrt{R^2 + (X_C - X_L)^2}$

$= \sqrt{20^2 + (63.69 - 31.4)^2}$

$= \sqrt{400 + 1039.41}$

$Z = 37.93$

$Z = R - (X_C - X_L)j$

$= 20 - 32.24j$ ... Rectangular

$= 37.94\angle -58.19$ ... Polar

$\cancel{\phi = 37.94}$ $\phi = -58.19$

$I = \dfrac{V}{Z} = \dfrac{200\angle 0}{37.94\angle -58.19} = 5.27\angle 58.19$

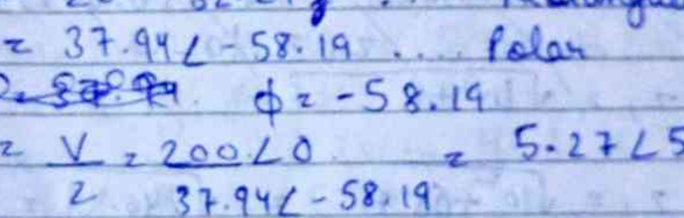
Power factor $= \cos\phi = \cos(-58.19) = 0.527$ (lagging)

Active Power $= P = VI\cos\phi$

$= 200(5.27)(0.527)$

$P = 555.46\,W$

Q11 From given circuit, Determine (1) Circuit current, (2) Voltage drop V_1 (3) Voltage drop V_2

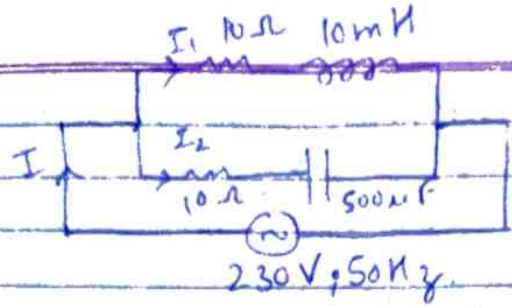


Ans 11) $R_1 = 10\Omega$, $L_1 = 0.05H$, $R_2 = 20\Omega$, $L_2 = 0.1H$, $C_2 = 50\mu F$

$X_{L_1} = 2\pi f L_1 = 2\times3.14\times50\times0.05 = 15.7\ \Omega$

$X_{L_2} = 31.4\ \Omega$

$R_{eq} = 30\Omega$, $X_{L_{eq}} = 47.1\ \Omega$



Ans) $X_L = 2\pi f L = 2\times3.14\times50\times10\times10^{-3}H = 3.14\,\Omega$

$\cancel{X_C = 2\pi f C = 2\times3.14\times50\times500\times10^{-6} =}$

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\times3.14\times50\times500\times10^{-6}} = 6.37\,\Omega$

$Z_1 = \sqrt{10^2+(3.14)^2} = 10.48\,\Omega$

$Z_2 = \sqrt{10^2+(6.37)^2} = 11.85\,\Omega$

$Z_1 \parallel Z_2$

$\dfrac{1}{Z_{eq}} = \dfrac{1}{10.48} + \dfrac{1}{11.85} = \dfrac{22.33}{124.188} =$

$Z_{eq} = \dfrac{124.188}{22.33} = 5.56\,\Omega$

$I_{total} = \dfrac{V}{Z_{eq}} = \dfrac{230}{5.56} = 41.36\,A$

$I_1 = \dfrac{V}{Z_1} = \dfrac{230}{10.48} = 21.95\,A$ $\quad \dfrac{1}{\omega C}$

$I_2 = \dfrac{V}{Z_2} = \dfrac{230}{11.86} = 19.39$

$\phi_1 = \tan^{-1}\left(\dfrac{X_L}{R}\right) = \tan^{-1}\left(\dfrac{3.14}{10}\right) = 17.43^\circ$

Power factor $= \cos\phi_1 = \cos 17.43^\circ = 0.954^\circ$

$\phi_2 = \tan^{-1}\left(\dfrac{X_C}{R}\right) = \tan^{-1}\left(\dfrac{6.37}{10}\right) =$

Power factor $= \cos\phi_2 = \cos 32.49^\circ = 0.843$

Total Power factor

$\phi_T = \tan^{-1}\left(R\left(\dfrac{1}{X_C} - \dfrac{1}{X_L}\right)\right)$

$= \tan^{-1}\left(10\left(\dfrac{1}{6.37} - \dfrac{1}{3.14}\right)\right)$

$\frac{215 \cdot 10}{295}$

$R + X_L \parallel X_C$

$\frac{(R+X_L)^2 X_C}{(R+X_L)C}$

$$\phi_1 = \tan^{-1}\left(10\left(\frac{6.37-3.14}{20}\right)\right)$$

$$= \tan^{-1}(1.615)$$

$$\phi_1 = \tan^{-1}\left(\frac{(R+X_L)(X_C)}{R+X_L+R+X_C}\right)$$

$$= \tan^{-1}\left(\cancel{3.14 \times 6.37}\right)$$

$\frac{1}{10} + \frac{1}{10} \quad \frac{100}{20}$

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

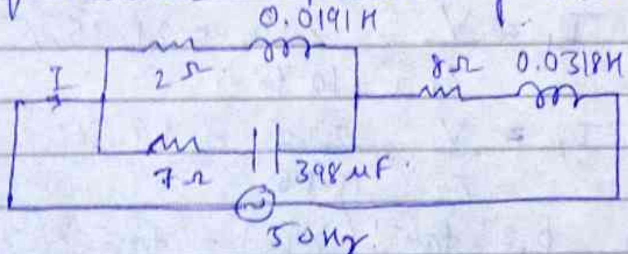
$$\phi_1 = \tan^{-1}\left[R\left(\frac{1}{X_L} - \frac{1}{X_C}\right)\right]$$

$$= \tan^{-1}\left[500\left(\frac{6.37-3.14}{20}\right)\right]$$

Power consumed $= P_1 = I_1^2 R = (21.95)^2 10 = 4.818\ kW$

$P_2 = I_2^2 R = (19.39)^2 10 = 3.76\ kW$

Q13 Determine equivalent impedance of circuit



Ans $X_{L_1} = 2 \times 3.14 \times 50 \times 0.0191 = 6\ \Omega$

$X_{C_1} = \frac{1}{2 \times 3.14 \times 398 \times 10^{-6}} = 8\ \Omega$

$X_{L_2} = 2 \times 3.14 \times 50 \times 0.0318 = 10\ \Omega$

$Z_1 = \sqrt{4+36} = \sqrt{40} = 6.32\ \Omega$ $\quad Z_3 = \sqrt{49+64} = \sqrt{113} = 10.63\ \Omega$

$Z_2 = \sqrt{64+100} = \sqrt{164} = 12.80\ \Omega$

$$Z' = \frac{6.32 \times 12.80}{6.32 + 12.80} = 4.23$$

$Z_{eq} = Z' +$

16.95

$z' = 3.96\,\Omega$

$z_T = 3.96 + 12.80 = 16.76$

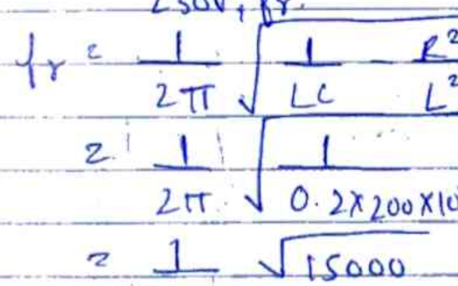
* Resonance Circuit :-

Parameter	Series circuit	Parallel circuit
(1) Impedance	Min $(Z = R)$	Max $\left(Z = \frac{L}{CR}\right)$
(2) Current	Max $\left(I = \frac{V}{R}\right)$	Min $\left(I = \frac{V}{Z_d}\right)$
(3) Resonant frequency	$f_r = \frac{1}{2\pi\sqrt{LC}}$	$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$
(4) Q factor	$Q = \frac{V_L \text{ or } V_C}{V}$	$Q = \frac{I_L \text{ or } I_C}{I}$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Q14 An inductive coil of resistance 20 Ω and inductance 0.2H is connected in parallel with 200 µF capacitor with var. freq, 230V supply. Find resonant freq at which total current taken from supply is inphase with supply voltage. Also find the value of Current

Ans



$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{0.2 \times 200 \times 10^{-6}} - \frac{20^2}{0.2^2}}$$

$$= \frac{1}{2\pi}\sqrt{15000}$$

$$f_r = 19.49\ Hz$$

$$Z_r = \frac{L}{CR} = \frac{0.2}{200 \times 10^{-6} \times 20} = 50\,\Omega$$

$$I_r = \frac{V}{Z_r} = \frac{230}{50} = 4.6\,A$$

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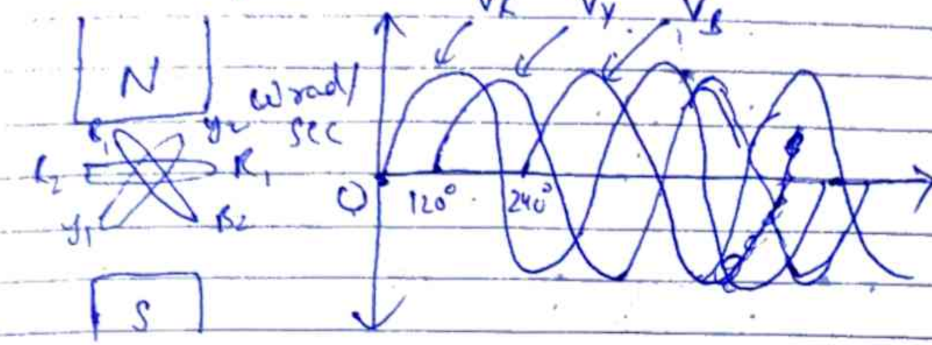
★ Generation of Three Phase

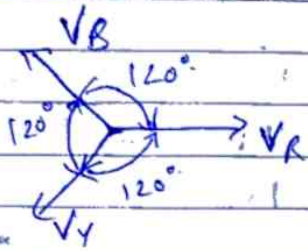


→ Equation for voltages.

$V_R = V_0 \sin \omega t$

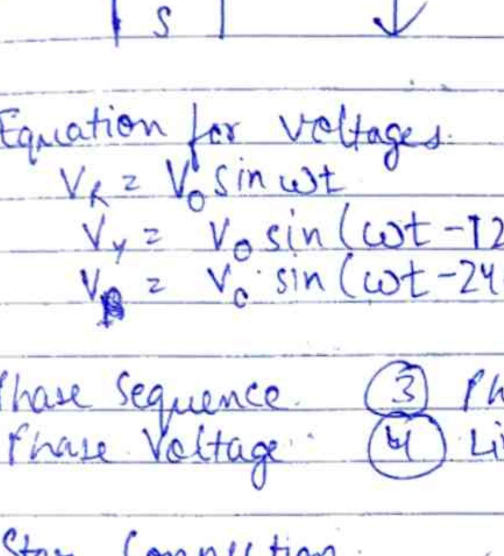
$V_Y = V_0 \sin(\omega t - 120°)$

$V_B = V_0 \sin(\omega t - 240°)$



(1) Phase Sequence (3) Phase Current (5) Line current
(2) Phase Voltage (4) Line voltage

→ Star Connection



- Line Current ($I_L = I_{ph}$)

$I_R = I_0 \sin \omega t$

$I_Y = I_0 \sin(\omega t - 120°)$

$I_B = I_0 \sin(\omega t - 240°)$

- Line voltage (V_L)

V_{ph} = Phase Voltage

$V_L = \sqrt{3}\, V_{ph}$

- Power :-

Total power = 3 × Power in each phase

$= 3 V_{ph} I_{ph} \cos\phi$

∴ For star connection

$$V_L = \sqrt{3}\, V_{ph}$$

$$P = 3 \times \frac{V_L}{\sqrt{3}} \times I_L \cos\phi \Rightarrow \boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$$

Star → Series
Delta → Parallel

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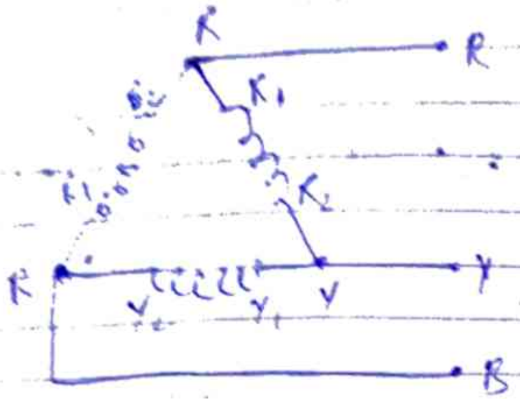
- Delta connection



Phase voltage = $V_{ph} = V_L$
Line current = $I_L = \sqrt{3}\, I_{ph}$
Power = P = $3 \times V_{ph} \times I_{ph} \times \cos\phi$

$$= 3\, V_L \frac{I_L}{\sqrt{3}} \cos\phi$$

$$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$$

★ Comparison b/w Star & Delta ~~delta~~

Star	Delta
(1) $V_L = \sqrt{3}\, V_{ph}$	(1) $V_L = V_{ph}$
(2) $I_L = I_{ph}$	(2) $I_L = \sqrt{3}\, I_{ph}$
(3) $P = \sqrt{3}\, V_L I_L \cos\phi$	(3) $P = \sqrt{3}\, V_L I_L \cos\phi$
(4) Line voltage leads the resp. phase voltage by 30°	(4) Line current lags behind I_{ph} by 30°

- Q8. Three similar coils, each of resistance 8 Ω and inductance 0.02H are connected in star across a 3 phase, 50 Hz, 230V supply. Calculate the line current, total power

Active Power $P = \sqrt{3} V_L I_L \cos\phi$

Apparent Power $P = \sqrt{3} I_L I_L$

Reactive Power $P = \sqrt{3} V_L I_L \sin\phi$

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Ans 8) $R_{ph} = 8\Omega$, $L = 0.02H$, $f = 50Hz$, $V_L = 230V$

$X_L = 2\pi f L = 2\pi(50)(0.02) = 6.28\Omega$

For star connection, $V_L = \sqrt{3} V_{ph}$

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{230}{\sqrt{3}} = 132.79V$$

$\bar{Z} = 8 + j6.28 = 10.1\angle 38.13$

$\cancel{I_L = I_{ph} = \frac{V_{ph}}{Z} = \frac{132.79}{}}$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{132.79\angle 0}{10.1\angle 38.13}$$

$$= 13.14\angle -38.13$$

$I_L = I_{ph} = 13.14\angle -38.13$

$P = \sqrt{3} V_L I_L \cos\phi = \sqrt{3} \times 230 \times 13.14 \cos(38.13)$

$= 4117.98W$