

$$R_b = \frac{R_1 R_3}{R_1 + R_2 + R_3} \quad \text{--- (5)}$$

To get  $R_c$  Simplify  $(2) + (3) - (1)$ .

$$R_0 + R_c + \cancel{R_b} + R_c = R_0 - \cancel{R_b} = R_1 R_3 + R_1 R_3 + R_3 R_1 + \cancel{R_3 R_2} - \cancel{R_2 R_1} - \cancel{R_2 R_3}$$

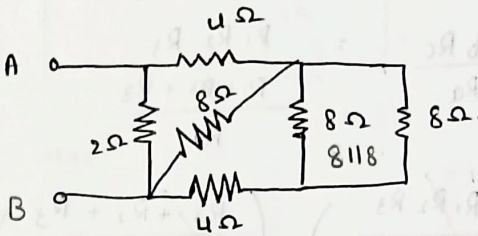
$$R_1 + R_2 + R_3$$

$$R_c = \frac{1}{2} \frac{R_1 R_3}{R_1 + R_2 + R_3}$$

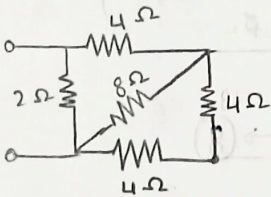
$$R_c = \frac{R_1 R_3}{R_1 + R_2 + R_3} \quad \text{--- (6)}$$

30/07/24 - Homework circuits

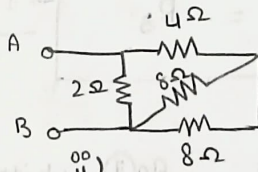
2)



9)

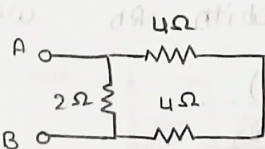


$$\frac{1}{8} + \frac{1}{8} = \frac{2}{8} = \frac{1}{4} \Rightarrow 4\Omega \text{ parallel}$$

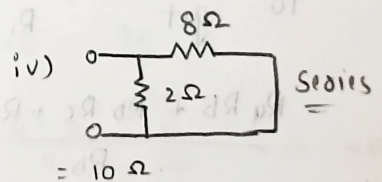


$$\frac{1}{8} + \frac{1}{8} = \frac{2}{8} = \frac{1}{4} \Rightarrow 4\Omega \text{ parallel}$$

1000)

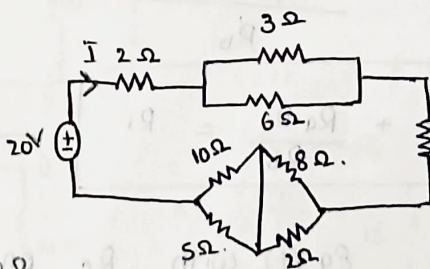


$$\text{Series } 4 + 4 = 8\Omega$$

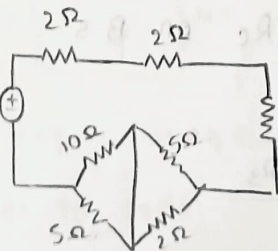


$$= 10\Omega$$

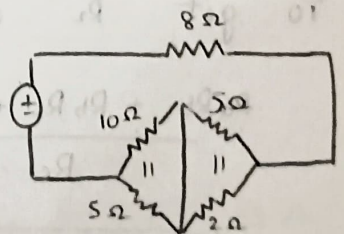
3)



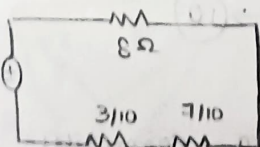
$$\frac{1}{3} + \frac{1}{6} = \frac{6+3}{18} = \frac{9}{18} = \frac{1}{2} \Rightarrow 2\Omega$$



$$2 + 2 + 4 = 8\Omega \text{ Series}$$



$$\frac{1}{5} + \frac{1}{2} = \frac{2+5}{10} = \frac{7}{10}$$



$$8 + \frac{3}{10} + \frac{7}{10}$$

$$\frac{1}{10} + \frac{1}{5} = \frac{5+10}{50} = \frac{15}{50} = \frac{3}{10}$$

$$8 + \frac{10}{10} = 8 + 1 = 9\Omega$$

# Star - Delta transformation: 05/08/24

Multiply Eqn (5) ; (5) (6) ; (6) (4) and all are added

$$R_a R_b + R_b R_c + R_c R_a = \frac{(R_1 R_2) (R_2 R_3) + (R_2 R_3) (R_3 R_1) + (R_3 R_1) (R_1 R_2)}{(R_1 + R_2 + R_3)^2}$$

$$= \frac{R_1 R_2 R_3 (R_1 + R_2 + R_3)}{(R_1 + R_2 + R_3)^2}$$

$$R_a R_b + R_b R_c + R_c R_a = \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3} \rightarrow (7)$$

Dividing Eqn (7) by  $R_a$  on B.S. we get

$$R_b + R_c + \frac{R_b R_c}{R_a} = \frac{R_1 R_2 R_3}{R_1 + R_2 + R_3} \cdot \frac{1}{R_a}$$

$$R_b + R_c + \frac{R_b R_c}{R_a} = \left( \frac{R_1 \cancel{R_2} R_3}{R_1 + R_2 + R_3} \right) \left( \frac{R_1 \cancel{R_2} R_3}{R_1 \cancel{R_2}} \right)$$

$$R_b + R_c + \frac{R_b R_c}{R_a} = R_3 \rightarrow (8)$$

To get  $R_1$  divide Eqn (8) with  $R_b$  with B.S.

$$\frac{R_a R_b + R_b R_c + R_c R_a}{R_b} = \frac{R_1 (R_2 \cancel{R_3})}{R_1 + R_2 + R_3} \cdot \frac{1}{R_b}$$

$$\Rightarrow R_a + R_c + \frac{R_a R_c}{R_b} = R_1 \rightarrow (9)$$

To get  $R_2$  divide Eqn (9) with  $R_c$  on B.S.

$$\frac{R_a R_b + R_b R_c + R_c R_a}{R_c} = \frac{R_1 \cancel{R_2} R_3}{R_1 + R_2 + R_3} \cdot \frac{1}{R_c}$$

$$\frac{R_a R_b}{R_c} + R_b + R_a = R_2 \rightarrow (10)$$

Eqn (8), (9), (10) represents Star-Delta Connection.

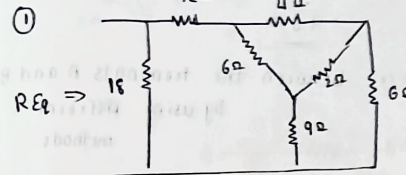
$\Delta$  to  $\lambda$

$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

$$R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

$$R_c = \frac{R_1 R_3}{R_1 + R_2 + R_3}$$

\* Inside connection



(1)

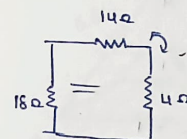
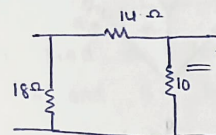
Req = 18

Delta to Star:

$$R_1 = \frac{6(1)}{6+2+4} = \frac{12}{12} = 1$$

$$R_2 = \frac{6(4)}{6+2+4} = \frac{24}{12} = 2$$

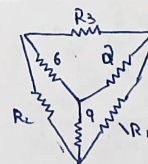
$$R_3 = \frac{4(1)}{6+2+4} = \frac{4}{12} = \frac{1}{3}$$



$$\Rightarrow \frac{1}{18} + \frac{1}{18} = \frac{1}{9} = 9\Omega$$

$$\therefore R_{eq} = 9\Omega$$

Star to Delta:



$$R_1 = 9 + 2 + \frac{9 \times 2}{6} = 13 + 3 = 16\Omega$$

$$R_2 = 9 + 6 + \frac{9 \times 6}{9} = 15 + 6 = 21\Omega$$

$$R_3 = 6 + 2 + \frac{6 \times 2}{9} = 10 + \frac{4}{3} = \frac{34}{3}\Omega$$

$$R_1 = 16 + 3 = 19\Omega$$

$$R_3 = 8 + \frac{4}{3} = \frac{28}{3}\Omega$$

$$R_2 = 15 + 6 = 21\Omega$$

$$= 42$$

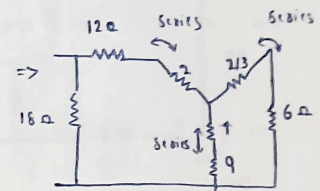
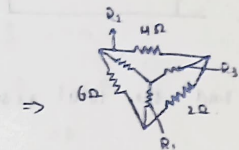
$\lambda$  to  $\Delta$

$$R_1 = \frac{R_a + R_c + \frac{R_a R_c}{R_b}}{R_c}$$

$$R_2 = \frac{R_a + R_b + \frac{R_a R_b}{R_c}}{R_b}$$

$$R_3 = \frac{R_b + R_c + \frac{R_b R_c}{R_a}}{R_a}$$

\* Outside connection

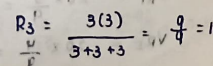


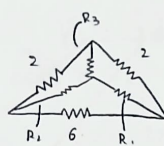
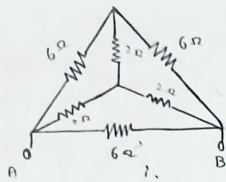
$$12 + 2 = 14$$

$$9 + 1 = 10$$

$$4/3 + 6 = \frac{20}{3}$$

$$\Rightarrow \frac{1}{10} + \frac{3}{20} = \frac{2+3}{20} = \frac{5}{20} = \frac{1}{4}\Omega = 4\Omega$$

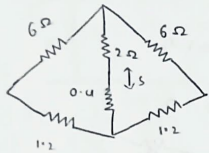




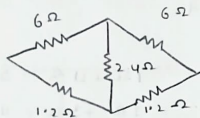
$$R_1 = \frac{2(6)}{2+6+2} = \frac{12}{10} = \frac{6}{5} = 1.2$$

$$R_2 = \frac{2(6)}{2+6+2} = \frac{12}{10} = \frac{6}{5} = 1.2$$

$$R_3 = \frac{2(2)}{10/5} = \frac{2}{5} = 0.4$$



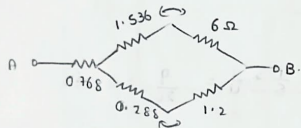
$$2 + 0.4 = 2.4 \Omega$$



$$R_1 = \frac{(1.2)(2.4)}{6.4 + 2.4 + 1.2} = \frac{36}{125} = 0.288$$

$$R_2 = \frac{(6.4)(2.4)}{6.4 + 2.4 + 1.2} = \frac{192}{125} = 1.536$$

$$R_3 = \frac{(6.4)(1.2)}{6.4 + 2.4 + 1.2} = \frac{96}{125} = 0.768$$



$$1.536 + 6 = 7.536$$

$$0.288 + 1.2 = 1.488$$

$$\frac{1}{7.536} + \frac{1}{1.488} = 0.8047$$

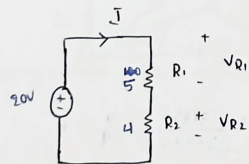
$$= 1.242 \Omega$$

$$\therefore R_{eq} = 0.768 + 1.242$$

$$R_{eq} = 2.01 \Omega$$

06/08/24

Voltage division rule: (series)



$$V_{R1} = V_T \times \frac{R_1}{R_1 + R_2}$$

$$V_{R2} = V_T \times \frac{R_2}{R_1 + R_2}$$

$V_T$ : Total voltage.

$$V_{R1} = 20 \times \frac{5}{9} = \frac{100}{9} V$$

$$V_{R2} = 20 \times \frac{4}{9} = \frac{80}{9} V$$

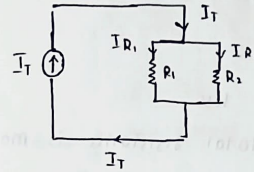
To verify voltages  
Apply kvl.

Voltage division rule

Current Division Rule: (parallel)

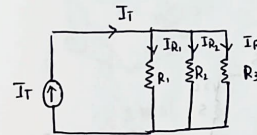
$$I_{R1} = I_T \times \frac{R_2}{R_1 + R_2}$$

$$I_{R2} = I_T \times \frac{R_1}{R_1 + R_2}$$



Exactly opp to voltage division rule.

$I_T$ : Total current.

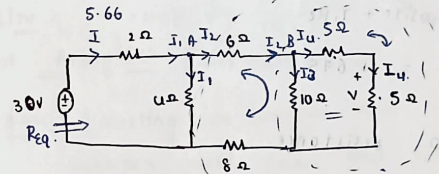


$$I_{R1} = I_T \times \frac{R_2 R_3}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

$$I_{R2} = I_T \times \frac{R_1 R_3}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

$$I_{R3} = I_T \times \frac{R_1 R_2}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

p) Find current and voltage for the given circuit.



$$I = \frac{V}{R_{eq}}$$

$$R_{eq} = 5 + 5 = 10 \Omega$$

$$\frac{1}{10} + \frac{1}{10} = 5 \Omega$$

$$6 + 5 + 8 = 19 \Omega$$

$$\frac{1}{19} + \frac{1}{4} = 3.304 + 2 \Omega = 5.304 \Omega$$

$$R_{eq} = 5.304 \Omega$$

$$I_T = \frac{30}{5.304} = 9.426 \text{ Amp}$$

$$I_2 = I_T \times \frac{4}{11 + 19}$$

$$= 5.66 \times \frac{4}{20} = 0.98 A$$

$$I_4 = 0.98 \times \frac{10}{10 + 10} = 0.98 \times \frac{10}{20} = \frac{0.98}{2} = 0.49 A$$

voltage of  $5\Omega$  Resistance.

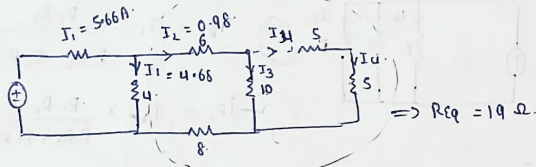
$$V = I \times (0.49) \times 5$$

$$= 2.45 \text{ V}$$

At the junction 'A' current  $I_1$  is divided into.

$I_1, I_2$ .

$I_1$  current is more and  $I_2$  is less because  $I_2$  current branch total resistance is more than the  $I_1$  branch ( $4\Omega$ ). So it opposes the current. So less current at  $I_2$ .

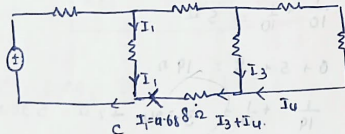


$$I_3 = I_4 = 0.98 \text{ A}$$

$$I_1 = 5.66 \times \frac{\text{opposite } R_{eq}}{\text{opposite} + I_1 R_c}$$

$$5.66 \times \frac{19}{19+4} = 4.675$$

current at  $8\Omega$  resistance.



$$I_3 + I_4 = 0.98 = I_2$$

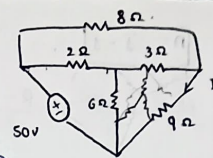
$$I_1 + I_2 = 0.98 + 4.68$$

$$= 5.66 \text{ A}$$

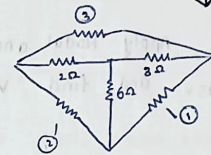
current is again added and accumulated at c.

$$\text{i.e.} = 5.66 \text{ Amp}$$

## Home work



Sol :



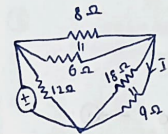
$$R_1 = 6 + 3 + \frac{6 \times 3}{2}$$

$$= 9 + \frac{18}{2} = 18$$

$$R_2 = 2 + 3 + \frac{2 \times 3}{3} = 12$$

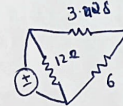
$$R_3 = 2 + 3 + \frac{2 \times 3}{6} = 5 + 1 = 6$$

Redrawing the circuit.



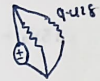
$$\frac{1}{8} + \frac{1}{6} = \frac{7}{24} = \frac{24}{7} = 3.428$$

$$\frac{1}{18} + \frac{1}{9} = \frac{1}{6} = 6$$



$$6 + 3.428 = 9.428$$

$$\frac{1}{9.428} + \frac{1}{12} = \frac{1}{0.189} = 5.291$$



$$R_{eq} = 5.291 \Omega$$

$$I = \frac{V}{R_{eq}}$$

$$I = \frac{50}{5.291} = 9.45 \text{ Ampere}$$

07/08/20

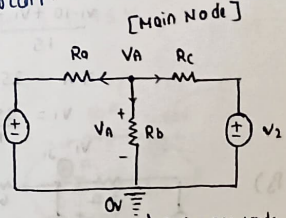
Nodal Analysis [KCL + Ohm's law]

\* Node: meeting or junction point where ever the branches meet. (more than two branches).

\* To calculate the unknown voltage for the given particular resistance in a circuit.

\* Apply Nodal Analysis at 'A'.

$$\frac{V_A - 0 - V_1}{R_a} + \frac{V_A - 0}{R_b} + \frac{V_A - 0 - V_2}{R_c} = 0$$



#1. Identify Nodes.

\*2. Calculate branches Node.

\*3. Apply Nodal analysis (eqns)

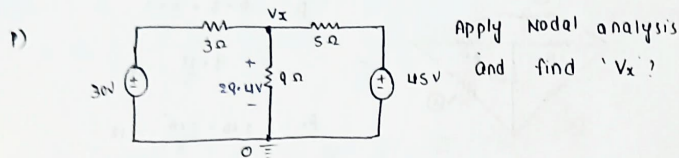
(If have doubt check whether the eqns

Satisfies KCL or Ohm's law).

⇒ For any circuit  $n = J - 1$

$n$  = no of nodes

$J$  = Junctions



Apply Nodal analysis  
and find  $V_x$ ?

i) Node - 1

ii) 3 branches are there.

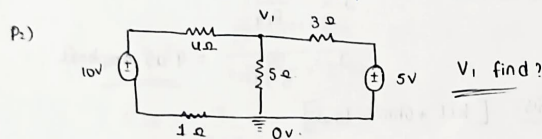
iii) Nodal Equation

$$\frac{V_x - 30}{3} + \frac{V_x - 0}{9} + \frac{V_x - 45}{5} = 0 \rightarrow (1)$$

$$15V_x - 450 + 5V_x + 9V_x - 405 = 0$$

$$29V_x = 855$$

$$V_x = \frac{855}{29} = 29.48 \text{ Volts}$$



$V_1$  find?

i) Node - 1

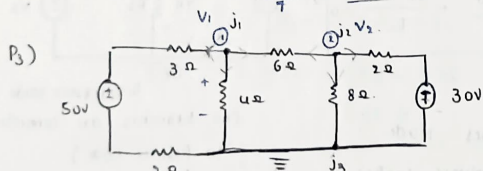
ii) 3 Branches

$$\frac{V_1 - 10}{5} + \frac{V_1 - 0}{5} + \frac{V_1 - 5}{3} = 0$$

$$\frac{V_1 - 10 + V_1 - 0 + 5V_1 - 25}{15} = 0$$

$$7V_1 = 35$$

$$V_1 = \frac{35}{7} = 5 \text{ Volts}$$



So Nodes = 2

$$\frac{V_1 - 50}{5} + \frac{V_1 - 0}{4} + \frac{V_1 - 30}{6} = 0 \rightarrow (1)$$

3rd Nodal Equation

$$\frac{V_1 - V_1}{6} + \frac{V_1 - 0}{8} + \frac{V_1 + 30}{2} = 0 \rightarrow (2)$$

$$\Rightarrow (1) \quad \frac{12V_1 - 600 + 15V_1 + 10V_1 - 10V_1}{60} = 0$$

$$\Rightarrow 37V_1 = 600 + 10V_1$$

$$\Rightarrow 37V_1 + 10V_1 = 600 \rightarrow (3)$$

$$\Rightarrow (2) \quad \frac{4V_1 - 4V_1 + 3V_1 - 0 + 12V_1 + 360}{24} = 0$$

$$\Rightarrow 19V_1 - 4V_1 = -360$$

$$4V_1 - 19V_1 = 360 \rightarrow (4)$$

$$37V_1 - 10V_1 = 600$$

Solving (3) & (4) we get

$$\begin{aligned} 37V_1 - 10V_1 &= 600 \quad \times 4 \Rightarrow 148V_1 - 40V_1 = 2400 \\ 4V_1 - 19V_1 &= 360 \quad \times 37 \Rightarrow -118V_1 + 703V_1 = -13320 \end{aligned}$$

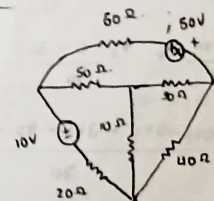
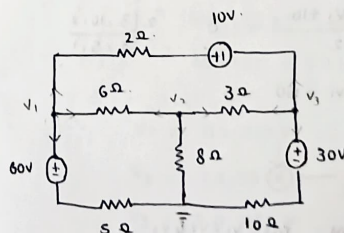
$$\Rightarrow (1) \quad \begin{aligned} 4V_1 - 19(139.57) &= 360 \\ 4V_1 - 2651.83 &= 360 \\ 4V_1 &= 360 + 2651.83 \end{aligned} \quad \times$$

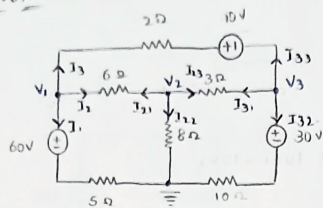
$$4V_1 - 19 \times 139.57 = 360$$

$$4V_1 = 360 + 2651.83 \quad 4V_1 = 3011.83$$

$$V_1 = \frac{3011.83}{4} = 752.96 \text{ V}$$

$$\therefore V_2 = -16.457 \text{ V} \quad V_1 = 11.76 \text{ V}$$





i) Number of Nodes = 3

ii) Apply KCL at Node  $V_1$ .

Sum of Entering currents = leaving currents

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_1 - 0 - 60}{5} + \frac{V_1 - V_2}{6} + \frac{V_1 - V_3 - 10}{2} = 0 \rightarrow (1)$$

$$\frac{6V_1 - 360 + 5V_1 - 5V_2 + 15V_1 - 15V_3 - 150}{30} = 0$$

$$26V_1 - 5V_2 - 15V_3 - 510 = 0$$

$$26V_1 - 5V_2 - 15V_3 = 510 \rightarrow (1)$$

Apply KCL at Node  $V_2$ .

$$\frac{V_2 - V_1}{6} + \frac{V_2 - 0}{8} + \frac{V_2 - V_3}{3} = 0$$

$$\frac{4V_2 - 4V_1 + 3V_2 + 8V_2 - 8V_3}{24} = 0$$

$$15V_2 - 4V_1 - 8V_3 = 0 \rightarrow (2)$$

Apply KCL at Node  $V_3$

$$I_3 + I_2 + I_6 = 0$$

$$\frac{V_3 - V_2}{3} + \frac{V_3 - 0 - 30}{10} + \frac{V_3 - V_1 + 10}{2} = 0$$

$$\frac{10V_3 - 10V_2 + 3V_3 - 90 + 15V_3 - 15V_1 + 150}{30} = 0$$

$$28V_3 - 10V_2 - 15V_1 = -60 \rightarrow (3)$$

Solve (1), (2), (3) Equations for  $V_1, V_2$  &  $V_3$

$$\begin{bmatrix} 26 & -5 & -15 \\ -4 & 15 & -8 \\ -15 & -10 & 28 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 510 \\ 0 \\ -60 \end{bmatrix} \quad \text{find } \Delta V$$

$$\Delta V = 26(420 - 80) + 5(-112 - 110) - 15(40 + 225) \\ = 26(340) + 5(-232) - 15(265) \\ = 8840 - 1160 - 3975$$

$$\Delta V = 3705$$

$$\frac{\Delta V_1}{\Delta V} = V_1 = \frac{\begin{vmatrix} 510 & -5 & -15 \\ 0 & 15 & -8 \\ -60 & -10 & 28 \end{vmatrix}}{\Delta V} \\ = 510(420 - 80) - 0(-) - 60(40 + 225) \\ = 510(340) - 60(265)$$

$$\Delta V_1 = 173400 - 15900 = 157500$$

$$V_1 = \frac{\Delta V_1}{\Delta V} = \frac{157500}{3705} = 42.510 \text{ V}$$

$$V_2 = \frac{\Delta V_2}{\Delta V} = \frac{\begin{vmatrix} 26 & 510 & -15 \\ -4 & 0 & -8 \\ -15 & -60 & 28 \end{vmatrix}}{\Delta V}$$

$$= -510(-112 - 120) + 0(-) + 60(-208 - 60) \\ = -510(-232) + 60(-268) \\ = +118320 - 16080$$

$$\Delta V_2 = 102240 \quad \therefore V_2 = \frac{\Delta V_2}{\Delta V} = \frac{102240}{3705} = 27.591 \text{ V}$$

$$V_3 = \frac{\Delta V_3}{\Delta V} = \frac{\begin{vmatrix} 26 & -5 & 510 \\ -4 & 15 & 0 \\ -15 & -10 & -60 \end{vmatrix}}{\Delta V}$$

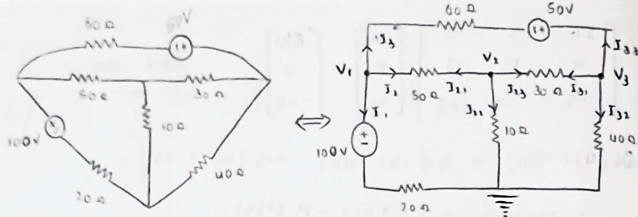
$$= 510(40 + 225) - 510(390 - 20) - 0(-) - 60(390 - 10) \\ = 510(265) - 60(380) \\ = 135150 - 22800 = \frac{112350}{3705} = 30.486 \text{ V}$$

$$\therefore V_1 = 42.510 \text{ V}$$

$$V_2 = 27.591 \text{ V}$$

$$V_3 = 30.486 \text{ V}$$

9



i) Number of Nodes = 3

ii) Apply KCL at node 'V1'.

$$I_1 + I_2 + I_3 = 0$$

$$\frac{V_1 - 0 - 100}{20} + \frac{V_1 - V_2}{50} + \frac{V_1 - V_3 + 50}{60} = 0$$

$$15V_1 - 1500 + 6V_1 - 6V_2 + 5V_1 - 5V_3 + 250 = 0$$

300

$$26V_1 - 6V_2 - 5V_3 = 1250 \rightarrow (1)$$

Apply KCL at Node 'V2'

$$I_{21} + I_{22} + I_{23} = 0$$

$$\frac{V_2 - V_1}{50} + \frac{V_2 - 0}{10} + \frac{V_2 - V_3}{30} = 0$$

$$3V_2 - 3V_1 + 15V_2 + 5V_2 - 5V_3 = 0$$

150

$$23V_2 - 3V_1 - 5V_3 = 0 \rightarrow (2)$$

Apply KCL at Node 'V3'

$$I_{31} + I_{32} + I_{33} = 0$$

$$\frac{V_3 - V_2}{30} + \frac{V_3 - 0}{40} + \frac{V_3 - V_1 - 50}{60} = 0$$

$$4V_3 - 4V_2 + 3V_3 + 2V_3 - 2V_1 - 100 = 0$$

120

$$9V_3 - 4V_2 - 2V_1 = 100 \rightarrow (3)$$

Solve Eqn (1), (2), (3) to find  $V_1, V_2, V_3$ .

$$\begin{bmatrix} 26 & -6 & -5 \\ -3 & 23 & -5 \\ -2 & -4 & 9 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 1250 \\ 0 \\ 100 \end{bmatrix}$$

$$= 26(207 - 20) + 6(-27 - 10) - 5(12 + 46)$$

$$= 26(187) + 6(-37) - 5(58)$$

$$= 4862 - 222 - 290$$

$$\Delta V = 4350$$

$$\frac{\Delta V_1}{\Delta V} = V_1 = \begin{bmatrix} 1250 & -6 & -5 \\ 0 & +23 & -5 \\ 100 & -4 & 9 \end{bmatrix}$$

$$= 1250(207 - 20) - 6( ) + 100(30 + 115)$$

$$= 1250(187) + 100(145)$$

$$= 233750 + 14500$$

$$\frac{\Delta V_1}{\Delta V} = \frac{248250}{4350} = 61.00V \quad 57.06V$$

$$\frac{\Delta V_2}{\Delta V} = V_2 = \begin{bmatrix} 26 & 1250 & -5 \\ -3 & 0 & -5 \\ -2 & 100 & 9 \end{bmatrix}$$

$$= -1250(-27 - 10) + 0( ) - 100(-130 - 15)$$

$$= -1250(-37) - 100(-145)$$

$$= 46250 + 14500 = \frac{37750}{3705} = 8.5695V \quad \frac{60750}{4350} = 16.396V \quad 13.965V$$

$$\frac{\Delta V_3}{\Delta V} = V_3 = \begin{bmatrix} 26 & -6 & 1250 \\ -3 & 23 & 0 \\ -2 & -4 & 100 \end{bmatrix}$$

$$= 1250(12 + 46) - 0( ) + 100(598 - 18)$$

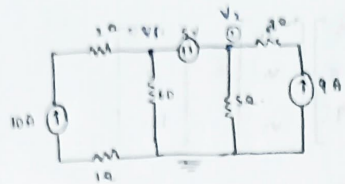
$$= 1250(58) + 100(580)$$

$$= 72500 + 58000 = \frac{130500}{4350} = 35.222V$$

$$V_1 = 57.00V$$

$$V_2 = 16.396V \quad 13.965V$$

$$V_3 = 35.222V$$



We are unable to write the complete nodal eqn for node 2

$$-10 + \frac{V_1}{6} + ( ) \times$$

for this we consider new method Super node analysis  
because there is an voltage source between two main nodes  
So the 2 nodes are considered as single node  
and complete the above equation

$$-10 + \frac{V_1}{6} + \frac{V_2}{5} - 9 = 0 \rightarrow (1)$$

\* This problem belongs to Super node Analysis

### Super Node Analysis:

While doing nodal analysis if you encountered any voltage source which is connected in b/w two main nodes we can treat it as a single node that node is called "Super node" and the technique is called "Super Node technique" (or) Analysis

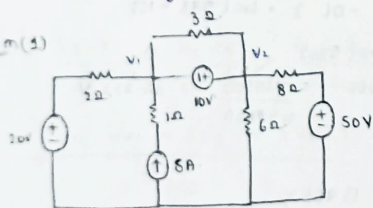
for Eq:  $-10 + \frac{V_1}{6} + ( ) \times -20$

$$( ) + \frac{V_2}{5} - 9 = \times \rightarrow (1)$$

(1) & (2) combine

$$-10 + \frac{V_1}{6} + \frac{V_2}{5} - 9 = 0 \rightarrow \text{Super Node equation}$$

problem (3)



Find Node voltage for the given circuit

Comparison Eqn  $V_2 - V_1 = 10 \rightarrow (1)$

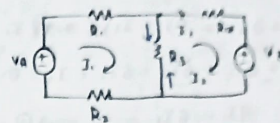
$$\frac{V_1 - 20}{2} + \frac{V_1 - V_2}{3} - 5 + \frac{V_2 - 0}{6} + \frac{V_2 - 50}{8} = 0 \rightarrow (2)$$

Ans: turn 2 pages

### MESH ANALYSIS (or) LOOP ANALYSIS [KVL + Ohm's]

\* It obeys "law of conservation of energy"

\* To find a particular branch current we use Mesh Analysis



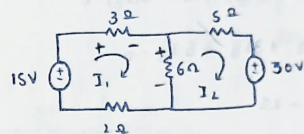
Apply Mesh analysis to loop 1

$$-V_1 + I_1 R_1 + (I_1 - I_2) R_3 + I_1 R_2 = 0 \rightarrow (1)$$

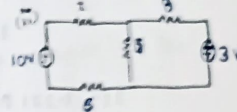
$$V_2 + (I_2 - I_1) R_4 + I_2 R_4 = 0 \rightarrow (2)$$

By solving above two Eqns we have  $I_1, I_2$  currents

Ex) P1)



Find Mesh currents



$$-30 + 3I_1 + (I_1 - I_2) 6 + 2I_1 = 0 \rightarrow (1)$$

$$5I_2 + 30 + (I_2 - I_1) 6 = 0 \rightarrow (2) \Rightarrow 5I_2 + 30 - 6I_1 = -30$$

$$-6I_1 + 5I_2 = -60$$

$$-15 + 3I_1 + 6I_1 - 6I_2 + 2I_1 = 0$$

$$6I_1 - 5I_2 = 30 \rightarrow (3)$$

$$11I_1 - 5I_2 = 30 \rightarrow (2)$$

Solve (2) & (3)

$$11I_1 - 6I_2 = 15 \times 6 \Rightarrow 66I_1 - 36I_2 = 90$$

$$6I_1 - 11I_2 = 30 \times 11 \Rightarrow 66I_1 - 121I_2 = 330$$

$$85I_2 = -240$$

$$I_2 = \frac{-240}{85} = -2.82$$

$$(2) \Rightarrow 11I_1 - 6(-2.82) = 15$$

$$11I_1 = 15 - 16.92$$

$$I_1 = \frac{-1.92}{11}$$

$$= -0.174$$

$$6I_1 - 11(-2.82) = 30$$

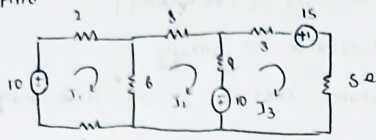
$$66I_1 - 30I_2 = 150$$

$$\Rightarrow 66I_1 + 121I_2 = 105$$

$$85I_2 = 25$$

$$I_2 = \frac{25}{85} = 0.176$$

p) Find the Mesh currents for the circuit.



First loop  $-10 + 2I_1 + (I_1 - I_2)6 + 18I_1 = 0$

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

$9I_1 - 6I_2 = 10 \rightarrow (1)$

Second loop  $8I_2 + (-10) + 6(I_2 - I_1) + 9(I_2 - I_3) = 10$

$8I_2 - 10 + 6I_2 - 6I_1 + 9I_2 - 9I_3 = 20$   
 $23I_2 - 6I_1 - 9I_3 = 30 \rightarrow (2)$

Third loop

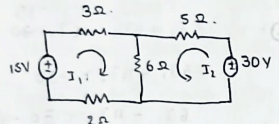
$10 + 9(I_3 - I_2) + 3(I_3) + 15 + 5(I_3) = 0$

$10 + 15 + 9I_3 - 9I_2 + 3I_3 + 5I_3 = 0$

$17I_3 - 9I_2 = -25$

$I_1 = 1.271 \text{ A}$  ,  $I_2 = 0.241 \text{ A}$  ,  $I_3 = 1.342 \text{ A}$

p)



Find the Mesh currents for the given circuit?

First loop

$-15 + 3I_1 + 6(I_1 + I_2) + 2I_1 = 0 \Rightarrow -15 + 3I_1 + 6I_1 + 6I_2 + 2I_1 = 0$

$11I_1 + 6I_2 = 15 \rightarrow (1)$

Second loop:

$-30 + 5I_2 + 6I_2 + 6I_1 = 0 \Rightarrow 11I_2 + 6I_1 = 30 \rightarrow (2)$

$11I_1 + 6I_2 = 15 \times 6 \Rightarrow 66I_1 + 36I_2 = 90$

$6I_1 + 11I_2 = 30 \times 11 \Rightarrow 66I_1 + 121I_2 = 330$

$-85I_2 = -240$

$I_2 = \frac{-240}{-85} = 2.823 \text{ A}$

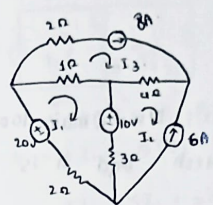
Sub in (1)

$11I_1 + 6(2.823) = 15$

$11I_1 = 15 - 16.938$

$I_1 = \frac{-1.938}{11} = -0.176$

# Mesh Analysis



1st loop  $-20 + 1(I_1 - I_3) + 10 + 3(I_1 + I_2) + 2I_1 = 0$

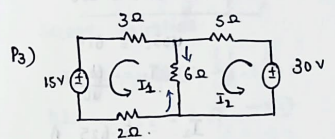
$-20 + I_1 - I_3 + 10 + 3I_1 + 3I_2 + 2I_1 = 0$

$6I_1 + 3I_2 - I_3 = 10 \rightarrow (1)$

2nd loop  $-10 + 4(I_2 - I_3) - 6 + 3(I_2) = 0$

directly current is flowing through

Second loop i.e.  $I_2 = -6 \text{ A}$



Find the Mesh current for the given circuit?

First loop

$3I_1 + 15 + 2I_1 + 6(I_1 + I_2) = 0$

$3I_1 + 2I_1 + 6I_1 - 6I_2 = -15$

$11I_1 - 6I_2 = -15 \rightarrow (1)$

Second loop

$-30 + 5I_2 + 6I_2 - 6I_1 = 0$

$11I_2 - 6I_1 = 30 \rightarrow (2)$

$11I_1 - 6I_2 = -15 \rightarrow (1)$

$-6I_1 + 11I_2 = 30 \rightarrow (2)$

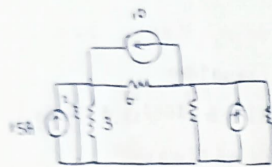
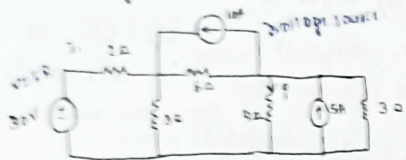
By Solving (1) and (2)

$I_1 = 0.176 \text{ A}$

$I_2 = 2.823 \text{ A}$



Find  $I$  using source transformation technique.



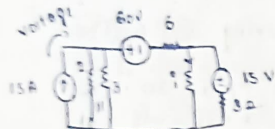
$$I = \frac{V}{R}$$

$$= \frac{30}{2} = 15 \text{ A}$$

$$V = IR$$

$$= 10 \times 6$$

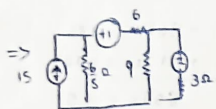
$$V = 60 \text{ V}$$



$$V = IR$$

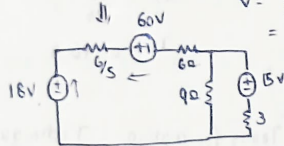
$$= 15 \times 3$$

$$= 45 \text{ V}$$

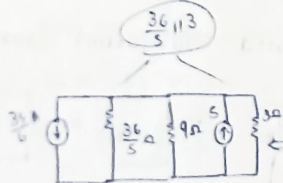


$$V = \frac{6}{5} \times 6$$

$$= 18$$



High  $V$  - low voltage and direction taken along highest  $V$ .

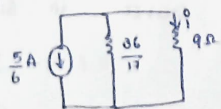


Two currents are in opposite direction so difference will taken

(high to low)

$$\frac{35}{6} - 5 = 0.8 \text{ A}$$

$$I = \frac{V}{R} = \frac{42}{36/5} = \frac{35}{6} \text{ A}$$



$$V = IR$$

$$= \frac{5}{4} \times \frac{36}{12}$$

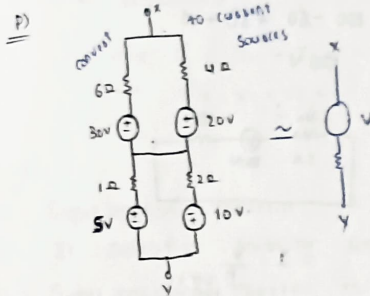
$$V = \frac{30}{14} \text{ V}$$

$$I = \frac{V}{R} = \frac{\frac{30}{14}}{\frac{36}{12} + 9}$$

$$= \frac{\frac{30}{14}}{\frac{36}{12} + 9} = \frac{30}{36} = \frac{5}{6}$$

$$= \frac{5}{6} \times \frac{1}{9} = -0.15$$

because source current and  $I$  are in opposite



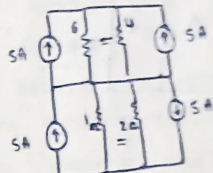
$$I_1 = \frac{V}{R_1} = \frac{30}{6} = 5 \text{ A}$$

$$I_2 = \frac{V}{R_2} = \frac{20}{4} = 5 \text{ A}$$

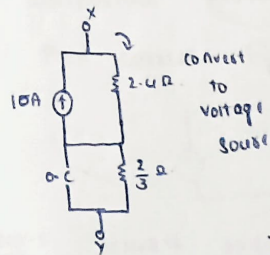
$$I_3 = \frac{V}{R_3} = \frac{5}{1} = 5 \text{ A}$$

$$I_4 = \frac{V}{R_4} = \frac{10}{2} = 5 \text{ A}$$

Two current sources are in same direction so add



Current sources are in opp direction so sub



convert to voltage source

$$5 + 5 = 10 \text{ A}$$

$$5 - 5 = 0 \text{ A}$$

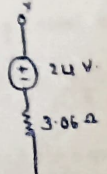
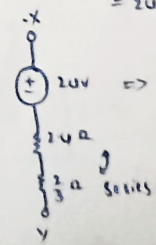
$$\frac{1}{6} + \frac{1}{6} = 24 \text{ ohm}$$

$$\frac{1}{6} + 2 = \frac{13}{6}$$

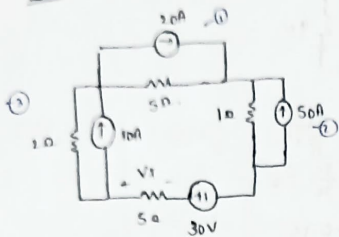
$$V = IR$$

$$= 10 \times 2 = 20 \text{ V}$$

$$= 20 \text{ V}$$



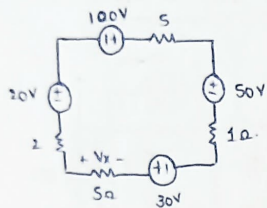
## Homework



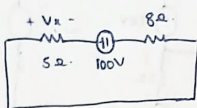
①, ②, ③ are converted  
to voltage sources

$$\begin{aligned} \text{① } V &= IR ; \quad \text{② } V = IR \\ V &= 20 \times 5 = 100 \text{ V} \\ V &= 50 \times 1 = 50 \text{ V} \end{aligned}$$

$$\begin{aligned} \text{③ } V &= IR \\ &= 10 \times 2 \\ &= 20 \text{ V} \end{aligned}$$

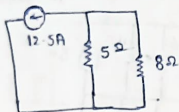


$$100 - 50 + 30 + 20$$



$$I = \frac{V}{R} = \frac{100}{8} = 12.5$$

$$I = 12.5 \text{ A}$$



19/08/24 UNIT-2

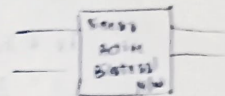
## Superposition Theorem

In any linear active bilateral network consisting of no. of energy sources and resistances. The response of Voltage or current through branch is equal to the sum of responses of Voltage or current through branch. The response acting alone (os).

Total responses = Sum of individual responses

$$I = I_1 + I_2 + \dots + I_n$$

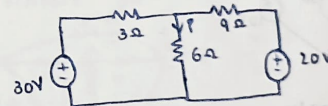
$$V = V_1 + V_2 + \dots + V_n$$



Note:

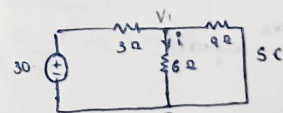
- ① Superposition theorem is only for valid for linear elements.
- ② It satisfies linearity and homogeneity.
- ③ Superposition theorem is applicable when the circuit consists of minimum two sources.
- ④ While doing Superposition theorem activate only one source at a time and the remaining source is deactivated (if it is a voltage source make it short circuit, if it is a current source make it open circuit).
- ⑤ Power calculations cannot be done directly by using Superposition theorem.

① Find current by using S.P.T?



Step-1: Activate 30V

Apply nodal analysis



$$\frac{-30 - 0 + V_1}{3} + \frac{V_1 - 0}{6} + \frac{V_1 - 0}{9} = 0$$

$$8V_1 - 180 + 3V_1 + 2V_1 = 0$$

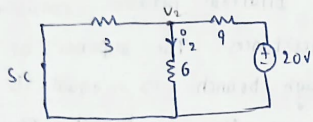
$$11V_1 = 180$$

$$V_1 = \frac{180}{11} = 16.36$$

$$I = \frac{V}{R} = \frac{16.36}{6} = 2.73$$

$$I = 2.72 \text{ A}$$

Step 2: Activate 30V only.



$$\frac{V_2 - 20}{9} + \frac{V_2}{6} + \frac{V_2}{3} = 0$$

$$6V_2 + 3V_2 + 2V_2 - 40 = 0$$

$$11V_2 = 40$$

$$V_2 = \frac{40}{11} \text{ V}$$

$$I_2 = \frac{40}{11} \times \frac{1}{6}$$

$$= \frac{20}{33} = 0.606 \text{ A}$$

$$I_0 = I_1 + I_2$$

$$I = \frac{30}{11} + \frac{20}{33} = \frac{110}{33} = \frac{10}{3} \text{ A (Ans)}$$

Alt to Super position theorem.

$$\frac{V-30}{3} + \frac{V-20}{9} + \frac{V}{6} = 0$$

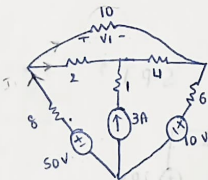
$$6V - 180 + 3V + 2V - 40 = 0$$

$$11V = 220$$

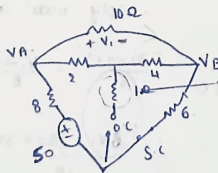
$$V = \frac{220}{11} = 20$$

$$I = \frac{V}{R} = \frac{20}{6} = \frac{10}{3} \text{ A}$$

2) Find 'V' using Super position Theorem.

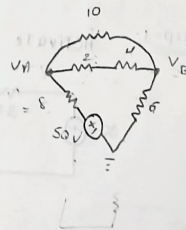


Step 1: Activate 50V only.



$$V_A - V_B$$

Neglected.



Apply Nodal Analysis at A & B.

$$\frac{V_A - 50}{8} + \frac{V_A - V_B}{10} + \frac{V_A - V_B}{6} = 0 \quad \text{--- (1)}$$

$$15V_A - 750 + 12V_A - 12V_B + 20V_A - 20V_B = 0$$

$$47V_A - 32V_B = 750 \rightarrow (1)$$

$$\frac{V_B}{6} + \frac{V_B - V_A}{6} + \frac{V_B - V_A}{10} = 0 \rightarrow (2)$$

$$5V_B + 5V_B - 5V_A + 3V_B - 3V_A = 0$$

$$13V_B - 8V_A = 0$$

$$V_A = 27.46 \quad V_B = 16.90$$

$$V_1 = V_A - V_B$$

$$= 10.56 \text{ V}$$

$$V = 50$$

6+10 are parallel

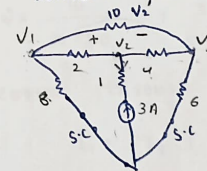
$$\frac{1}{6} + \frac{1}{10} = \frac{10+6}{60} = \frac{16}{60} = \frac{4}{15}$$

$$\frac{15}{4} + 8 + 6 = \frac{15}{4} + 14$$

$$R = \frac{71}{4} = 17.75$$

$$I = \frac{5000}{17.75} = 281$$

Step 2: Activate 3A.



$$\frac{V_1}{8} + \frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{10} = 0$$

$$5V_1 + 20V_1 - 20V_2 + 4V_1 - 4V_3 = 0$$

$$29V_1 - 20V_2 - 4V_3 = 0 \rightarrow (1)$$

$$\frac{V_2 - V_1}{2} - 3 + \frac{V_2 - V_3}{4} = 0$$

$$2V_2 - 2V_1 - 12 + V_2 - V_3 = 0$$

$$3V_2 - 2V_1 - V_3 = 12 \rightarrow (2)$$

$$\frac{V_3 - V_1}{10} + \frac{V_3 - V_2}{4} + \frac{V_3}{6} = 0$$

$$-6V_1 - 15V_2 + 31V_3 = 0$$

$$6V_3 - 6V_1 + 15V_3 - 15V_2 + 10V_3 = 0$$

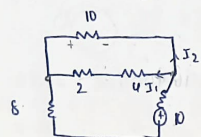
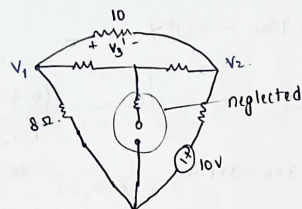
$$V_1 = 11.4 \text{ V}$$

$$V_2 = 14.7 \text{ V}$$

$$V_3 = 9.38 \text{ V}$$

$$V_3' = V_1 - V_3 = 11.4 - 9.38 = 2.11 \text{ V}$$

Step -3: Activate 10V.



$$\frac{1}{10} + \frac{1}{6} =$$

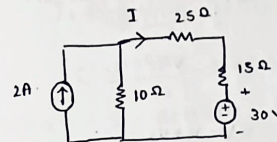
$$R_{eq} = 17.75$$

$$I = \frac{V}{R_{eq}} = \frac{10}{17.75}$$

$$I_2 = \frac{0.56 \times 6}{6+10} = 0.21 \text{ A}$$

$$V_3' = 10(I_2) = -10(0.21) = -2.1 \text{ V}$$

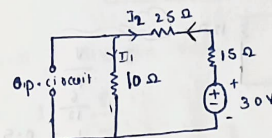
$$V = 10.56 + 2.11 - 2.1 = 10.67 \text{ V}$$



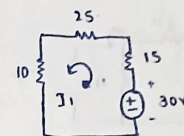
Find the current 'I' at 25Ω using SPT.

Sol

Step-1: Activate 30V.



$$I = I_1 + I_2$$



Mesh analysis

$$-30 + 15I_1 + 25I_1 + 10I_1 = 0$$

$$R_{eq} = 10 + 25 + 15 \text{ (oh)}$$

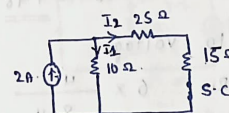
$$R_{eq} = 50$$

$$I = \frac{V}{R_{eq}} = \frac{30}{50} = 0.6 \text{ A}$$

$$I_1 = \frac{30}{50}$$

$$I_1 = 0.6 \text{ A}$$

Step-2: Activate 2A.



25 + 15 are parallel resistors

$$\frac{1}{25} + \frac{1}{15} = \frac{8}{75} = \frac{4}{37.5}$$

$$= 4.375$$

$$\frac{1}{40} + \frac{1}{10} = \frac{1+4}{40} = \frac{5}{40} = \frac{1}{8}$$

using the current division rule.

$$I_2 = I_T \times \frac{\text{Resistance of opp. resistor}}{\text{Resistance of oppes} + \text{Resistance of currentis}}$$

$$= 2 \times \frac{10}{10+40} = 2 \times \frac{10}{50} = \frac{2}{5} = 0.4 \text{ A}$$

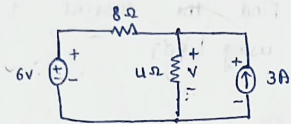
The current through 25Ω.

$$I_1' = I_1 - I_2$$

$$= 0.6 - 0.4$$

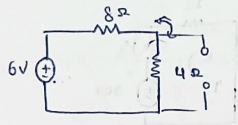
$$= 0.2 \text{ amp}$$

\* Use the Superposition theorem to find  $V$  in the ckt



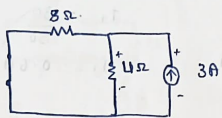
$$V = V_1 + V_2$$

Sol:- Step-1: Activate 6V



$$I = \frac{V}{R} = \frac{6}{12} = \frac{1}{2} = 0.5 \text{ A}$$

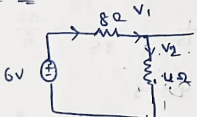
Step-2: Activate 3A



$$\frac{1}{8} + \frac{1}{4} = \frac{1+2}{8} = \frac{3}{8} = 2.66$$

$$V = IR = 3 \times 2.66 = 7.98 \text{ V}$$

Step-1:



Atc to Voltage

$$V_{R_u} = 6 \times \frac{4}{8+4}$$

$$= \frac{2}{3} \times \frac{4}{12}$$

$$V_{R_u} = 2$$

$$3 \times \frac{8}{8+4}$$

$$3 \times \frac{8}{12}$$

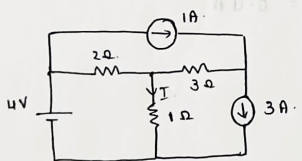
$$2 \times \frac{8}{12}$$

$$I = 2 \times \frac{8}{12} = \frac{8}{3}$$

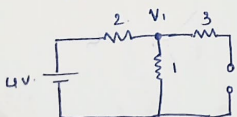
$$V = 2 + 7.98$$

$$V = 9.98 \text{ V}$$

\* Find the current in the  $1\Omega$  resistor using Superposition theorem.



Step-1: Activate 4V



Nodal analysis

$$V_1 - \frac{4}{2} + \frac{V_1}{1} + \frac{V_1}{3} = 0$$

$$3V_1 - 12 + 6V_1 + 2V_1 = 0$$

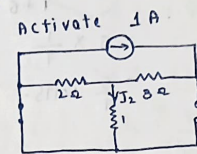
$$11V_1 = 12$$

$$V_1 = \frac{12}{11} = 1.0909 \text{ V}$$

$$I_1 = \frac{V_1}{R}$$

$$= \frac{1.0909}{1} = 1.09 \text{ A}$$

Step-2:



Current division rule

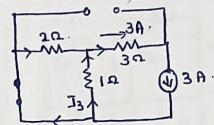
$$= 1 \times \frac{2}{2+1}$$

$$= 1 \times \frac{2}{3}$$

$$= 1 \times 0.6$$

$$I_2 = 0.6 \text{ A}$$

Step-3: Activate 3A



Current division rule

$$= 3 \times \frac{2}{2+1}$$

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

$$I_3 = 2 \text{ A}$$

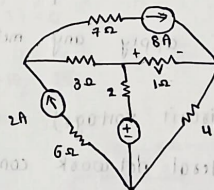
$$I = I_1 + I_2 + I_3$$

$$= 1.09 + 0.6 + 2$$

$$= 3.69$$

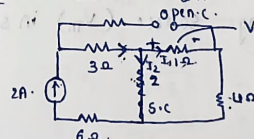
Example 24:

\* Find 'V' using S.P.T.



Step-1

Activate: 3A



Current division rule

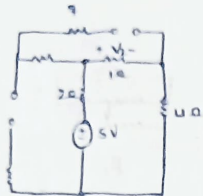
$$I_1 = 2 \times \frac{2}{2+5}$$

$$= 2 \times \frac{2}{7} = \frac{4}{7} \text{ A}$$

$$V_1 = I_1 R$$

$$= \frac{4}{7} \times 1 = \frac{4}{7} \text{ Volts}$$

Step-1: Activate SV



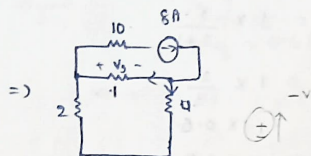
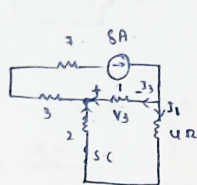
Apply voltage division rule

$$V_1 = 5 \times \frac{1}{1+6}$$

$$= 5 \times \frac{1}{7}$$

$$= \frac{5}{7} \text{ volts}$$

Step-2: Activate 8A



$$I_3 = 8 \times \frac{6}{6+1}$$

$$= \frac{8 \times 6}{7} = \frac{32}{7} \text{ A}$$

$$= -\frac{48}{7}$$

Apply current division

$$V_3 = I_3 R$$

$$= -\frac{48}{7} \times 1$$

$$= -\frac{48}{7} \text{ V}$$

∴ Total responses

$$= \frac{4}{7} + \frac{5}{7} - \frac{48}{7} = \text{V}$$

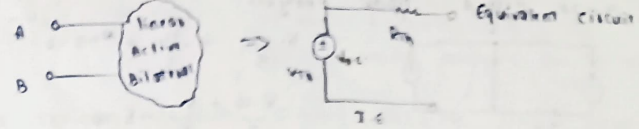
$$\frac{9}{7} - \frac{48}{7} = \text{V}$$

$$\text{V} = -\frac{39}{7} \text{ V}$$

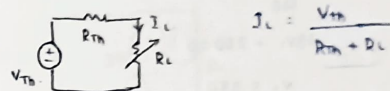
If have doubt apply any method to find 'V'

Thevenin's Theorem: (Open Circuit Voltage)

In any linear active bilateral network consisting of no. of Energy sources with open output target terminals can be converted into a single voltage source ( $V_{th}$ ) in series with single Resistance ( $R_{th}$ )

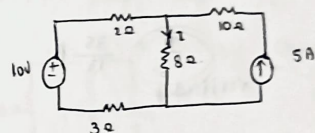


To Find  $I_L$

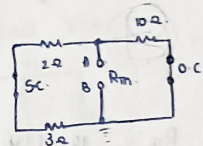


$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

① Find current using Thevenin's Theorem



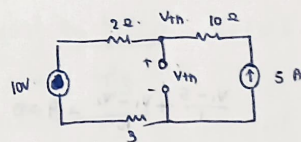
Sol: Step-1 To find  $R_{th}$



The  $R_{th}$  connected terminals calculate only the  $R_{th}$  connected to  $R_{th}$

$$R_{th} = 2 + 3 = 5\Omega$$

Step-2: To find  $V_{th} / V_{oc}$



$$V = IR$$

$$= 50$$

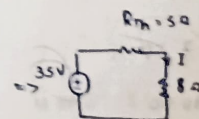
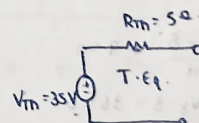
Nodal Analysis

$$\frac{V_{th} - 10}{5} + (-5) = 0$$

$$V_{th} - 10 - 25 =$$

$$V_{th} = 35$$

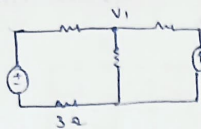
Step-3:



$$I = \frac{35}{5+8}$$

$$I = \frac{35}{13} \text{ A}$$

# General Method Nodal Analysis



$$\frac{V_1 - 10}{5} + \frac{V_1}{8} + 5 = 0$$

$$\frac{V_1 - 10}{5} + \frac{V_1}{8} - 5 = 0$$

$$8V_1 - 80 + 5V_1 - 200 = 0$$

$$13V_1 - 280 = 0$$

$$13V_1 - 280 = 0$$

$$V_1 = \frac{280}{13}$$

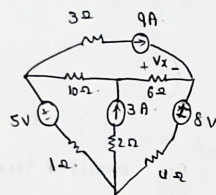
$$V_1 = \frac{280}{13} \quad I_1 = \frac{V}{R} = \frac{280}{13} \times \frac{1}{8}$$

$$I_1 = \frac{35}{13} \text{ A}$$

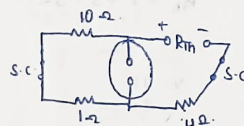
verified

Find 'V1' using Thevenin's Theorem

2)



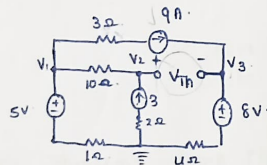
Step-1: To Find  $R_{Th}$



$$R_{Th} = 10 + 1 + 4$$

$$R_{Th} = 15 \Omega$$

Step-2: To Find  $V_{Th}$



$$\frac{V_1 - 5}{1} + \frac{V_1 - V_2}{10} + 9 = 0$$

$$10V_1 - 50 + V_1 - V_2 + 90 = 0$$

$$11V_1 + 40 - V_2 = 0$$

$$11V_1 - V_2 = -40 \rightarrow (1)$$

$$\frac{V_2 - V_1}{10} - 3 = 0$$

$$V_2 - V_1 - 30 = 0$$

$$V_2 - V_1 = 30 \rightarrow (2)$$

$$11V_1 - V_2 = -40$$

$$-V_1 + V_2 = 30$$

$$10V_1 = -10$$

$$V_1 = -1$$

$$\frac{V_3 - 8}{4} + 9 = 0$$

$$V_3 - 8 - 36 = 0$$

$$V_3 = 44 \rightarrow (3)$$

$$V_2 + 1 = 30$$

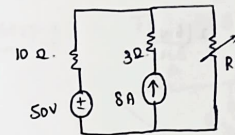
$$V_2 = 29$$

$$V_2 - V_3 = -15 \text{ volts}$$

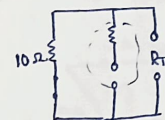
if have a doubt verify by applying nodal analysis for the entire ckt.

21/08/20

p) Obtain thevenin's Equivalent circuit for the circuit shown below.



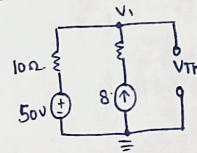
Step-1: To find  $R_{Th}$



by observing the circuit

$$R_{Th} = 10 \Omega$$

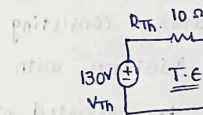
Step-2: To find  $V_{Th}$



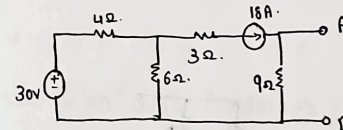
$$\frac{V_1 - 50}{10} - 8 = 0$$

$$V_1 - 50 - 80 = 0$$

$$V_{Th} = 130 \text{ V}$$



p) Find the thevenin's Eqant ckt for the circuit shown below.

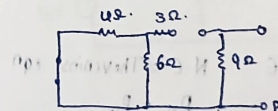


Step-1: To find  $R_{Th}$

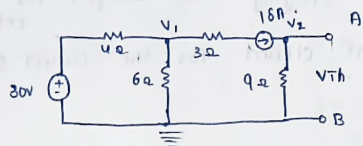
4 and 6Ω are series

$$4 + 6 + 9 = 19 \Omega$$

$$R_{Th} = 9 \Omega$$



Step-2: To Find  $V_{TH}$



$$\frac{V_1 - 30}{4} + \frac{V_1}{6} + 18 = 0$$

$$\frac{3V_1 - 90 + 2V_1 + 216}{12} = 0$$

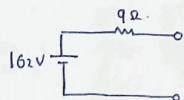
$$5V_1 - 90 + 216 = 0 \rightarrow V_1 = -25.2 \text{ Volts}$$

$$V_1 = V_2 \quad -18 + \frac{V_2}{9} = 0$$

$$-162 + V_2 = 0$$

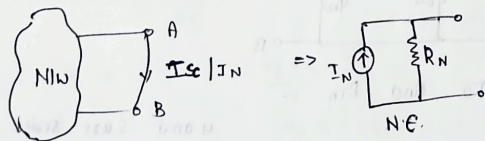
$$V_2 = 162$$

$$V_2 = V_{TH} = 162 \text{ V}$$



23/08/20: Norton's Theorem

In any linear active Bilateral network consisting of number of energy sources and resistances with short circuit target terminals can be converted into a single current source ( $I_N$ ) in parallel with a single resistance ( $R_N$ )

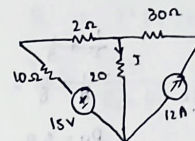


NOTE - N.E = Thevenin's eqn

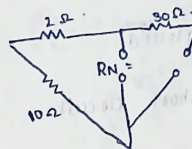
$$R_N = R_{TH}$$

$$V_N = V_{TH}$$

P) Find current using Norton's theorem

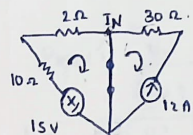


Step-1: To find  $R_N$



$$R_N = 12 \Omega$$

Step-2: To find  $I_N$



$$-15 + 10I_1 + 2I_1 = 0$$

$$12I_1 = 15$$

$$I_1 = \frac{15}{12} \text{ A}$$

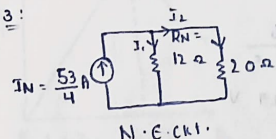
$$I_2 = +12$$

$$I_2 = 12$$

$$I_N = \frac{15}{12} + 12$$

$$= \frac{53}{4} \text{ A}$$

Step-3:



current division rule

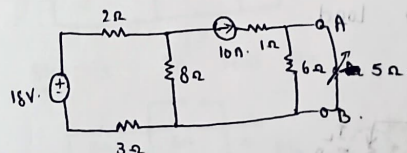
$$= 13.25 \times \frac{12}{12 + 20}$$

$$= 13.25 \times \frac{12}{32} = 13.25 \times \frac{3}{8}$$

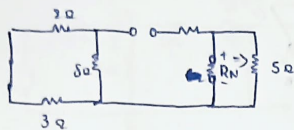
$$= 13.25 \times \frac{3}{8}$$

$$= 4.968 \text{ Amp}$$

P) Find  $V_{TH}$  using Norton's Theorem



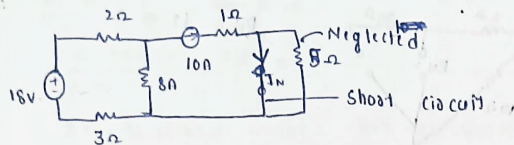
Step-1: To find  $R_N$



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

$$R_N = 5 \Omega$$

Step 2:

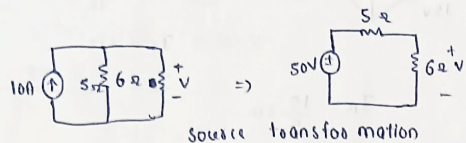


$$-18 + 5I_1 + 8(I_1 - I_2) = 0$$

$$-18 + 5I_1 + 8I_1 - 8I_2 = 0$$

$$-18 + 13I_1 - 8I_2 = 0$$

Step-3:



voltage division rule.

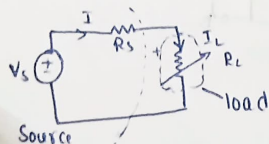
$$V_{6\Omega} = 50 \times \frac{6}{6+5}$$

$$= \frac{300}{11} = 27.27 \text{ V}$$

Maximum power transfered theorem:

In any linear active bilateral network consisting of no. of energy sources. If load resistance is equal to source resistance then only max. power is transferred to source to load.

$$i.e., R_L = R_S$$



we know that power delivered by the load is

$$P_L = I^2 R_L \rightarrow (1)$$

$$I = \frac{V_S}{R_S + R_L} \rightarrow (2)$$

$$P_L = \frac{V_S^2}{(R_S + R_L)^2} \cdot R_L$$

$$\frac{dP_L}{dR_L} = 0 \quad [\because f'(x) = 0]$$

$$V_S^2 \left( \frac{d}{dR_L} \left[ \frac{R_L}{(R_S + R_L)^2} \right] \right) = 0$$

$$V_S^2 \left[ R_L \cdot \frac{-2(R_S + R_L) \cdot 1 - (R_S + R_L)^2}{(R_S + R_L)^4} \right] = 0$$

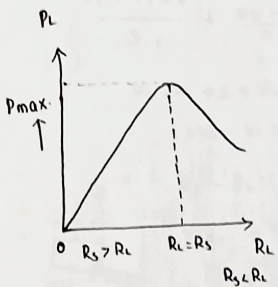
$$(R_S + R_L) \left[ \frac{2R_L - R_S - R_L}{(R_S + R_L)^3} \right] = 0$$

$$R_L - R_S = 0$$

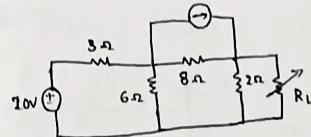
$$R_L = R_S$$

$$P_{max} = \frac{V_S^2}{(R_S + R_S)^2} \cdot R_S$$

$$P_{max} = \frac{V_S^2}{4R_S} \Rightarrow P_{max} = \frac{V_{th}^2}{4R_{th}}$$



p) Find  $P_{max}$ .



Sol: Step-1 To Find  $R_{Th}$

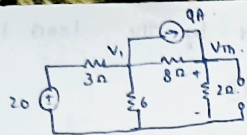


$$\frac{1}{\frac{1}{10} + \frac{1}{6}} = 0.266$$

$$= R_{Th} = \frac{5}{3} \Omega$$

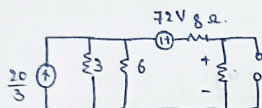
$$\frac{1}{8} + \frac{1}{8} = \frac{1}{4}$$

Step-1:



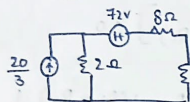
Apply source transformation

$$I = \frac{V}{R} = \frac{20}{3}$$



$$V = IR = 9 \times 8 = 72$$

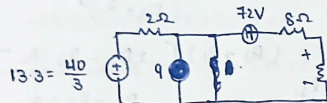
$$\frac{1}{3} + \frac{1}{6} = \frac{1}{2}$$



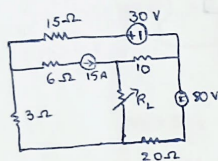
$$V = IR = \frac{20}{3} \times 2 = \frac{40}{3}$$

$$I = \frac{V}{R} = \frac{72}{8} = 9$$

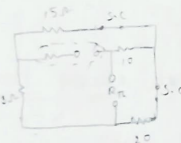
$$= \frac{40}{3} = 13.33$$



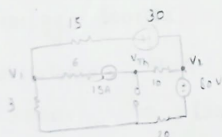
$$72 + 13.33 = 85.33$$



Step 2: To find  $R_{th}$



$$P_{th} = 19.47$$



$$\frac{V_1 - 0}{3} - 15 + \frac{V_1 - 30 - V_1}{15} = 0$$

$$5V_1 - 225 + V_1 - 30 - V_1 = 0$$

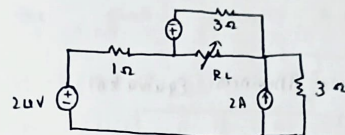
$$\frac{V_2 - V_{th}}{10} + \frac{V_2 + 30 - V_1}{15} + \frac{V_2 - 80}{20} = 0$$

$$6V_1 - V_1 = 255$$

$$\frac{V_{th} - V_2}{10} + 15 = 0$$

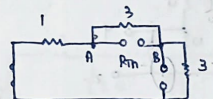
$$V_{th} - V_2 = -150$$

① What is the max. power to the load.



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

Step-1 To find  $R_{th}$

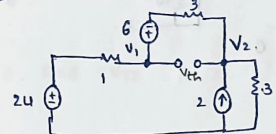


$$1 + 3 = 4$$

$$\frac{1}{4} + \frac{1}{3} = \frac{U+3}{12} = \frac{7}{12} = \frac{12}{7}$$

$$R_{th} = \frac{12}{7}$$

Step-2 To find  $V_{th}$



$$\frac{V_1 - 20}{1} + \frac{V_1 + 6 - V_2}{3} = 0$$

$$3V_1 - 72 + V_1 + 6 - V_2 = 0$$

$$4V_1 - V_2 = 66 \rightarrow (1)$$

$$\frac{V_2 - V_1 + 6}{3} + \frac{V_2 - 0}{3} = 0$$

$$V_1 = 22.28V$$

$$V_2 = 11.14V$$

$$V_2 - V_1 + 6 + V_2 + 6 = 0$$

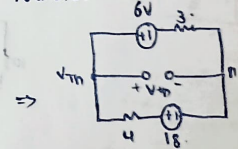
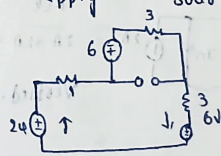
$$2V_2 - V_1 = 0$$

$$V_1 - V_2 = 11.14V$$

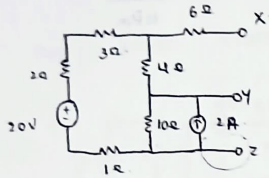
$$\therefore V_{th} = 11.14V$$

$$P_{max} = \frac{(11.14)^2}{4 \left( \frac{12}{7} \right)} = 17.96W$$

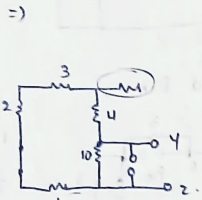
also apply source transformation to find  $V_{th}$



① Determine Thevenin's and Norton's Equivalent circuit across y and z terminals

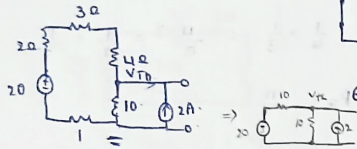


Thevenin's Equivalent



$$\frac{1}{10} + \frac{1}{10}$$

$$= \frac{2}{10} = \frac{1}{5} = 5 \Omega$$



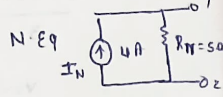
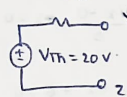
$$-2 + \frac{V_{Th} - 0}{10} = 0 \Rightarrow \frac{V_{Th} - 20}{10} = 0$$

$$2V_{Th} - 20 = 0 \Rightarrow V_{Th} = 20V$$

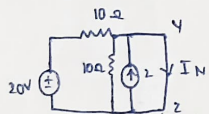
$$2V_{Th} = 40$$

$$V_{Th} = 20V$$

$$R_{Th} = 5\Omega$$

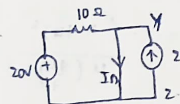


Norton's Current

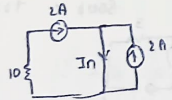


10Ω is neglected because

Resistance is passive element



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

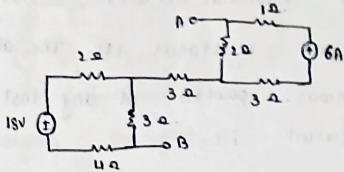


KCL

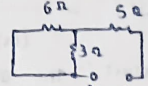
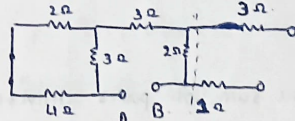
$$2A + 2A = 4A$$

Verified

Determine Thevenin's and Norton's Equivalent circuit for the given circuit A G B



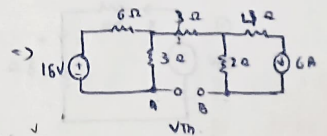
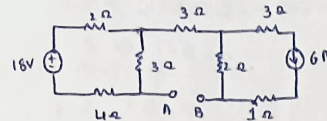
Step 1: To find  $R_{Th}$



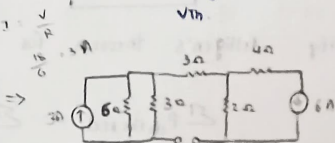
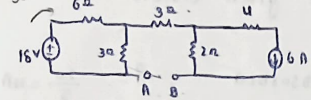
$$\frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} = \frac{1}{2} = 2$$

$$5 + 2 = R_{Th} = 7\Omega$$

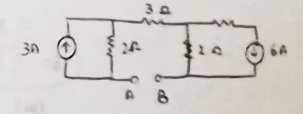
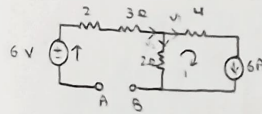
② To Find  $V_{Th}$



Source transformation



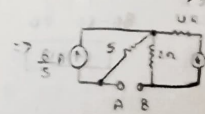
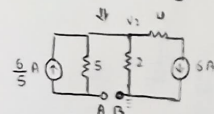
$$\frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} = \frac{1}{2} = 2$$



$$3 + 2 = 5\Omega$$

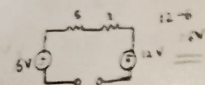
$$V = IR = 2 \times 5 = 10V$$

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



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

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



Telligen's Theorem

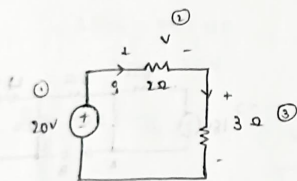
In any linear active bilateral network consisting of no. of energy sources and resistances etc. The algebraic sum of the instantaneous powers at any instant is equal to 0 in a circuit i.e.,

$$\sum_{i=1}^n P_i = 0$$

(or)

In a circuit the algebraic sum of power delivered is equal to the algebraic sum of power absorbed at a particular instant i.e.,

$$\sum P_{\text{delivered}} = \sum P_{\text{absorbed}}$$



Verify Telligen's theorem for the given circuit.

$$\sum P_{\text{delivered}} = \sum P_{\text{absorbed}} \quad \therefore I = \frac{20}{5} = 4A$$

$$\begin{aligned} P &= VI \Rightarrow \sum P(u) = i^2 R_1 + i^2 R_2 \\ &= u^2(2) + (u)^2(3) \\ &= 2u^2 + 3u^2 \end{aligned}$$

$$80 = 80$$

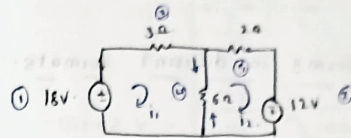
(or)

$$- \sum P(u) + 2(u^2) + (u)^2(3) = 0$$

$$80 - 80 = 0$$

$$0 = 0$$

2) Verify Telligen's theorem for the given circuit.



Mesh analysis to loop 1

$$-16 + 3I_1 + 6(I_1 - I_2) = 0$$

$$9I_1 - 6I_2 = 16 \rightarrow (1)$$

Mesh analysis to loop 2

$$6(I_2 - I_1) + 12I_2 = 0$$

$$-6I_1 + 8I_2 = 0 \rightarrow (2)$$

Solving (1) & (2)

$$I_1 = 6A$$

$$I_2 = 8A$$

Applying Telligen's Theorem

$$16(6) + 12(8) - (6)^2(3) - 0(6) - (6)^2(6) = 0$$

$$108 + 96 - 108 - 42 = 0$$

$$\Rightarrow 0 = 0$$