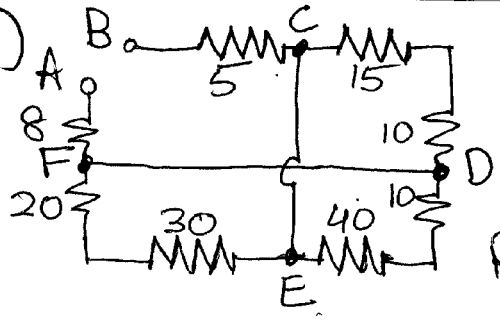
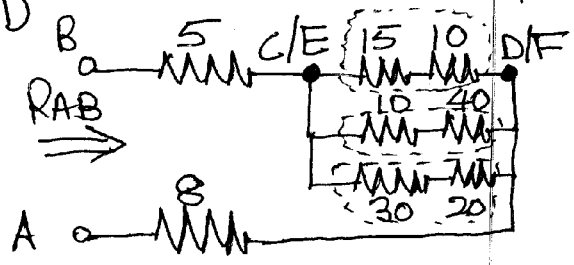
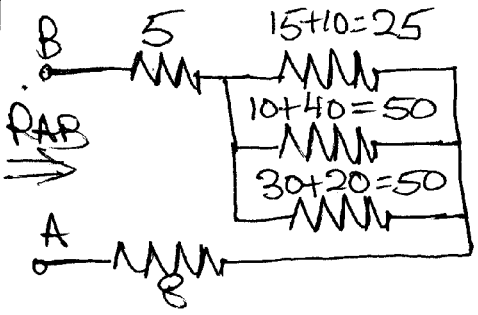
Q1)



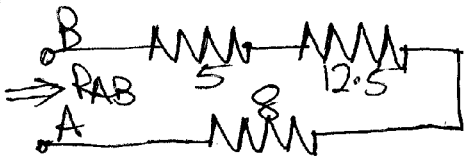
Points F and D, C and E are shorted hence they can be considered as one points





$25\Omega // 50\Omega // 50\Omega$

$\therefore \frac{1}{R} = \frac{1}{25} + \frac{1}{50} + \frac{1}{50} \quad \therefore R = 12.5\Omega$



$\therefore R_{AB} = 5 + 12.5 + 8$

$= 25.5\Omega$

Q2) $R_{40} = 25\Omega$, $R_{100} = 40\Omega$, $R_0 = ?$, $\alpha_0 = ?$

$\therefore R_t = R_0(1 + \alpha_0 t)$

Put $t = 40°C \quad \therefore R_{40} = R_0(1 + 40\alpha_0) \quad \ldots (I)$

Put $t = 100°C \quad \therefore R_{100} = R_0(1 + 100\alpha_0) \quad \ldots (II)$

$\therefore \frac{R_{40}}{R_{100}} = \frac{R_0(1 + 40\alpha_0)}{R_0(1 + 100\alpha_0)}$ {Dividing eqn (I) & (II)}

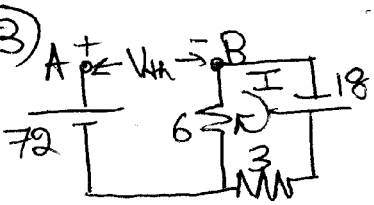
$\therefore \frac{25}{40} = \frac{1+40\alpha_0}{1+100\alpha_0}$ $\therefore 25+2500\alpha_0 = 40+1600\alpha_0$

$\therefore \alpha_0 = 0.0167/°C$ Subs. in eqn (I)

$\therefore 25 = R_0(1+40\times0.0167)$

$\therefore R_0 = 15\Omega$

Q3)



KVL to loop II :-

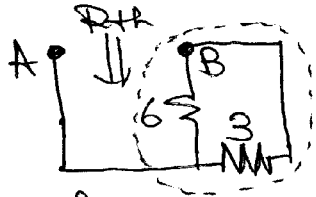
$\therefore 9I = 18$

$\therefore I = 2A$

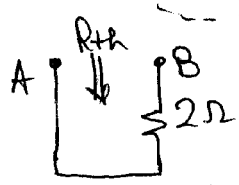
KVL to loop I :-

$\therefore -6I = 72 - V_{th}$ $\therefore V_{th} = 84\ V$

For R_{th}, short 18V & 72V Batteries

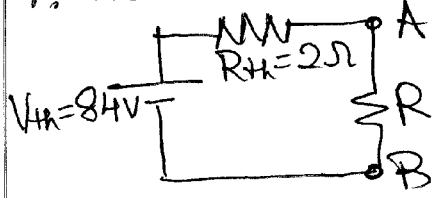


$6\Omega // 3\Omega \equiv 2\Omega$

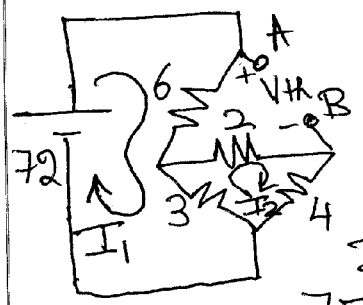


$\therefore R_{th} = 2\Omega$

$\therefore$ Thevenin's Equivalent circuit is:-



84) For V_{th} :-



KVL to loop I :-

$9I_1 - 3I_2 = 72 \quad \ldots (I)$

KVL to loop II :-

$-3I_1 + 9I_2 = 0 \quad \ldots (II)$

In matrix form :-

$$\begin{bmatrix} 9 & -3 \\ -3 & 9 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 72 \\ 0 \end{bmatrix}$$

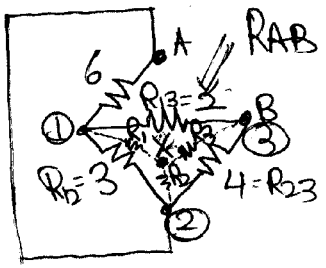
$\therefore I_1 = 9A, \quad I_2 = 3A$

KVL to loop III :-

$-6I_1 - 2I_2 = -V_{th}$

$\therefore V_{th} = 60V$

For R_{th}, short 72V Battery

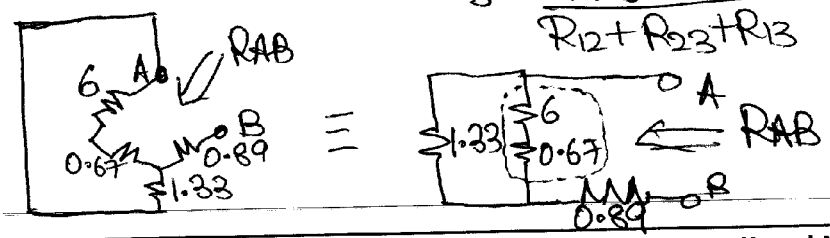


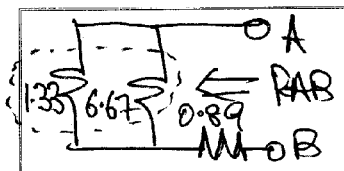
Converting Delta to Star

$$\therefore R_1 = \frac{R_{12} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = \frac{3 \times 2}{3+4+2} = 0.67\Omega$$

$$R_2 = \frac{R_{12} \cdot R_{23}}{R_{12}+R_{23}+R_{13}} = 1.33\Omega$$

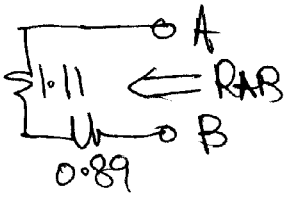
$$R_3 = \frac{R_{23} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = 0.89\Omega$$





$1.33\Omega \,//\, 6.67\Omega$

$\therefore \frac{1}{R} = \frac{1}{1.33} + \frac{1}{6.67} \quad \therefore R = 1.11\Omega$

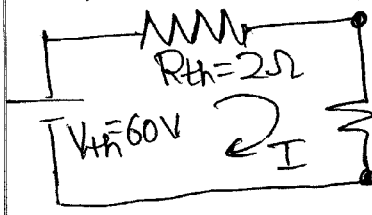


$\therefore R_{AB} = 0.89 + 1.11 = 2\Omega$

For maximum power transfer

$R_L = R_{th} = R_{AB} \quad \therefore R_L = 2\Omega \quad \therefore R = 2\Omega$

Thevenins Eq. ckt is :-

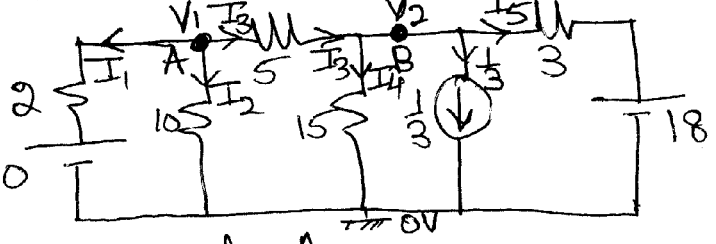


By KVL,

$4I = 60 \quad \therefore I = 15A$

Maximum power $= I^2 \cdot R_L = 450W$

Q5)



KCL at node A :-

$I_1 + I_2 + I_3 = 0$

$\frac{V_1 - 10}{2} + \frac{V_1}{10} + \frac{V_1 - V_2}{5} = 0 \quad \therefore V_1\left(\frac{1}{2} + \frac{1}{10} + \frac{1}{5}\right) + V_2\left(-\frac{1}{5}\right) = 5 \quad \text{---(I)}$

KCL at node B:-

$I_3 = I_4 + \frac{1}{3} + I_5$

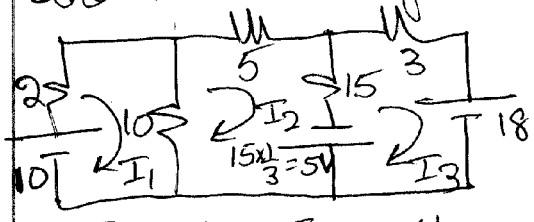
$\therefore \frac{V_1 - V_2}{5} = \frac{V_2}{15} + \frac{1}{3} + \frac{V_2 - 18}{3}$ $\therefore V_1\left(\frac{1}{5}\right) + V_2\left(\frac{-1}{5} - \frac{1}{15} - \frac{1}{3}\right) = \frac{1}{3} - 6$ ...(II)

$V_1 = 9.39V$, $V_2 = 12.58V$

Current through 2Ω is $I_1 = \frac{V_1 - 10}{2} = -0.305A$

Current through 3Ω is $I_5 = \frac{V_2 - 18}{3} = -1.81A$

NOTE: For verification we use source conversion and mesh analysis

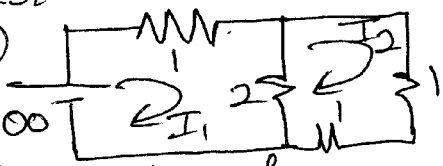


$\therefore I_1 = 0.303, I_2 = -0.64,$
$I_3 = -1.81A$

KVL to loop I:-
$12I_1 - 10I_2 + 0I_3 = 10$
KVL to loop II:-
$-10I_1 + 30I_2 - 15I_3 = 5$
KVL to loop III:-
$0I_1 - 15I_2 + 18I_3 = -23$

$I_{2\Omega} = I_1 = 0.303$, $I_{3\Omega} = I_3 = -1.81A$

86)



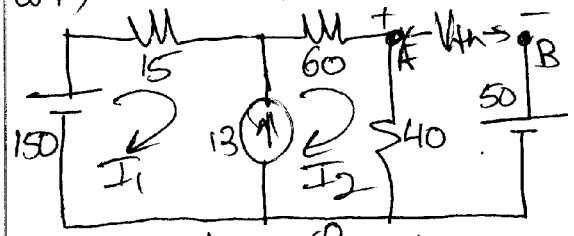
KVL to loop I:-
$3I_1 - 2I_2 = 100$ ...(I)
KVL to loop II:-
$-2I_1 + 4I_2 = 0$ ...(II)

In matrix form

$\begin{bmatrix} 3 & -2 \\ -2 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 100 \\ 0 \end{bmatrix}$ $\therefore I_1 = 50A, I_2 = 25A$

$\therefore$ Reading of ammeter $= I_2 = 25A$

Q7) For V_{Th}:-



Eqn. of supermesh is:-

$I_2 - I_1 = 13$

$\therefore -I_1 + I_2 = 13 \cdots (I)$

KVL to loop I & loop II:-

$\therefore 15I_1 + 100I_2 = 150 \cdots (II)$

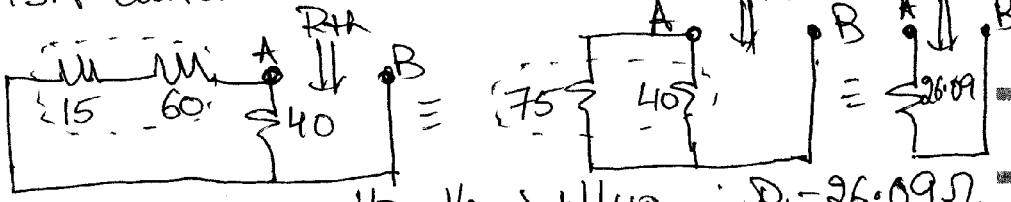
In matrix form:-

$$\begin{bmatrix} -1 & 1 \\ 15 & 100 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 13 \\ 150 \end{bmatrix} \quad \therefore I_1 = -10A, I_2 = 3A$$

KVL to loop III:-

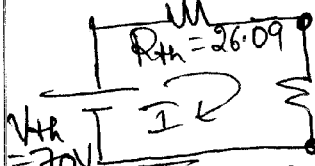
$-40I_2 = -V_{Th} - 50 \quad \therefore V_{Th} = 70V$

For R_{Th}, short 150V, 50V Batries & open 13A current source



$75\Omega \,||\, 40\Omega \quad \therefore 1/R_{Th} = 1/(75) + 1/40 \quad \therefore R_{Th} = 26.09\Omega$

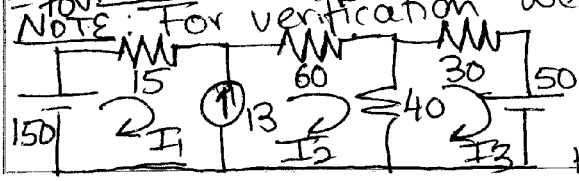
Thevenin's Eq. ckt. is:-



By KVL.

$I = 1.25A$

NOTE: For verification we use mesh & supermesh



Eqn. of supermesh is:-

$I_2 - I_1 = 13 \quad \therefore -I_1 + I_2 + 0I_3 = 13$

KVL to loop I & II:-

$15I_1 + 100I_2 - 40I_3 = 150$

KVL to loop III:-

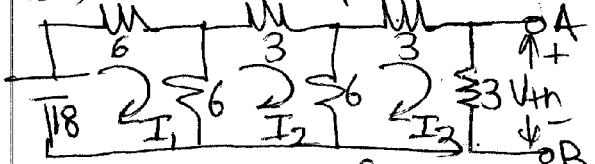
$0I_1 - 40I_2 + 70I_3 = -50$

$I_1 = -9.57A$

$I_2 = 3.43A$

$I_3 = 1.25A$

Q8) For V_{th}, open R_L



KVL to loop I :-
$12I_1 - 6I_2 + 0I_3 = 18 \cdots (I)$
KVL to loop II :-
$-6I_1 + 15I_2 - 6I_3 = 0 \cdots (II)$
KVL to loop III :-
$0I_1 - 6I_2 + 12I_3 = 0 \cdots (III)$

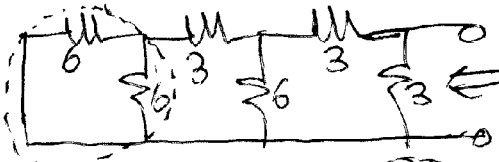
In matrix form :-

$$\begin{bmatrix} 12 & -6 & 0 \\ -6 & 15 & -6 \\ 0 & -6 & 12 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 18 \\ 0 \\ 0 \end{bmatrix}$$

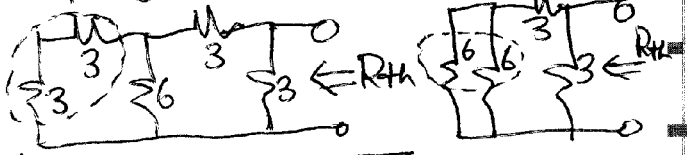
$\therefore I_1 = 2A, I_2 = 1A,$
$I_3 = 0.5A$

KVL to loop IV :-
$-3I_3 = -V_{th}$ $\therefore V_{th} = 1.5V$

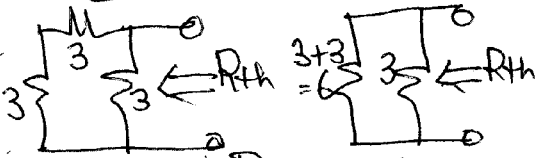
For R_{th}, short 18V Battery :-



$6\Omega // 6\Omega = 3\Omega$

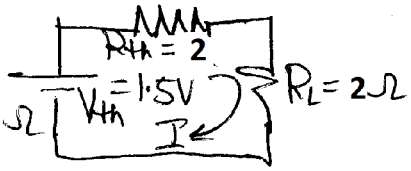


$6\Omega // 6\Omega = 3\Omega$



$6\Omega // 3\Omega$ $\therefore \frac{1}{R_{th}} = \frac{1}{6} + \frac{1}{3}$ $\therefore R_{th} = 2\Omega$

Thevenin's Eq. ckt is :-



For max power $R_L = R_{th} = 2\Omega$

By KVL, $I = 0.375$ A

Max power $= I^2 R_L = (0.375)^2 \times 2 = 0.28125$ W

Q9) $R'_{30} = 400\Omega$, $R''_{30} = 200\Omega$, $\alpha'_{30} = 0.001$, $\alpha''_{30} = 0.004$

$R_t = \frac{R_0}{1+\alpha_0 t}$ $\therefore \alpha'_{30} = \frac{\alpha'_0}{1+\alpha'_0 t}$ $\therefore 0.001 = \frac{\alpha'_0}{1+30\alpha'_0}$ $\therefore \alpha'_0 = 1.031\times10^{-3}/°C$

$\alpha''_{30} = \frac{\alpha''_0}{1+\alpha''_0 t}$ $\therefore 0.004 = \frac{\alpha''_0}{1+30\alpha''_0}$ $\therefore \alpha''_0 = 4.55\times10^{-3}/°C$

$\because R_t = R_0(1+\alpha_0 t)$ $\therefore R'_{60} = R'_0(1+60\alpha'_0)$ — (I); $R'_{30} = R'_0(1+30\alpha'_0)$ — (II)

Dividing (I) by (II) $\therefore \frac{R'_{60}}{R'_{30}} = \frac{1+60\alpha'_0}{1+30\alpha'_0}$ $\therefore R'_{60} = 412\Omega$

$R''_{60} = R''_0(1+60\alpha''_0)$ — (III); $R''_{30} = R''_0(1+30\alpha''_0)$ — (IV)

Dividing (III) by (IV) $\therefore \frac{R''_{60}}{R''_{30}} = \frac{1+60\alpha''_0}{1+30\alpha''_0}$ $\therefore R''_{60} = 224.02\Omega$

$\therefore$ At 60°C, $R_{60} = R'_{60} + R''_{60} = 636.02\Omega$

$\because$ From eq. (I) & (III), $R'_0 = 388\Omega$, $R''_0 = 175.98\Omega$

At 0°C, $R_0 = R'_0 + R''_0 = 563.98\Omega$

$\because R_t = R_0(1+\alpha_0 t)$ $\therefore R_{60} = R_0(1+60\alpha_0)$

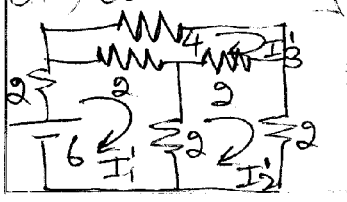
$\therefore 636.02 = 563.98(1+60\alpha_0)$ $\therefore \alpha_0 = 2.13\times10^{-3}/°C$

Q10) Since current is zero in branch OA

$\therefore$ circuit is balanced wheatstone's bridge

$\therefore \frac{1}{4} = \frac{1.5}{R}$ $\therefore R = 6\Omega$

Q11) Considering 6V Battery & shorting 10V & opening 5A



KVL to loop I:-

$6I_1' - 2I_2' - 2I_3' = 6$ — (I)

KVL to loop II:-

$-2I_1' + 6I_2' - 2I_3' = 0$ — (II)

KVL to loop III:-

$-2I_1' - 2I_2' + 8I_3' = 0$ — (III)

In matrix form

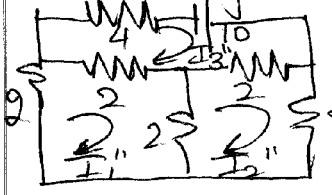
$$\begin{bmatrix} 6 & -2 & -2 \\ -2 & 6 & -2 \\ -2 & -2 & 8 \end{bmatrix} \begin{bmatrix} I_1' \\ I_2' \\ I_3' \end{bmatrix} = \begin{bmatrix} 6 \\ 0 \\ 0 \end{bmatrix}$$

$\therefore I_1' = 1.375A$

$I_2' = 0.625A$

$I_3' = 0.5A$, $I_4' = 0A$

Considering 10V Battery & shorting 6V & opening 5A



KVL to loop I :-

$6I_1'' - 2I_2'' - 2I_3'' = 0$

KVL to loop II :-

$-2I_1'' + 6I_2'' - 2I_3'' = 0$

KVL to loop III :-

$-2I_1'' - 2I_2'' + 8I_3'' = 10$

In matrix form :-

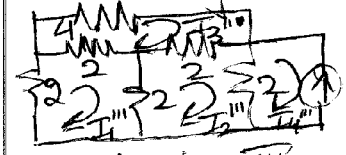
$$\begin{bmatrix} 6 & -2 & -2 \\ -2 & 6 & -2 \\ -2 & -2 & 8 \end{bmatrix} \begin{bmatrix} I_1'' \\ I_2'' \\ I_3'' \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 10 \end{bmatrix}$$

$\therefore I_1'' = 0.833A$

$I_2'' = 0.833A$

$I_3'' = 1.67A$, $I_4'' = 0A$

Considering 5A current source & shorting 6V & 10V



KVL to loop I :- $+6I_1''' - 2I_2''' - 2I_3''' = 0$

KVL to loop II :- $-2I_1''' + 6I_2''' - 2I_3''' - 2I_4''' = 0$

$\because I_4''' = -5A$ $\therefore -2I_1''' + 6I_2''' - 2I_3''' = -10$

KVL to loop III :- $-2I_1''' - 2I_2''' + 8I_3''' = 0$

In matrix form :-

$$\begin{bmatrix} 6 & -2 & -2 \\ -2 & 6 & -2 \\ -2 & -2 & 8 \end{bmatrix} \begin{bmatrix} I_1''' \\ I_2''' \\ I_3''' \end{bmatrix} = \begin{bmatrix} 0 \\ -10 \\ 0 \end{bmatrix}$$

$I_1''' = -1.042A$

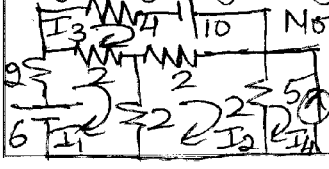
$I_2''' = -2.29A$

$I_3''' = -0.833A$, $I_4''' = -5$

By Superposition theorem,

$I_1 = I_1' + I_1'' + I_1''' = 1.166A$, $I_2 = I_2' + I_2'' + I_2''' = -0.832A$

$I_3 = I_3' + I_3'' + I_3''' = 1.337A$, $I_4 = -5A$



NOTE: For verification we use mesh analysis

KVL to loop I : $6I_1 - 2I_2 - 2I_3 = 6$

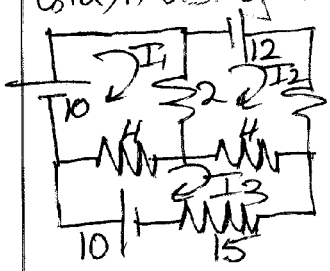
KVL to loop II : $-2I_1 + 6I_2 - 2I_3 - 2I_4 = 0$,

$\because I_4 = -5A$ $\therefore -2I_1 + 6I_2 - 2I_3 = -10$

KVL to loop III : $-2I_1 - 2I_2 + 8I_3 = 10$

$\therefore I_1 = 1.167A$, $I_2 = -0.833A$, $I_3 = 1.333A$

Q12) i) Using mesh analysis:-



KVL to loop I:- $6I_1 - 2I_2 - 4I_3 = 10$

KVL to loop II:- $-2I_1 + 11I_2 - 4I_3 = 12$

KVL to loop III:- $-4I_1 - 4I_2 + 23I_3 = 10$

In matrix form:-

$$\begin{bmatrix} 6 & -2 & -4 \\ -2 & 11 & -4 \\ -4 & -4 & 23 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 12 \\ 10 \end{bmatrix}$$

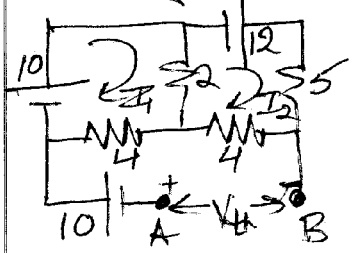
$\therefore I_1 = 3.33A$

$I_2 = 2.21A$

$I_3 = 1.4A$

$\therefore$ Current through 15Ω resistor $= I_3 = 1.4A$

ii) Using Thevenins theorem:-



KVL to loop I:- $6I_1 - 2I_2 = 10$

KVL to loop II:- $-2I_1 + 11I_2 = 12$

In matrix form:-

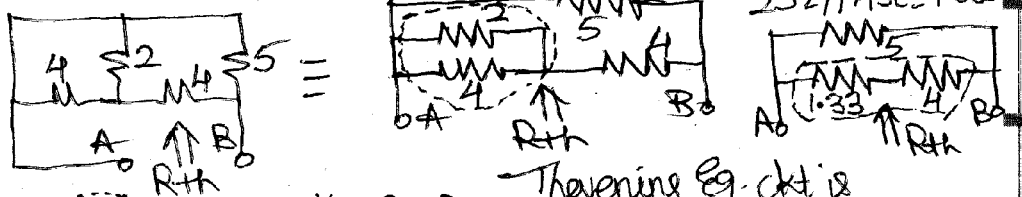
$$\begin{bmatrix} 6 & -2 \\ -2 & 11 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 12 \end{bmatrix}$$

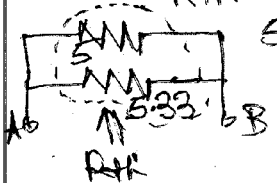
$\therefore I_1 = 2.16A$

$I_2 = 1.48A$

KVL to loop III:- $-4I_1 - 4I_2 = V_{th} + 10 \therefore V_{th} = -24.56V$

For R_{th}, short 10V, 12V, 10V Batteries

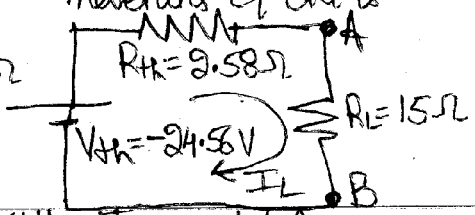




$5Ω || 5.33Ω$

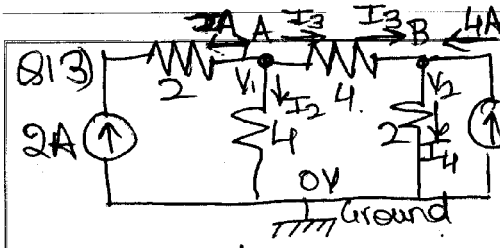
$\therefore R_{th} = 2.58Ω$

Thevenins Eq. ckt is



By KVL, $I_L = -1.4A$

Q13)



Applying KCL at node A:-

$I_2 + I_3 = 2$

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

$\therefore V_1\left(\frac{1}{4} + \frac{1}{4}\right) + V_2\left(\frac{-1}{4}\right) = 2$ --- (I)

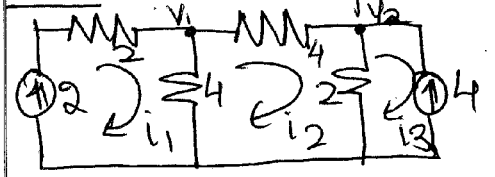
KCL at node B:- $I_3 + 4 = I_4$ $\therefore \frac{V_1 - V_2}{4} + 4 = \frac{V_2 - 0}{2}$

$\therefore V_1\left(\frac{1}{4}\right) + V_2\left(\frac{-1}{4} - \frac{1}{2}\right) = -4$ --- (II)

$\begin{bmatrix} \frac{1}{4}+\frac{1}{4} & -\frac{1}{4} \\ \frac{1}{4} & -\frac{1}{4}-\frac{1}{2} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 2 \\ -4 \end{bmatrix}$

$\therefore V_1 = 8V$, $V_2 = 8V$

NOTE:- For verification we use mesh analysis



$i_1 = 2A$; $i_3 = -4A$

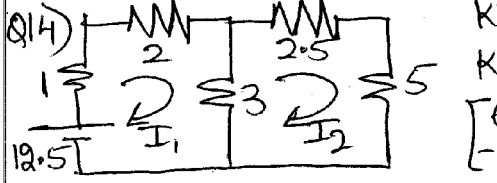
KVL to loop II:-

$-4i_1 + 10i_2 - 2i_3 = 0$

$\therefore i_2 = 0A$

$V_1 = 4(i_1 - i_2) = 4(2-0) = 8V$ & $V_2 = 2(i_2 - i_3) = 2(0+4) = 8V$

Q14)



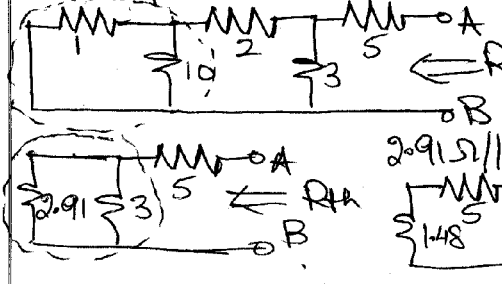
KVL to loop I:- $6I_1 - 3I_2 = 12.5$

KVL to loop II:- $-3I_1 + 10.5I_2 = 0$

$\begin{bmatrix} 6 & -3 \\ -3 & 10.5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 12.5 \\ 0 \end{bmatrix}$ $\therefore I_1 = 2.43A$, $I_2 = 0.69A$

$\therefore$ Current through 1Ω resistor is 2.43A in clockwise direction

Q15) For max. power $R_L = R_{th}$. We short 5V battery and open 1A current source.



$R_{th} = 5 + 1.48 = 6.48\Omega$

$\therefore R_L = R_{th} = 6.48\Omega$

Q16) $V_{15\Omega} = 30V \therefore V_{15\Omega} = I \times 15$

$\therefore 30 = I \times 15 \therefore I = 2A$

Applying KVL to loop:-

$+15I + 5(5+I) + I \times R = 100$

$\therefore 30 + 35 + 2R = 100 \therefore R = 17.5\Omega$

Q17) By KVL:- $4I = 8 \therefore I = 2A$

$V_{AB} = 2I + 4I = 12V$

$P_{2\Omega} = I^2 \times 2 = 8W$.

Q18)

KVL to loop I:- $10I_1 - 10I_2 = 10 \quad \text{(I)}$

Eqn. of supermesh is $I_3 - I_2 = 4 \quad \text{(II)}$

KVL to loop II & III:- $-10I_1 + 10I_2 + 7I_3 = -20$

$$\begin{bmatrix} 10 & -10 & 0 \\ 0 & -1 & 1 \\ -10 & 10 & 7 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 4 \\ -20 \end{bmatrix} \therefore I_1 = -4.43A$$

$I_2 = -5.43A, \; I_3 = -1.43A$

KVL to loop IV :- $-5I_3 + 2(0) = 8 + 6 - V_{th} \therefore V_{th} = 6.85V$

For R_{th}, short 10V, 12V, 8V, 6V Batteries & open 4A current source

10Ω // short = short, 4Ω series open $\equiv$ open

$2\Omega // 15\Omega = 1.43\Omega$

$\therefore R_{th} = 1.43 + 2 = 3.43\Omega$

Thevenin's Eq. ckt is $V_{th} = 6.85$, $R_{th} = 3.43$

By KVL, $5.43I = 6.85$

$\therefore I = 1.26A$

NOTE: For verification use mesh

KVL to loop I:- $10I_1 - 10I_2 = 10 \quad \text{(I)}$

Eqn of supermesh:- $I_3 - I_2 = 4 \quad \text{(II)}$

KVL to loop IV:- $-5I_3 + 8I_4 = 14$

$\therefore I_4 = (14 + 5I_3)/8 \quad \text{(III)}$

KVL to loop II & III:- $-10I_1 + 10I_2 + 7I_3 - 5I_4 = -20$

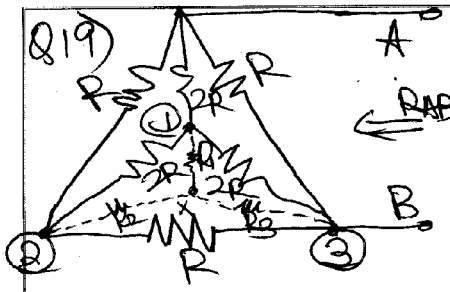
From eq (III): $-10I_1 + 10I_2 + 2.38I_3 = -12.38 \quad \text{(IV)}$

$I_1 = -3.53, \; I_2 = -4.53$

$I_3 = -0.53 \quad \therefore I_4 = 1.26$

Converting delta to star

Q19)



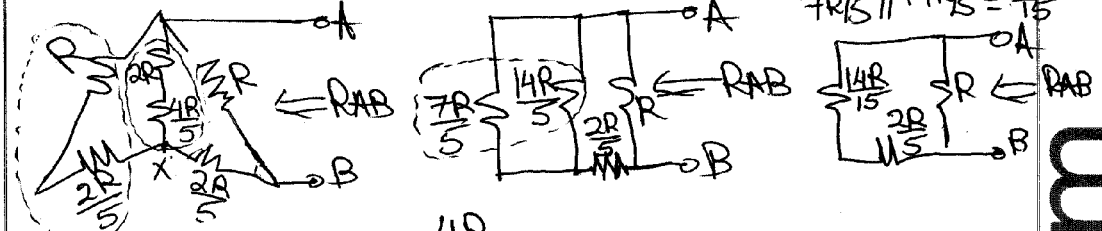
R_{AB}

$R_1 = \frac{R_{12} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = \frac{2R \times 2R}{2R+R+2R} = \frac{4R}{5}$

$R_2 = \frac{R_{12} \cdot R_{23}}{R_{12}+R_{23}+R_{13}} = \frac{2R \times R}{2R+R+2R} = \frac{2R}{5}$

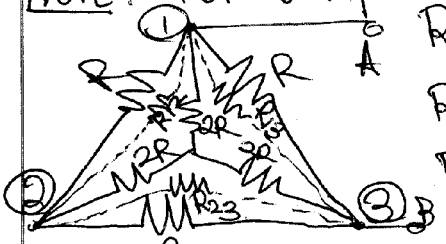
$R_3 = \frac{R_{23} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = \frac{2R \times R}{2R+R+2R} = \frac{2R}{5}$

$7R/5 \,||\, 14R/5 = \frac{14R}{15}$



$R_{AB} = \left(\frac{14R}{15} + \frac{2R}{5}\right) || R = \frac{4R}{7}$

NOTE:- For verification we convert inner star to delta

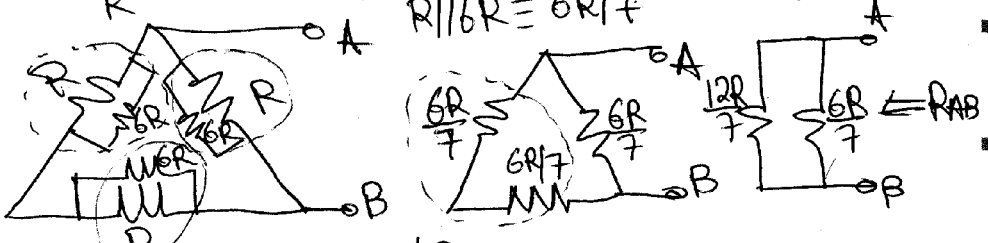


$R_{12} = R_1 + R_2 + \frac{R_1 \cdot R_2}{R_3} = 2R+2R+\frac{2R \times 2R}{2R} = 6R$

$R_{23} = R_2 + R_3 + \frac{R_2 \times R_3}{R_1} = 6R$

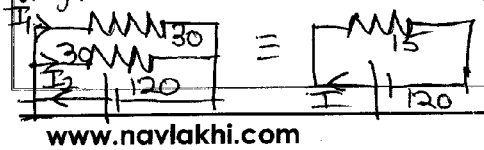
$R_{13} = R_1 + R_3 + \frac{R_1 \times R_3}{R_2} = 6R$

$R \,||\, 6R = 6R/7$



$R_{AB} \equiv 12R/7 \,||\, 6R/7 \equiv \frac{4R}{7}$

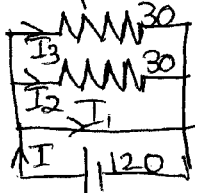
20) i) One resistor burns out (open circuit)



$\therefore I = 8A$

$I_1 = I_2 = 4A$

(ii) If one resistor gets shorted



I_1 = Infinite

$I_2 = I_3 = 0A$

Q21) $R_{15} = 50\Omega$, $R_{55} = 58\Omega$, $\alpha_0 = ?$

$R_t = R_0(1+\alpha_0 t)$

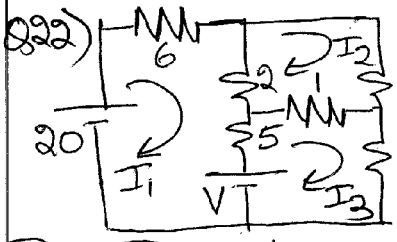
$\therefore R_{15} = R_0(1+15\alpha_0) \therefore 50 = R_0(1+15\alpha_0)$ --- (I)

$R_{55} = R_0(1+55\alpha_0) \therefore 58 = R_0(1+55\alpha_0)$ --- (II)

Divide eq. (I) & (II)

$\therefore \frac{50}{58} = \frac{1+15\alpha_0}{1+55\alpha_0}$ $\therefore \alpha_0 = 4.26\times10^{-3}/°C$

Q22)



By KVL to loop I :-

$13I_1 - 2I_2 - 5I_3 = 20 - V$ --- (I)

By KVL to loop II :-

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

By KVL to loop III :-

$-5I_1 - I_2 + 10I_3 = V$ --- (III)

Put $I_1 = 0$ in eqn. (I), (II) & (III)

$V - 2I_2 - 5I_3 = 20$

$6I_2 - I_3 = 0$

$-V - I_2 + 10I_3 = 0$

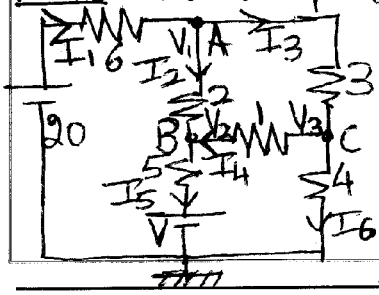
$$\begin{bmatrix} 1 & -2 & -5 \\ 0 & 6 & -1 \\ -1 & -1 & 10 \end{bmatrix} \begin{bmatrix} V \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \\ 0 \end{bmatrix}$$

$\therefore V = 43.7V$

$I_2 = 0.74A$

$I_3 = 4.44A$

NOTE :- For verification we use Nodal Analysis :-



By KCL, $I_1 = \frac{20 - V_1}{6}$ $\because I_1 = 0 \therefore V_1 = 20V$

KCL at node A :- $I_1 = I_2 + I_3$ $\because I_1 = 0$

$\therefore I_2 + I_3 = 0$ $\therefore \frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{3} = 0$

$\therefore \frac{V_2}{2} + \frac{V_3}{3} = 16.67$ --- (I) By KCL at node B :-

$\therefore I_2 + I_4 = I_5$ $\therefore \frac{V_1 - V_2}{2} + \frac{V_3 - V_2}{1} = \frac{V_2 - V}{5}$

$\therefore V_2\left(\frac{1}{5} + \frac{1}{2}\right) - V_3 - \frac{V}{5} = 10$ --- (II) KCL at node C :-

$I_3 = I_4 + I_6$ $\therefore \frac{V_1 - V_3}{3} = \frac{V_3 - V_2}{1} + \frac{V_3}{4}$

$-V_2 + V_3\left(1 + \frac{1}{4} + \frac{1}{3}\right) = 6.67$ --- (III)

$\therefore V_2 = 21.49V$, $V_3 = 17.78V$, $V = 43.7V$

Q23) i) By KVL to loop F-G-a-B-C-D-a'-F

$\therefore V_{aa'} + 3 + 2 - 1 = 0 \quad \therefore V_{aa'} = -4V$

By KVL to loop F-G-a-B-H-E-D-a'-F

$V_{aa'} + 5 - 1 = 0 \quad \therefore V_{aa'} = -4V$

ii) By KCL at node b:-

$I_{bb'} = 1 + 2 + 5 = 8A$

By KCL at node b':-

$4 - 1 + 5 = I_{bb'} \quad \therefore I_{bb'} = 8A$

Q24)

By KVL,

$I + 2I + 3I + 4I = V_o$

$\therefore I = V_o/10$

Also, $V_1 = 3I = 3V_o/10$

$\therefore V_1/V_o = 0.3$

Also, $V_2 = 4I = 4V_o/10 \quad \therefore V_2/V_o = 0.4$

Q25) Short 1Ω resister for I_{sc} :-

$I_1 = 1A$

KVL to loop II :-

$-3I_1 + 5I_2 - 2I_{sc} = 1$

$\therefore 5I_2 - 2I_{sc} = 4 \cdots (I)$

KVL to loop III :- $4I_3 - 2I_{sc} = -1 \cdots (II)$

KVL to loop IV :- $-2I_2 - 2I_3 + 4I_{sc} = 0 \cdots (III)$

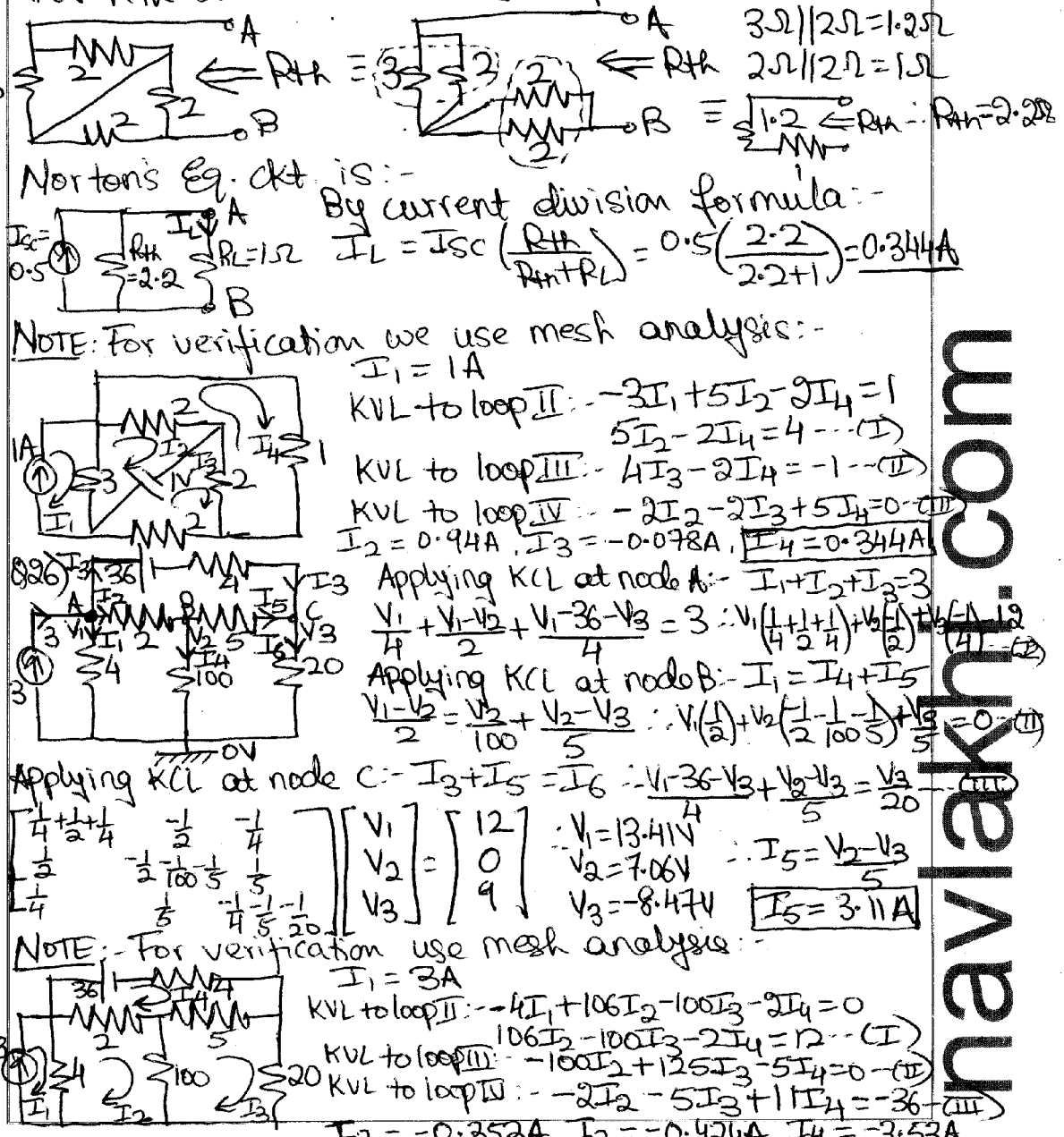
$$\begin{bmatrix} 5 & 0 & -2 \\ 0 & 4 & -2 \\ -2 & -2 & 4 \end{bmatrix} \begin{bmatrix} I_2 \\ I_3 \\ I_{sc} \end{bmatrix} = \begin{bmatrix} 4 \\ -1 \\ 0 \end{bmatrix}$$

$\therefore I_2 = 1A$

$I_3 = 0A$

$I_{sc} = 0.5A$

For R_{th} Short 1V Battery & open 1A current source



Norton's Eq. ckt is:-

By current division formula:-

$$I_L = I_{SC}\left(\frac{R_{th}}{R_{th}+R_L}\right) = 0.5\left(\frac{2.2}{2.2+1}\right) = \underline{0.344A}$$

NOTE: For verification we use mesh analysis:-

$I_1 = 1A$

KVL to loop II :- $-3I_1 + 5I_2 - 2I_4 = 1$

$5I_2 - 2I_4 = 4$ --- (I)

KVL to loop III :- $4I_3 - 2I_4 = -1$ --- (II)

KVL to loop IV :- $-2I_2 - 2I_3 + 5I_4 = 0$ --- (III)

$I_2 = 0.94A$, $I_3 = -0.078A$, $\boxed{I_4 = 0.344A}$

Applying KCL at node A:- $I_1 + I_2 + I_3 = 3$

$$\frac{V_1}{4} + \frac{V_1 - V_2}{2} + \frac{V_1 - 36 - V_3}{4} = 3 \quad \therefore V_1\left(\frac{1}{4}+\frac{1}{2}+\frac{1}{4}\right) + V_2\left(\frac{-1}{2}\right) + V_3\left(\frac{-1}{4}\right) = 12 \quad \text{(I)}$$

Applying KCL at node B:- $I_1 = I_4 + I_5$

$$\frac{V_1 - V_2}{2} = \frac{V_2}{100} + \frac{V_2 - V_3}{5} \quad \therefore V_1\left(\frac{1}{2}\right) + V_2\left(\frac{-1}{2} - \frac{1}{100} - \frac{1}{5}\right) + V_3\left(\frac{1}{5}\right) = 0 \quad \text{(II)}$$

Applying KCL at node C:- $I_3 + I_5 = I_6$

$$\frac{V_1 - 36 - V_3}{4} + \frac{V_2 - V_3}{5} = \frac{V_3}{20} \quad \text{(III)}$$

$$\begin{bmatrix} \frac{1}{4}+\frac{1}{2}+\frac{1}{4} & -\frac{1}{2} & -\frac{1}{4} \\ \frac{1}{2} & -\frac{1}{2}-\frac{1}{100}-\frac{1}{5} & \frac{1}{5} \\ \frac{1}{4} & \frac{1}{5} & -\frac{1}{4}-\frac{1}{5}-\frac{1}{20} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 12 \\ 0 \\ 9 \end{bmatrix}$$

$V_1 = 13.41V$

$V_2 = 7.06V$

$V_3 = -8.47V$

$$\therefore I_5 = \frac{V_2 - V_3}{5}$$

$$\boxed{I_5 = 3.11A}$$

NOTE:- For verification use mesh analysis:-

$I_1 = 3A$

KVL to loop II :- $-4I_1 + 106I_2 - 100I_3 - 2I_4 = 0$

$106I_2 - 100I_3 - 2I_4 = 12$ --- (I)

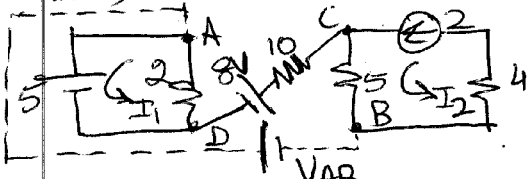
KVL to loop III :- $-100I_2 + 125I_3 - 5I_4 = 0$ --- (II)

KVL to loop IV :- $-2I_2 - 5I_3 + 11I_4 = -36$ --- (III)

$I_2 = -0.353A$, $I_3 = -0.424A$, $I_4 = -3.53A$

$I_{5\Omega} = I_3 - I_4 = \underline{3.11A}$

Q27) 3Ω // short $\equiv$ short



KVL to loop I: $-2I_1 = -5 \therefore I_1 = -2.5A$

$I_2 = 2A$, KVL to loop B-A-D-C-B:-

$-2I_1 + 10(0) + 5I_2 = V_{AB} + 8$

$\therefore V_{AB} = 7V$

Q28) $R_{20} = 15\Omega$, $R_{50} = 20\Omega$, $R_t = 25\Omega$

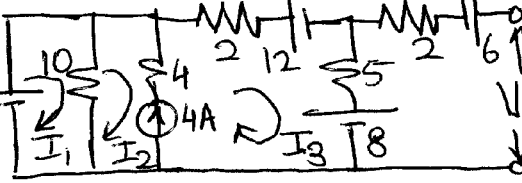
$R_t = R_o(1+\alpha_o t) \therefore R_{20} = R_o(1+20\alpha_o) \therefore 15 = R_o(1+20\alpha_o)$ — (I)

$R_{50} = R_o(1+50\alpha_o) \therefore 20 = R_o(1+50\alpha_o)$ — (II) Divide (I) by (II)

$\therefore \frac{15}{20} = \frac{1+20\alpha_o}{1+50\alpha_o} \therefore \alpha_o = 0.0143/^\circ C$ Subs. in (I) $\therefore R_o = 11.67\Omega$

$\therefore R_t = R_o(1+\alpha_o t) \therefore 25 = 11.67(1+0.0143t) \therefore t = 79.88^\circ C$

Q29)



KVL to loop I:-

$10I_1 - 10I_2 = 10$ — (I)

Eqn. of supermesh

$I_3 - I_2 = 4$ — (II)

KVL to loop II & III: $-10I_1 + 10I_2 + 7I_3 = -20$ — (III)

$$\begin{bmatrix} 10 & -10 & 0 \\ 0 & -1 & 1 \\ -10 & 10 & 7 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 4 \\ -20 \end{bmatrix}$$

$\therefore I_1 = -4.43A$

$I_2 = -5.43A$

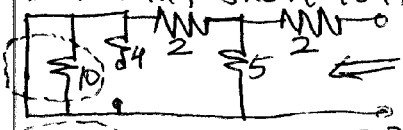
$I_3 = -1.43A$

KVL to loop IV:-

$-5I_3 + 2(0) = 8 + 6 - V_{th}$

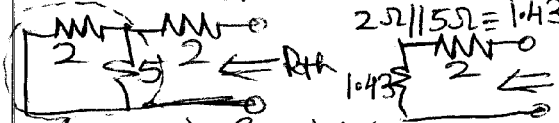
$V_{th} = 6.85V$

For R_{th}, short 10V, 12V, 8V, 6V Batteries & open 4A current source



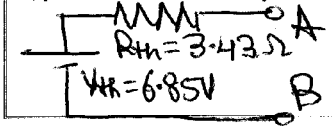
10Ω // short $\equiv$ short

4Ω series with open $\equiv$ open



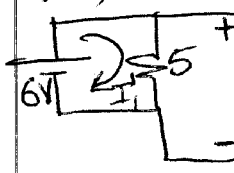
$\therefore R_{th} = 1.43 + 2 = 3.43\Omega$

Thevenin's Eq. ckt is:-



NOTE: For verification we can assume $R_L = 2\Omega$ & find I_L in Thevenin & verify with mesh (same as Q18)

Q30) Consider 6V Battery, short 10V & open 5A



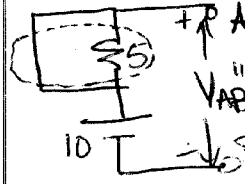
By KVL, $5I_1' = 6$

$\therefore I_1' = 1.2A$

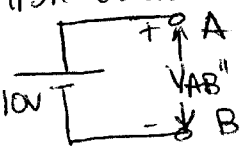
By KVL, $-5I_1 = -V_{AB}'$

$\therefore V_{AB}' = 6V$

Consider 10V Battery, short 6V & open 5A current source

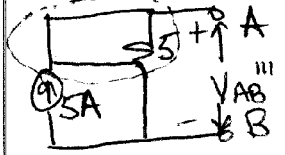


5Ω ||short = short

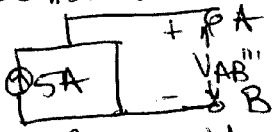


$V_{AB}'' = 10V$

Consider 5A current source & Short 6V & 10V Batteries



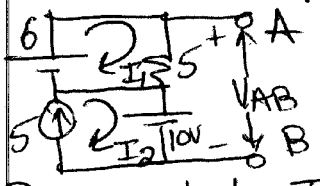
5Ω ||short = short



$V_{AB}''' = 0V$

By Superposition Theorem, $V_{AB} = V_{AB}' + V_{AB}'' + V_{AB}''' = 16V$

NOTE:- For verification



$I_2 = 5A$

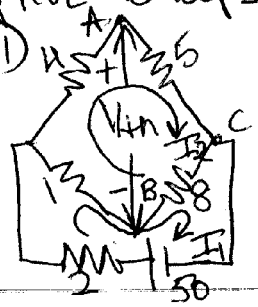
By KVL to loop I:-

$5I_1 = 6$

$\therefore I_1 = 1.2A$

By KVL to loop III:- $-5I_1 = 10 - V_{AB}$ $\boxed{\therefore V_{AB} = 16V}$

Q31)



KVL to loop I :- $11I_1 - 9I_2 = 50$ --- (I)

KVL to loop II :- $-9I_1 + 18I_2 = 0$ --- (II)

$$\begin{bmatrix} 11 & -9 \\ -9 & 18 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 50 \\ 0 \end{bmatrix}$$

$\therefore I_1 = 7.69A$

$I_2 = 3.85A$

KVL to loop B-A-C-B:- $-8I_1 + 13I_2 = V_{th}$

$\therefore V_{th} = -11.47V$

For R_{th}, short 50V Battery

Converting delta to star

$R_1 = \frac{R_{12} \times R_{13}}{R_{12}+R_{23}+R_{13}} = 1.82\Omega$

$R_2 = \frac{R_{12} \times R_{23}}{R_{12}+R_{23}+R_{13}} = 0.73\Omega$

$R_3 = \frac{R_{23} \times R_{13}}{R_{12}+R_{23}+R_{13}} = 0.91\Omega$

$\therefore R_{th} = 1.82 + 1.45$

$\therefore R_{th} = 3.27\Omega$

Thevenin's eq. ckt is

By KVL,

$V_{th} = I_L(R_{th}+R_L) \quad \therefore I_L = -1.75A$

Max power $P_L = I_L^2 R_L = 10.06W$

Q32)

Applying KVL to loop I:-

$40I_1 - 40I_2 = 50 \quad \cdots (I)$

ISc KVL to loop II:- $-40I_1 + 110I_2 - 20I_{Sc} = -10 \quad \cdots (II)$

B KVL to loop III:- $-20I_2 + 20I_{Sc} = 10 \quad \cdots (III)$

$$\begin{bmatrix} 40 & -40 & 0 \\ -40 & 110 & -20 \\ 0 & -20 & 20 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_{Sc} \end{bmatrix} = \begin{bmatrix} 50 \\ -10 \\ 10 \end{bmatrix}$$

$\therefore I_1 = 2.25A$

$I_2 = 1A$

$I_{Sc} = 1.5A$

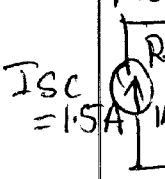
For R_{th} short 50V, 10V Batteries

$40\Omega \,||\, \text{short} \equiv \text{Short}$

$50\Omega \,||\, 20\Omega$

$\therefore R_{th} = 14.29\Omega$

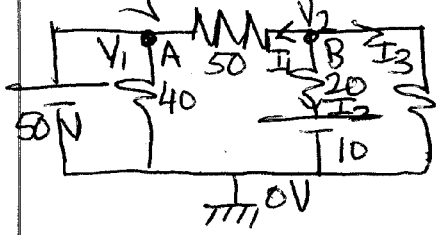
Norton's Eq. ckt. is:-



By current division formula

$I_L = I_{sc}\left(\frac{R_{th}}{R_{th}+R_L}\right) = 0.88A$

Using Nodal analysis:-



At node A:-

$V_1 = +50V$

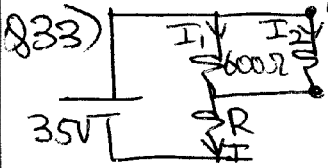
KCL at node B:-

$\therefore I_1 + I_2 + I_3 = 0$

$\therefore \frac{V_2 - V_1}{50} + \frac{V_2 - 10}{20} + \frac{V_2}{10} = 0 \quad \therefore V_2 = 8.82V$

$I_3 = V_2/10 = 0.882A$

Q33)



$I_1 = \frac{V_{AB}}{600} = \frac{5}{600} = 0.00833A$

$I_2 = \frac{V_{AB}}{1200} = \frac{5}{1200} = 0.00417A$

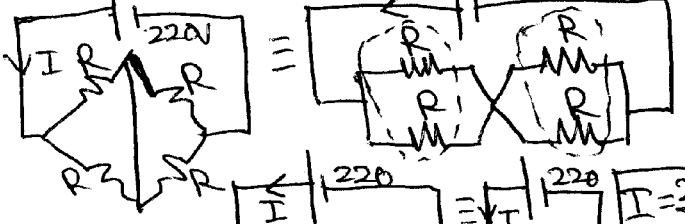
$I = I_1 + I_2 = 0.0125A$

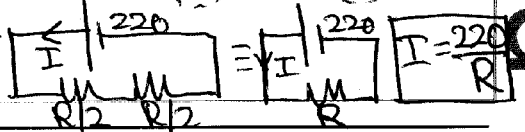
By KVL, $600I_1 + RI = 35$

$\therefore 600(0.00833) + R(0.0125) = 35 \quad \therefore R = 2400.16\Omega$

Q34) When S is closed

R ||short ≡ short





Q35) $R_{AB}=6\Omega$, $R_{BC}=11\Omega$, $R_{AC}=9\Omega$

$\therefore R_A+R_B=6\Omega$, $R_B+R_C=11\Omega$, $R_A+R_C=9\Omega$

$\therefore R_A=2\Omega$, $R_B=4\Omega$, $R_C=7\Omega$

Q36)

KVL to loop I: $-60I_1-50I_2-10I_3=80$

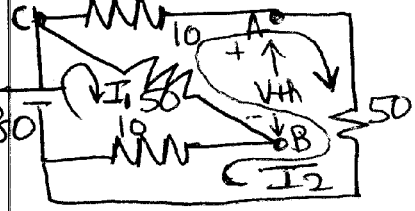
KVL to loop II: $-50I_1+120I_2-60I_3=0$

KVL to loop III: $-10I_1-60I_2+120I_3=0$

$$\begin{bmatrix}60 & -50 & -10\\ -50 & 120 & -60\\ -10 & -60 & 120\end{bmatrix}\begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix}=\begin{bmatrix}80\\0\\0\end{bmatrix}$$

$\therefore I_1=3.13A$, $I_2=1.91A$, $I_3=1.22A$

$I_{60\Omega}=I_2-I_3=0.69A$



KVL to loop I: $-60I_1-50I_2=80$

KVL to loop II: $-50I_1+120I_2=0$

$$\begin{bmatrix}60 & -50\\ -50 & 120\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}=\begin{bmatrix}80\\0\end{bmatrix}$$

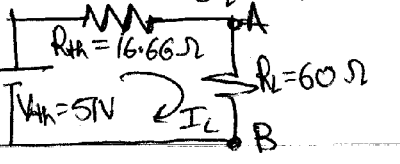
$I_1=2.04A$, $I_2=0.85A$

By KVL to loop B-A-C-B: $-50I_1-60I_2=V_{th}$ $\therefore V_{th}=51V$

For R_{th} short 80V Battery:-

$R_{th}=16.66\Omega$

Thevenin's Eq ckt is:-



By KVL:-

$$I_L=\frac{V_{th}}{R_{th}+R_L}=0.67A$$

Q37)

$6\Omega \,||\, 6\Omega$

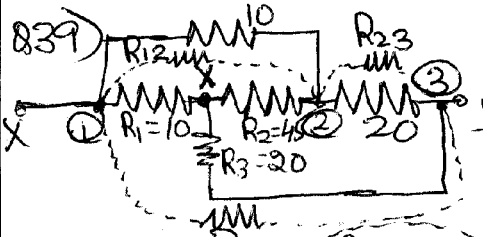
$\therefore R_{AB} = 3\Omega$

Q38) $A_1 = \pi r_1^2 = \frac{\pi d_1^2}{4} = \frac{\pi d^2}{4}$, $A_2 = \pi r_2^2 = \frac{\pi d_2^2}{4} = \frac{\pi (2d)^2}{4} = \pi d^2$

$R_1 = \frac{\rho l}{A_1}$, $R_2 = \frac{\rho (4l)}{A_2}$ $\therefore \frac{R_2}{R_1} = \frac{\rho(4l)}{A_2} \times \frac{A_1}{\rho l}$

$\therefore \frac{R_2}{R} = \frac{4}{\pi d^2} \times \frac{\pi d^2}{4}$ $\therefore \boxed{R_2 = R}$

Q39)

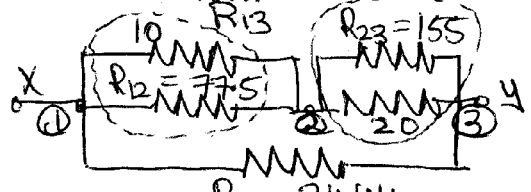


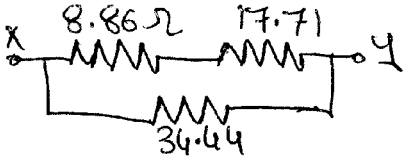
Converting star to delta

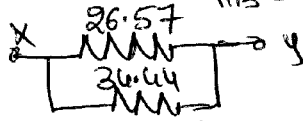
$R_{12} = R_1 + R_2 + \left(\frac{R_1 R_2}{R_3}\right) = 77.5\Omega$

$R_{23} = R_2 + R_3 + \left(\frac{R_2 R_3}{R_1}\right) = 155\Omega$

$R_{13} = R_1 + R_3 + \left(\frac{R_1 R_3}{R_2}\right) = 34.44\Omega$

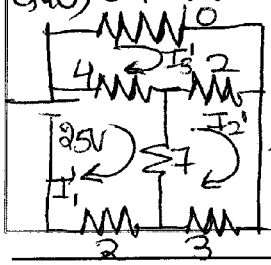






$\because 26.57\Omega \,||\, 36.44\Omega$ $\therefore \boxed{R_{xy} = 15\Omega}$

Q40) Considering 25V Battery & shorting 12V Battery



KVL to loop I :-

$13I_1' - 7I_2' - 4I_3' = 25$

KVL to loop II :-

$-7I_1' + 12I_2' - 2I_3' = 0$

KVL to loop III :-

$-4I_1' - 2I_2' + 16I_3' = 0$

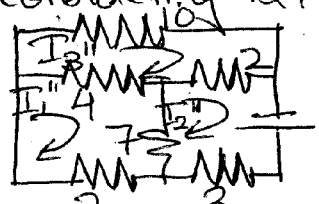
$$\begin{bmatrix} 13 & -7 & -4 \\ -7 & 12 & -2 \\ -4 & -2 & 16 \end{bmatrix} \begin{bmatrix} I_1' \\ I_2' \\ I_3' \end{bmatrix} = \begin{bmatrix} 25 \\ 0 \\ 0 \end{bmatrix}$$

$\therefore I_1' = 3.47A$

$I_2' = 2.21A$

$I_3' = 1.14A$

Considering 12V Battery & shorting 25V Battery



KVL to loop I :-
$13I_1'' - 7I_2'' - 4I_3'' = 0$

KVL to loop II :-
$-7I_1'' + 12I_2'' - 2I_3'' = 12$

KVL to loop III :-
$-4I_1'' - 2I_2'' + 16I_3'' = 0$

$$\begin{bmatrix} 13 & -7 & -4 \\ -7 & 12 & -2 \\ -4 & -2 & 16 \end{bmatrix} \begin{bmatrix} I_1'' \\ I_2'' \\ I_3'' \end{bmatrix} = \begin{bmatrix} 0 \\ 12 \\ 0 \end{bmatrix}$$

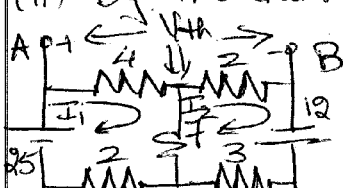
$\therefore I_1'' = 1.06A$
$I_2'' = 1.7A$
$I_3'' = 0.48A$

By superposition theorem :-

$I_1 = I_1' + I_1'' = 4.53A$, $I_2 = I_2' + I_2'' = 3.91A$, $I_3 = I_3' + I_3'' = 1.62A$

∴ Current through 10Ω is $\boxed{I_3 = 1.62A}$

(ii) By Thevenin's theorem :-



KVL to loop I :-
$13I_1 - 7I_2 = 25$

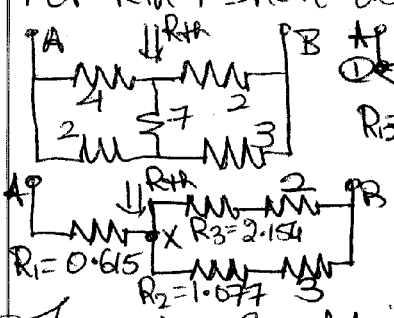
KVL to loop II :-
$-7I_1 + 12I_2 = 12$

$$\begin{bmatrix} 13 & -7 \\ -7 & 12 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 25 \\ 12 \end{bmatrix}$$

$\therefore I_1 = 3.59A$
$I_2 = 3.09A$

KVL to loop III :- $-4I_1 - 2I_2 = -V_{th}$ $\therefore V_{th} = 20.54V$

For R_{th}, short 25V, 12V Batteries :-

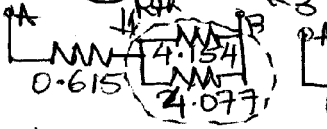


Converting delta to star :-

$R_1 = \frac{R_{12}R_{13}}{R_{12}+R_{23}+R_{13}} = 0.615\Omega$

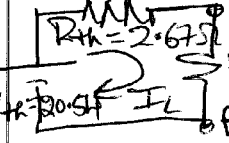
$R_2 = \frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{13}} = 1.077\Omega$

$R_3 = 2.154\Omega$



$R_{th} = 2.675\Omega$

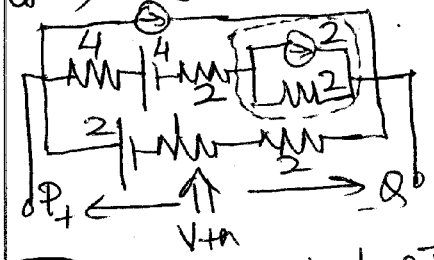
Thevenin's Eq. ckt is :-



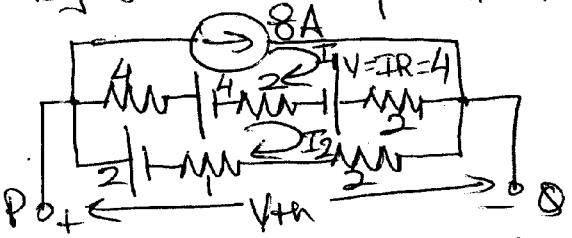
By KVL,

$$I_L = \frac{V_{th}}{R_{th}+R_L} = 1.62A$$

Q41) 8A



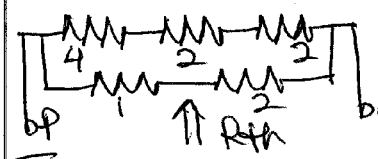
By source transformation:-

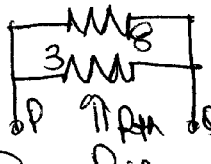


$I_1 = 8A$, KVL to loop II :- $-8I_1 + 11I_2 = 2 \therefore I_2 = 6A$

KVL to loop III :- $-3I_2 = V_{th} - 2 \therefore V_{th} = -16V$

For R_{th}, short 4V, 2V batteries & open 8A, 2A current source



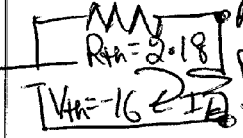


$8\Omega \,||\, 3\Omega$

$\therefore R_{th} = 2.18\Omega$

For max. power $R_L = R_{th} = 2.18\Omega$

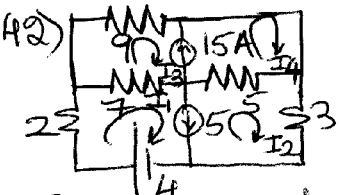
Thevenin's eq. ckt is:-



$$I_L = \frac{V_{th}}{R_{th}+R_L} = 3.67A$$

Max. power $= I_L^2 R_L = 29.36W$

Q42)



Eq. of supermesh for loop I & II :-

$I_1 - I_2 = 5 \quad \ldots (I)$

KVL to loop I & II :-

$9I_1 + 8I_2 - 7I_3 - 5I_4 = 4 \quad \ldots (II)$

Eq. of supermesh for loop III & IV :- $I_4 - I_3 = 15 \therefore I_4 = 15 + I_3 \quad \ldots (III)$

KVL to loop III & IV :- $-7I_1 - 5I_2 + 16I_3 + 5I_4 = 0 \quad \ldots (IV)$

Subs. eqn. (III) in (II) & (IV) $\therefore 9I_1 + 8I_2 - 12I_3 = 79 \quad \ldots (V)$

$-7I_1 - 5I_2 + 21I_3 = -75 \quad \ldots (VI)$

$$\begin{bmatrix} 1 & -1 & 0 \\ 9 & 8 & -12 \\ -7 & -5 & 21 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 79 \\ -75 \end{bmatrix}$$

$\therefore I_1 = 6.1A$

$I_2 = 1.1A$

$I_3 = -1.28A$

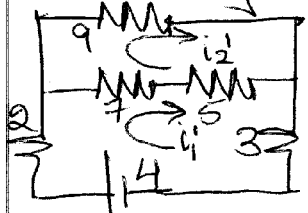
From eq. (III)

$I_4 = 13.72A$

$V_{3\Omega} = 3 \times I_2 = 3 \cdot 3V$

By Superposition theorem:-

Considering 4V battery & opening 5A, 15A current source



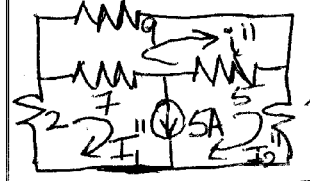
By KVL to loop I :- $17i_1' - 12i_2' = 4 \quad \text{--- (I)}$

By KVL to loop II :- $-12i_1' + 21i_2' = 0 \quad \text{--- (II)}$

$$\begin{bmatrix} 17 & -12 \\ -12 & 21 \end{bmatrix} \begin{bmatrix} i_1' \\ i_2' \end{bmatrix} = \begin{bmatrix} 4 \\ 0 \end{bmatrix} \quad \therefore i_1' = 0.394A \quad i_2' = 0.225A$$

$I_1' = I_2' = i_1' = 0.394A$ & $I_3' = I_4' = i_2' = 0.225A$

Consider 5A current source, short 4V & open 15A



Eqn. of supermesh of loop I & II is:-

$I_1'' - I_2'' = 5 \quad \text{--- (I)}$

KVL to loop I & II :-

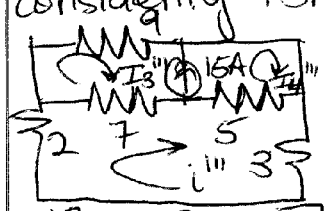
$9I_1'' + 8I_2'' - 12i'' = 0 \quad \text{--- (II)}$

KVL to loop III :- $-7I_1'' - 5I_2'' + 21i'' = 0 \quad \text{--- (III)}$

$$\begin{bmatrix} 1 & -1 & 0 \\ 9 & 8 & -12 \\ -7 & -5 & 21 \end{bmatrix} \begin{bmatrix} I_1'' \\ I_2'' \\ i'' \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix} \quad \therefore I_1'' = 2.539A \quad I_2'' = -2.465A \quad i'' = 0.258A$$

$I_3'' = I_4'' = i'' = 0.258A$

Considering 15A current source, short 4V & open 5A



KVL to loop I :- $17i''' - 7I_3''' - 5I_4''' = 0 \quad \text{--- (I)}$

Eqn. of supermesh :- $I_4''' - I_3''' = 15 \quad \text{--- (II)}$

KVL to loop III & loop IV :-

$-12i''' + 16I_3''' + 5I_4''' = 0 \quad \text{--- (III)}$

$$\begin{bmatrix} 17 & -7 & -5 \\ 0 & -1 & 1 \\ -12 & 16 & 5 \end{bmatrix} \begin{bmatrix} i''' \\ I_3''' \\ I_4''' \end{bmatrix} = \begin{bmatrix} 0 \\ 15 \\ 0 \end{bmatrix} \quad \therefore i''' = 3.169A \quad I_3''' = -1.761A \quad I_4''' = 13.24A$$

$I_1''' = I_2''' = i''' = 3.169A$

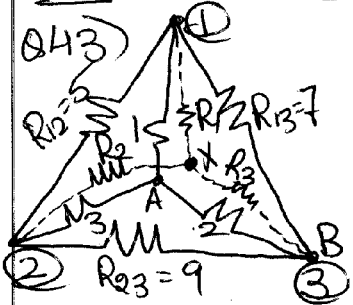
By superposition theorem:-

$I_1 = I_1' + I_1'' + I_1''' = 6.1A$, $I_2 = I_2' + I_2'' + I_2''' = 1.1A$

$I_3 = I_3' + I_3'' + I_3''' = -1.28A$, $I_4 = I_4' + I_4'' + I_4''' = 13.72A$

$V_{3\Omega} = 3 \times I_2 = 3.3V$

Q43)

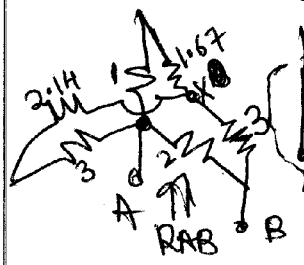


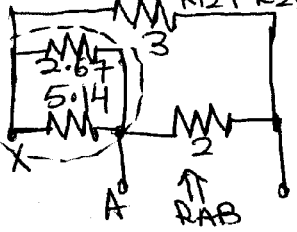
Converting outer delta to star:-

$R_1 = \frac{R_{12} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = 1.67\Omega$

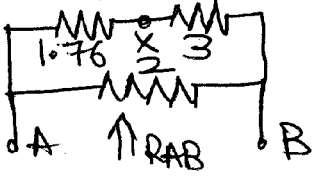
$R_2 = \frac{R_{12} \cdot R_{23}}{R_{12}+R_{23}+R_{13}} = 2.14\Omega$

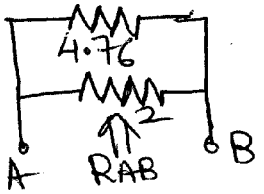
$R_3 = \frac{R_{23} \cdot R_{13}}{R_{12}+R_{23}+R_{13}} = 3\Omega$





$2.67\Omega // 5.14\Omega$





$4.76\Omega // 2\Omega$

$\therefore \boxed{R_{AB} = 1.41\Omega}$

Q44) a) Since dc arc and resistor are connected in series, current I remains the same.

Voltage across resistor is $V_R = I.R$

For DC component $V_{supply} = V_{arc} + V_R$

$$\therefore 100 = \left(44 + \frac{30}{I}\right) + IR \quad \text{— (I)}$$

Also, $V_{arc} = V_R$ (given

$$\therefore 44 + \frac{30}{I} = I.R \quad \text{— (II)}$$

Subs. (II) in (I)

$$\therefore 100 = IR + IR$$

$$\therefore 2IR = 100$$

$$\therefore IR = 50 \quad \text{— (III)}$$

Subs. (III) in (II)

$$\therefore 44 + \frac{30}{I} = 50$$

$$\therefore \frac{30}{I} = 50 - 44$$

$$\therefore \frac{30}{I} = 6$$

$$\therefore I = \frac{30}{6} = 5A$$

Subs. in (III)

$$\therefore 5R = 50 \quad \boxed{\therefore R = 10\,\Omega}$$

b) $L_{AL} = 10m = 1000cm$, $d_{AL} = 2mm = 0.2cm$, $L_{Cu} = 6m = 6000cm$

$I = 2A$, $I_{AL} = 1.25A$, $\rho_{Cu} = 1.6 \times 10^{-6}\,\Omega cm$, $\rho_{AL} = 2.6 \times 10^{-6}\,\Omega cm$

$$A_{AL} = \pi r_{AL}^2 = \frac{22}{7} \times (0.1)^2 = 0.0314\,cm^2$$

$$R_{AL} = \frac{\rho_{AL} L_{AL}}{A_{AL}} = 0.083\,\Omega$$

$$R_{Cu} = \frac{\rho_{Cu} L_{Cu}}{A_{Cu}} = \frac{0.0096}{A_{Cu}}\,\Omega$$

For parallel connection.

$$I = I_{Al} + I_{Cu}$$

$$\therefore I_{Cu} = 2 - 1.25 = 0.75A$$

Since $V_{Al} = V_{Cu}$ (for parallel connection)

$$I_{Al} \cdot R_{Al} = I_{Cu} \cdot R_{Cu}$$

$$\therefore 1.25 \times 0.083 = 0.75 \times \frac{0.0096}{A_{Cu}}$$

$$\therefore A_{Cu} = 0.0694\ cm^2$$

$$\therefore A_{Cu} = \pi r_{Cu}^2$$

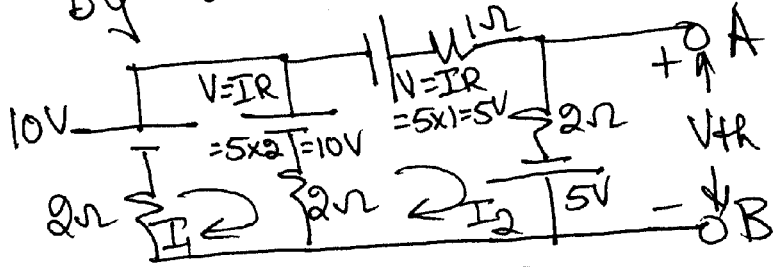
$$\therefore 0.0694 = 3.142 \times r_{Cu}^2$$

$$\therefore r_{Cu} = 0.149cm$$

$$\therefore \boxed{d_{Cu} = 0.297cm = 2.97mm}$$

045)

By Source conversion,



By KVL to loop I,

$$4I_1 - 2I_2 = 0 \quad \text{— (I)}$$

By KVL to loop II,

$$-2I_1 + 5I_2 = 20 \quad \text{— (II)}$$

$$\therefore I_1 = 2.5A$$

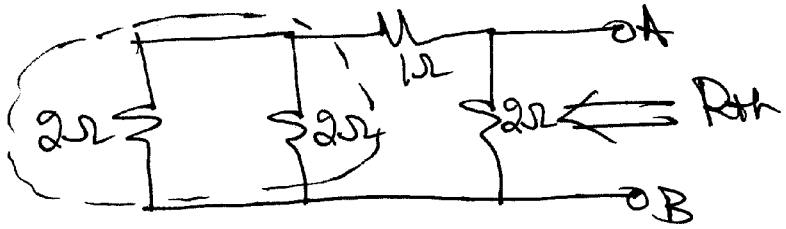
$$I_2 = 5A$$

By KVL to loop III,

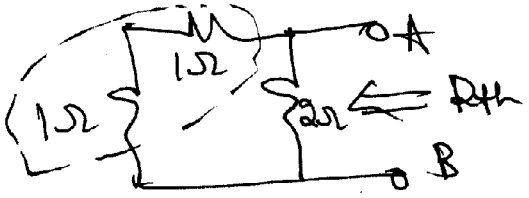
$-2I_2 = -5 - V_{th}$

$\therefore V_{th} = 5V$

For R_{th}, open 5A current sources and short 10V and 5V batteries,



$2\Omega || 2\Omega \equiv 1\Omega$

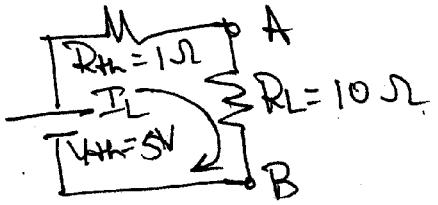


$1\Omega + 1\Omega \equiv 2\Omega$

$2\Omega || 2\Omega \equiv 1\Omega$

$\therefore R_{th} = 1\Omega$

$\therefore$ Thevenin's equivalent circuit is



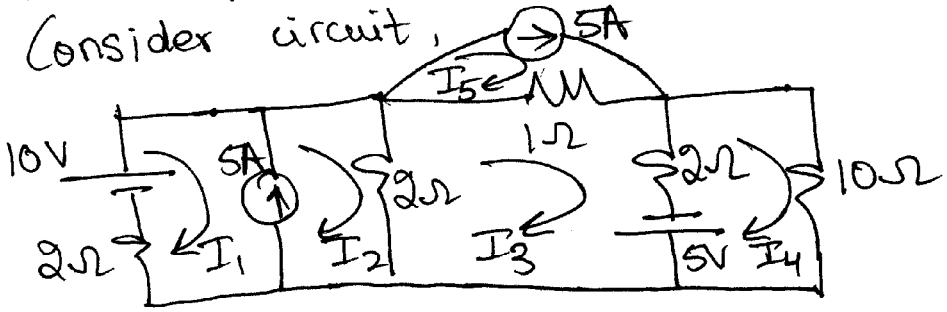
By KVL,

$11 I_L = 5$

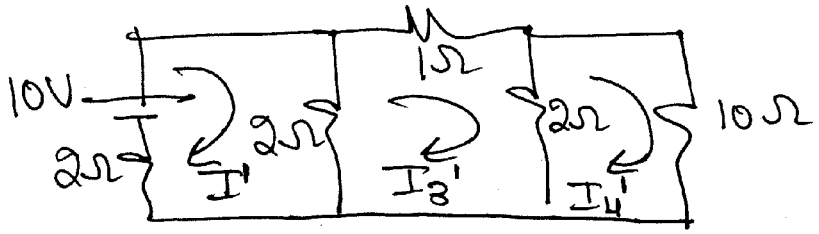
$\therefore I_L = 0.455A$

For Superposition theorem,

Consider circuit,



Consider 10V Battery and open 5A current source and short 5V Battery



$I_5' = 0$

By KVL to loop I,

$4I' - 2I_3' + 0I_4' = 10$ — (I)

By KVL to loop II,

$-2I' + 5I_3' - 2I_4' = 0$ — (II)

By KVL to loop III,

$0I' - 2I_3' + 12I_4' = 0$ — (III)

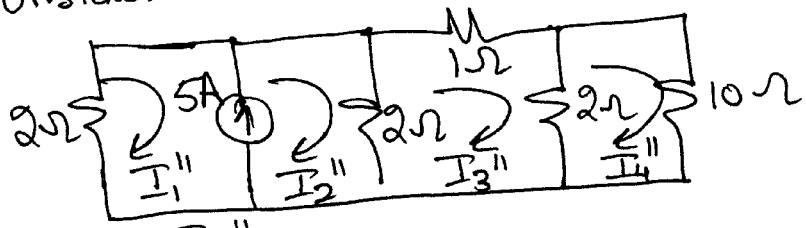
$\therefore I' = 3.18A$

$I_3' = 1.36A$

$I_4' = 0.23A$

$I_1' = I_2' = I' = 3.18A$

Consider 5A current source, short 10V, 5V & open 5A



$I_5'' = 0$

Equation of supermesh for loop I & II is

$I_2'' - I_1'' = 5$

$\therefore I_1'' = I_2'' - 5$ — (I)

By KVL to loop I & II

$$2I_1'' + 2I_2'' - 2I_3'' = 0$$

Subs. from eq (I)

$$\therefore 2I_2'' - 10 + 2I_2'' - 2I_3'' = 0$$

$$\therefore 4I_2'' - 2I_3'' + 0I_4'' = 10 \quad \text{—— (II)}$$

By KVL to loop III,

$$-2I_2'' + 5I_3'' - 2I_4'' = 0 \quad \text{—— (III)}$$

By KVL to loop IV,

$$0I_2'' - 2I_3'' + 12I_4'' = 0$$

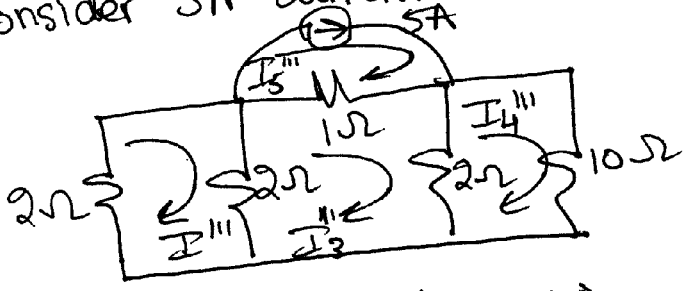
$$\therefore I_2'' = 3.18A$$

$$I_3'' = 1.36A$$

$$I_4'' = 0.23A$$

Subs. in eq (I) $\therefore I_1'' = -1.82A$

Consider 5A current source, short 10V, 5V & open 5A



$$I_5''' = 5A \quad \text{— (I)}$$

By KVL to loop I,

$$4I''' - 2I_3''' + 0I_4''' = 0 \quad \text{—— (II)}$$

By KVL to loop II,

$$-2I''' + 5I_3''' - 2I_4''' - I_5''' = 0$$

$$\therefore -2I''' + 5I_3''' - 2I_4''' = 5 \quad \text{— (III) \{ Subs. from (I) \}}$$

By KVL to loop III,

$$0I''' - 2I_3''' + 12I_4''' = 0 \quad \text{— (IV)}$$

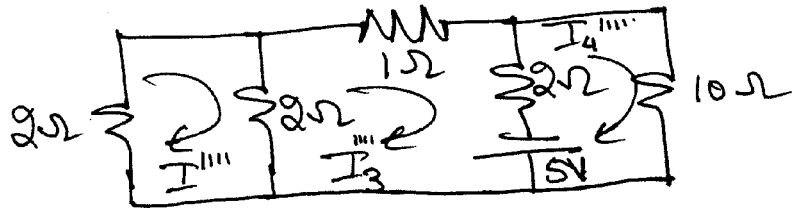
$I''' = 0.68A$

$I_3''' = 1.36A$

$I_4''' = 0.23A$

$\therefore I_1''' = I_2''' = I''' = 0.68A$

Consider 5V, short 10V & open 5A



$I_5''' = 0$

By KVL to loop I,

$4I''' - 2I_3''' + 0I_4''' = 0$ — (I)

By KVL to loop II,

$-2I''' + 5I_3''' - 2I_4''' = 5$ — (II)

By KVL to loop III,

$0I''' - 2I_3''' + 12I_4''' = -5$ — (III)

$\therefore I''' = 0.57A$

$I_3''' = 1.14A$

$I_4''' = -0.23A$

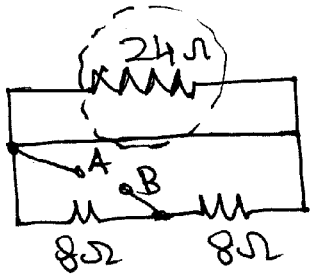
$I_1''' = I_2''' = I''' = 0.57A$

By superposition theorem,

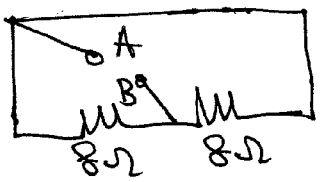
$I_4 = I_4' + I_4'' + I_4''' + I_4''''$

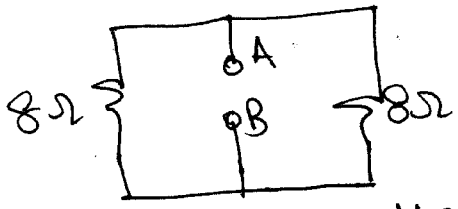
$= 0.46A$

Q46)

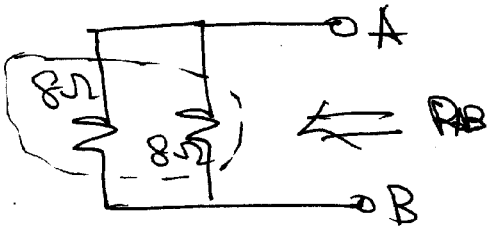


24Ω // short
≡ short





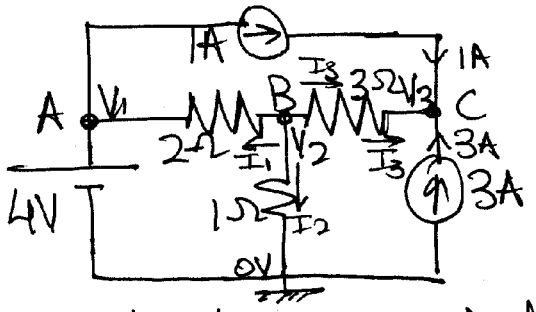
≡



$8\Omega \,//\, 8\Omega \equiv 4\Omega$

$\therefore R_{AB} = 4\Omega$

Q47)



Since node A is connected to a battery and directly to ground without a series resistor

$\therefore V_1 = +4V$ — (I)

KCL at node B,

$\therefore I_1 + I_2 + I_3 = 0$

$\therefore \frac{V_2 - V_1}{2} + \frac{V_2 - 0}{1} + \frac{V_2 - V_3}{3} = 0$

$\therefore V_1\left(\frac{-1}{2}\right) + V_2\left(\frac{1}{2} + 1 + \frac{1}{3}\right) + V_3\left(\frac{-1}{3}\right) = 0$ — (II)

KCL at node C,

$I_3 + 1 + 3 = 0$

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

$\therefore V_1(0) + V_2\left(\frac{1}{3}\right) + V_3\left(\frac{-1}{3}\right) = -4$ — (III)

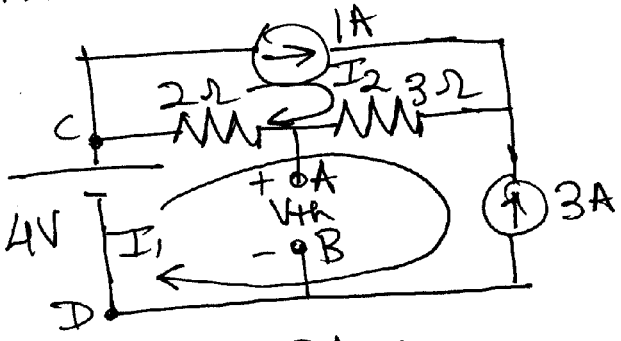
$\therefore V_1 = 4V$

$V_2 = 4V$

$V_3 = 16V$

$I_2 = \frac{V_2 - 0}{1} = 4A.$

For Thevenin's theorem,



$I_1 = -3A$

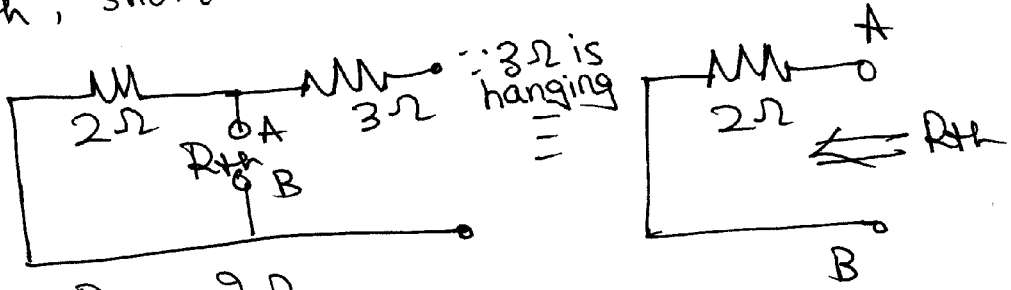
$I_2 = 1A$

By KVL to loop D-C-A-B-D:-

$2I_1 - 2I_2 = 4 - V_{th}$

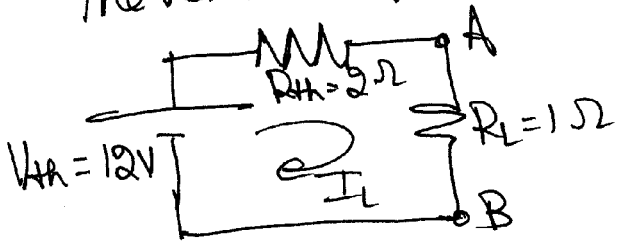
$\therefore V_{th} = \cancel{8V}\ 12V$

For Rth, short 4V & open 3A & 1A



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

Thevenin's eq. ckt. is

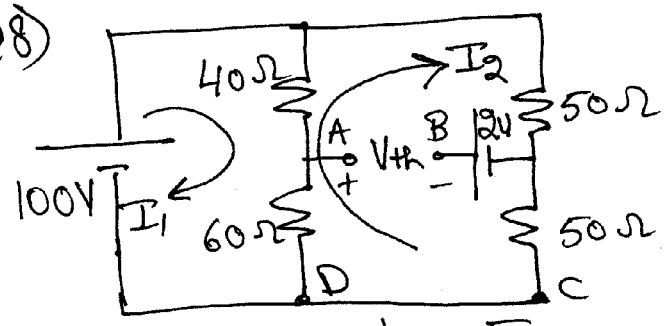


By KVL,

$3I_L = 12$

$\therefore I_L = 4A$

Q48)



By KVL to loop I,

$100I_1 - 100I_2 = 100$ — (I)

By KVL to loop II,

$-100I_1 + 200I_2 = 0$ — (II)

$\therefore I_1 = 2A$

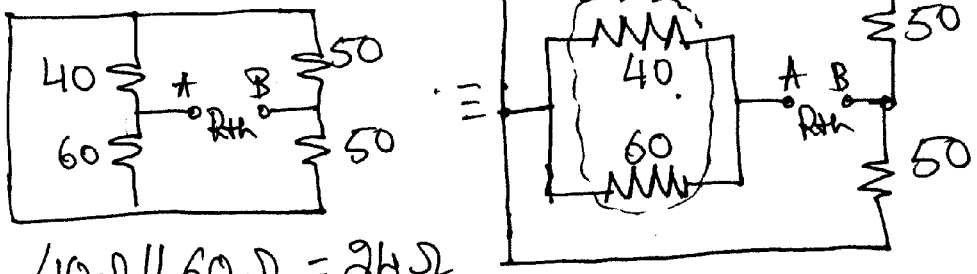
$I_2 = 1A$

By KVL to loop A-B-C-D-A,

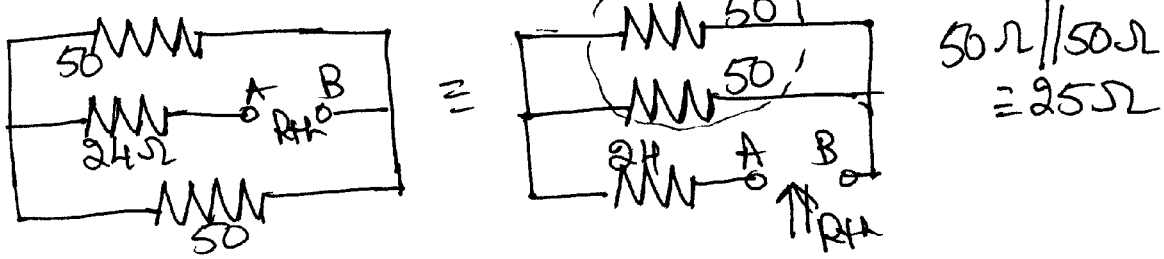
$-60I_1 + 110I_2 = -V_{th} - 12$

$\therefore V_{th} = -2V$

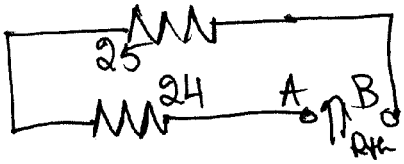
For R_{th}, short 100V & 2V



$40\Omega // 60\Omega \equiv 24\Omega$

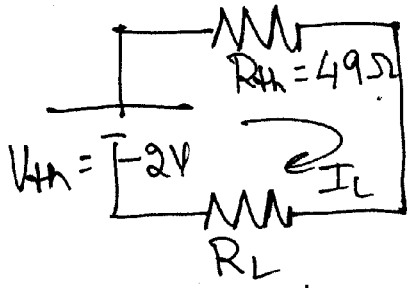


$50\Omega // 50\Omega = 25\Omega$



$R_{th} = 25 + 24 = 49\Omega$

Thevenin's Eq. ckt. is

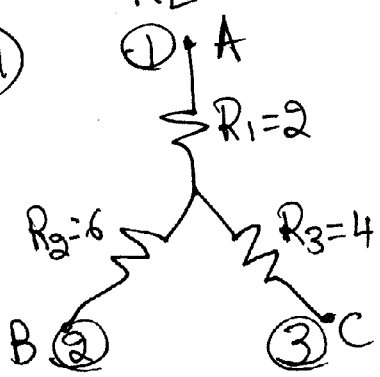


For max. power $R_L = R_{Th} = 49\Omega$

$I_L = 0.02\,A$

$P_L = I_L^2 \times R_L = 0.02\,W$

Q49)



$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3} = 11\Omega$

$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1} = 22\Omega$

$R_{13} = R_1 + R_3 + \frac{R_1 R_3}{R_2} = 7.33\Omega$

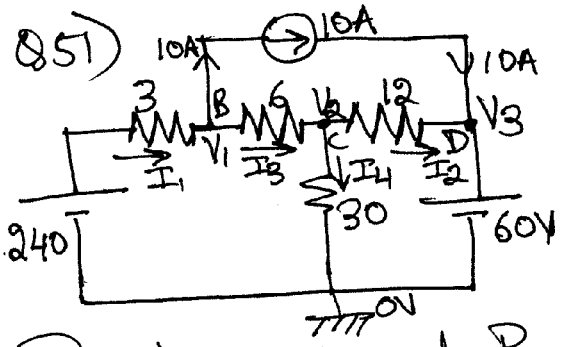
Q50) $\because E = V + Ir$

$\therefore 12 = 100 \times 0.10 + 100 \times r$

$\therefore 12 = 10 + 100r$

$\therefore r = 0.02\Omega$

Q51)



Since node D is connected to battery and ground without any resistor in series

$\therefore V_3 = +60V$

By KCL at node B,

$I_1 = I_3 + 10$

$\therefore \frac{240 - V_1}{3} = \frac{V_1 - V_2}{6} + 10$

$\therefore V_1\left(-\frac{1}{3} - \frac{1}{6}\right) + V_2\left(\frac{1}{6}\right) = -\frac{240}{3} + 10 \quad \text{— (I)}$

By KCL at node C,

$I_3 = I_4 + I_2$

$$\therefore \frac{V_1 - V_2}{6} = \frac{V_2 - 0}{30} + \frac{V_2 - V_3}{12}$$

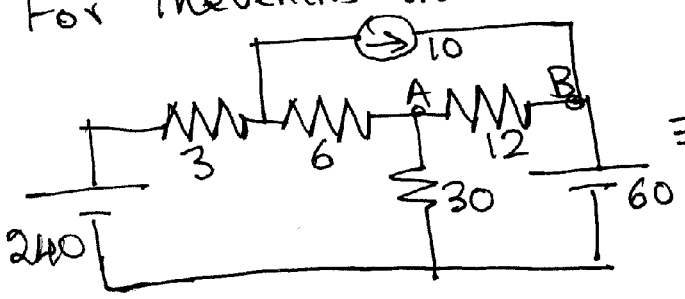
$$\therefore V_1\left(\frac{1}{6}\right) + V_2\left(-\frac{1}{6} - \frac{1}{30} - \frac{1}{12}\right) = -\frac{60}{12} \quad \text{— (IV)}$$

$$\therefore V_1 = 181.46\ V$$

$$V_2 = 124.39\ V$$

$$\therefore I_2 = \frac{V_2 - V_3}{12} = 5.57\ A$$

For Thevenins theorem,



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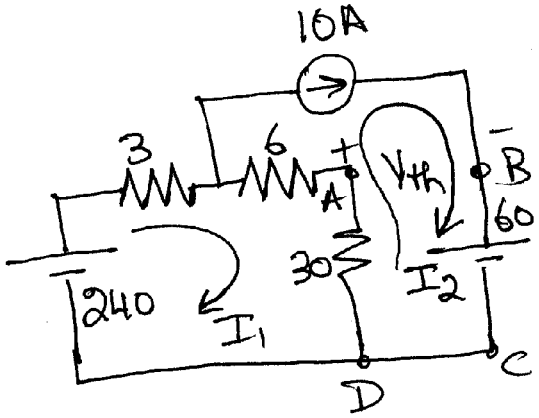


$I_2 = 10A$

By KVL to loop I,

$$39I_1 - 36I_2 = 240$$

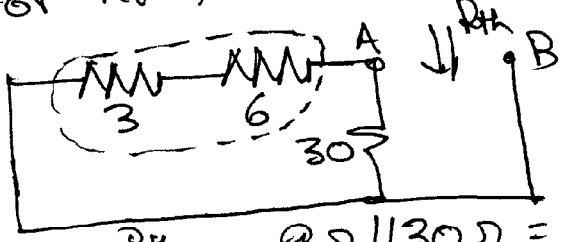
$$\therefore I_1 = 15.385A$$

By KVL to loop A-B-C-D-A

$$\therefore -30I_1 + 30I_2 = -V_{th} - 60$$

$$\therefore V_{th} = 101.55\ V$$

For Rth, short 240V, 60V and open 10A



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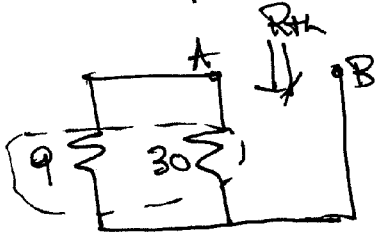
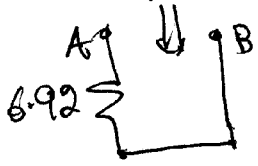
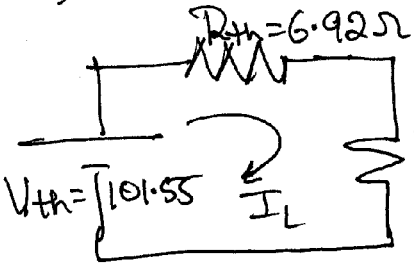


$9\Omega \,||\, 30\Omega \equiv 6.92\Omega$



$$\therefore R_{th} = 6.92\Omega$$

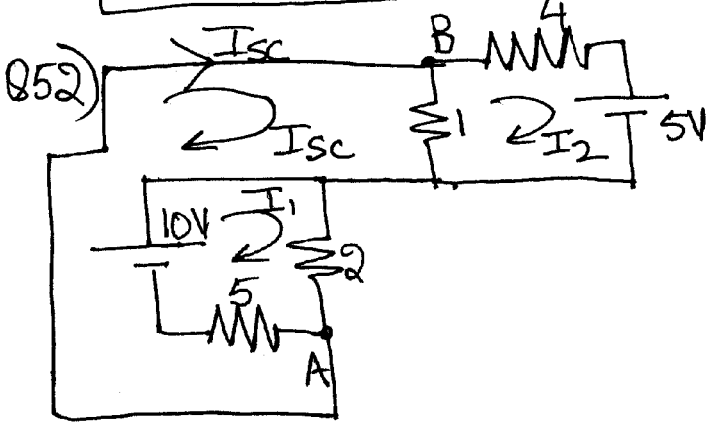
∴ Thevenin's Eq. ckt. is



By KVL,

$I_L = 5.37A$

Q52)



By KVL to loop I,

$7I_1 + 0I_2 - 5I_{sc} = 10$

By KVL to loop II,

$0I_1 + 5I_2 - I_{sc} = -5$

By KVL to loop III,

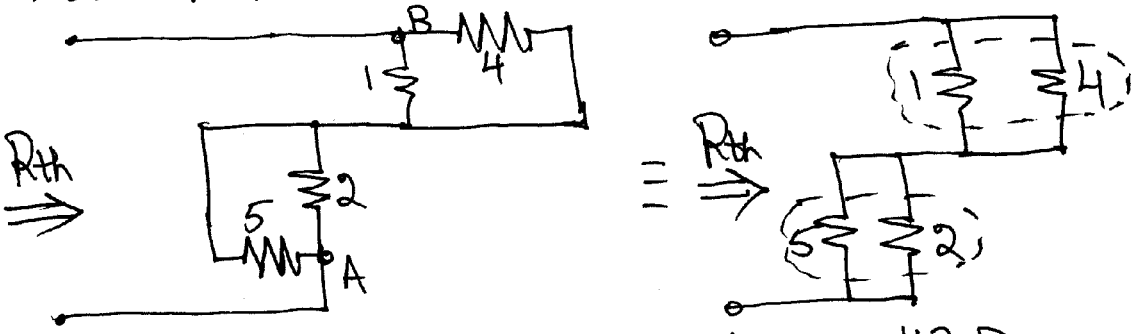
$-5I_1 - I_2 + 6I_{sc} = -10$

$\therefore I_1 = 0.19A$

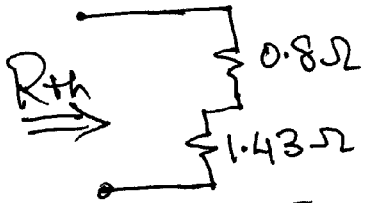
$I_2 = -1.35A$

$I_{sc} = -1.73A$

For Rth, Short 10V & 5V



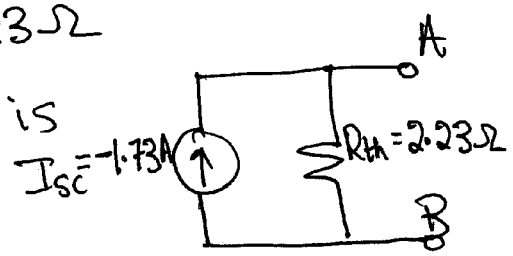
$1\Omega || 4\Omega \equiv 0.8\Omega$, $5\Omega || 2\Omega \equiv 1.43\Omega$



$\therefore R_{th} = 0.8 + 1.43$

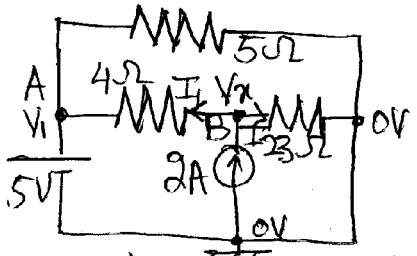
$= 2.23\Omega$

Norton's Equivalent circuit is



Q54) At node A,

$V_1 = +5V$



[NOTE: If a node is connected to a battery and directly to ground then nodal voltage = Battery voltage with sign as the nearest polarity to the node. KCL cannot be applied to that node.]

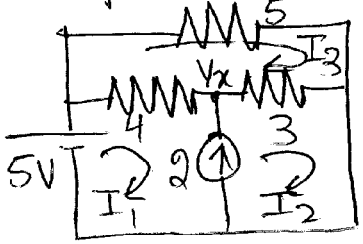
KCL at node B:-

$\therefore I_1 + I_2 = 2$

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

$\therefore V_x = 5.57\,V$

NOTE: For Verification, use mesh analysis



Eq. of supermesh is

$I_2 - I_1 = 2$

KVL to loop I & II:-

$4I_1 + 3I_2 - 7I_3 = 5$

KVL to loop III:-

$-4I_1 - 3I_2 + 12I_3 = 0$

$\therefore I_1 = 0.86A$

$I_2 = 2.86A$

$I_3 = 1A$

$I_2 - I_3 = \frac{V_x - 0}{3} \quad \therefore V_x = 5.58V$

Q55) $R_1 = 25\Omega$

$R_2 = 25 + \frac{10}{100} \times 25 = 27.5\Omega$

$T_1 = 15°C$, $T_2 = 50°C$

$\because R_t = R_0(1 + \alpha_0 t)$

$\therefore R_1 = R_0(1 + \alpha_0 T_1)$

$\therefore 25 = R_0(1 + 15\alpha_0)$ — (I)

$R_2 = R_0(1 + \alpha_0 T_2)$

$\therefore 27.5 = R_0(1 + 50\alpha_0)$ — (II)

Dividing eqn. (I) & (II)

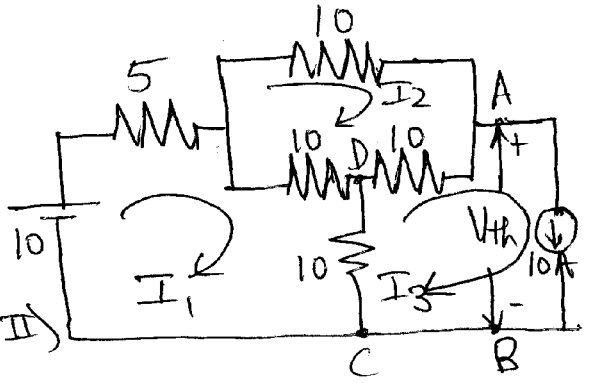
$$\therefore \frac{25}{27.5} = \frac{1+15\alpha_0}{1+50\alpha_0}$$

$$\therefore \alpha_0 = 2.99\times10^{-3}/^\circ C$$

Subs in eq. (I)

$$\therefore R_0 = 23.93\Omega$$

Q56) For V_{th}:-



KVL to loop I:-

$$25I_1 - 10I_2 - 10I_3 = 10 \quad \text{(I)}$$

KVL to loop II:-

$$-10I_1 + 30I_2 - 10I_3 = 0 \quad \text{(II)}$$

In loop III:-

$$I_3 = 10A$$

$$\therefore I_1 = 6.62A$$

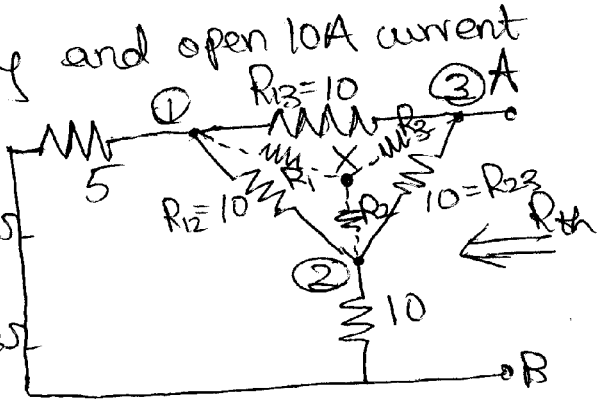
$$I_2 = 5.54A$$

KVL to loop A-B-C-D-A:-

$$-10I_1 - 10I_2 + 20I_3 = -V_{th}$$

$$\therefore V_{th} = -78.4V$$

For R_{th}, short 10V Battery and open 10A current source:-

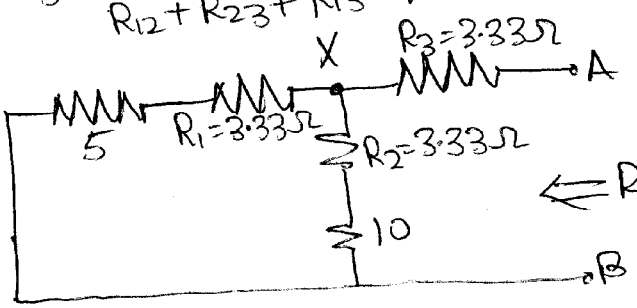


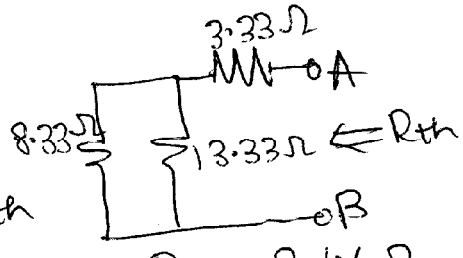
Converting Delta to Star:-

$$R_1 = \frac{R_{12}\times R_{13}}{R_{12}+R_{23}+R_{13}} = \frac{10\times10}{10+10+10} = 3.33\Omega$$

$$R_2 = \frac{R_{12}\times R_{23}}{R_{12}+R_{23}+R_{13}} = \frac{10\times10}{10+10+10} = 3.33\Omega$$

$$R_3 = \frac{R_{23}\times R_{13}}{R_{12}+R_{23}+R_{13}} = \frac{10\times10}{10+10+10} = 3.33\Omega$$

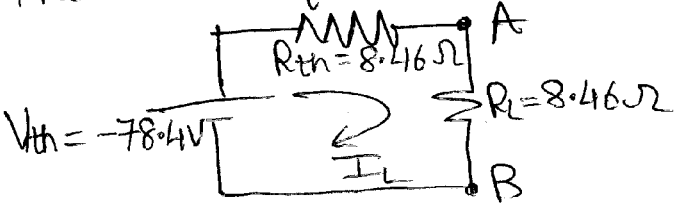




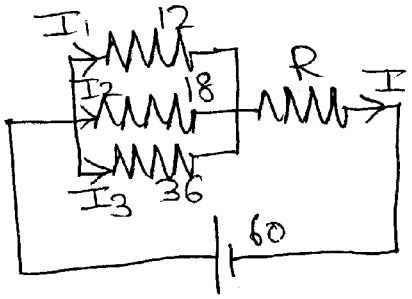
$R_{th} = 8.46\Omega$

For Maximum Power,
$R_L = R_{th} = 8.46\,\Omega$

Thevenin's Equivalent circuit is



By KVL,
$I_L = -4.63A$
Max Power = 181.64 W



Q57) $P_{12\Omega} = 36W$

$P_{12\Omega} = I_1^2 \times 12$

$\therefore I_1 = 1.73A$

$V_1 = I_1 \times 12 = 20.79V$

$V_1 = V_2 = V_3 = 20.79V$

$I_2 = \frac{V_2}{18} = 1.16A$

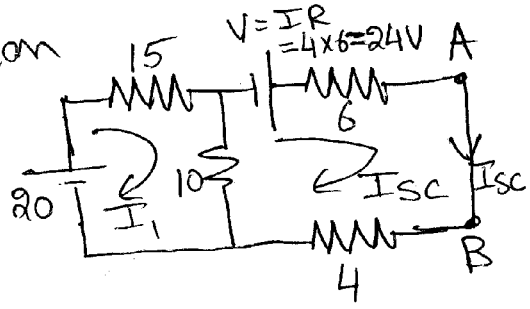
$I_3 = \frac{V_3}{36} = 0.58A$

$I = I_1 + I_2 + I_3 = 3.47A$

$V = V_1 + V_R \quad \therefore V_R = 60 - 20.79 = 39.21V$

$V_R = I R \quad \therefore R = 11.3\,\Omega$

Q58) For Isc, by source conversion



By KVL to loop I :-

$25I_1 - 10I_{sc} = 20 \quad -(I)$

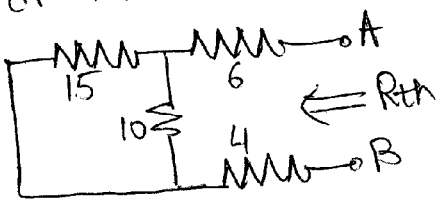
By KVL to loop II :-

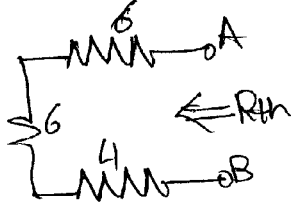
$-10I_1 + 20I_{sc} = 24 \quad -(II)$

$\therefore I_1 = 1.6A$

$I_{sc} = 2A$

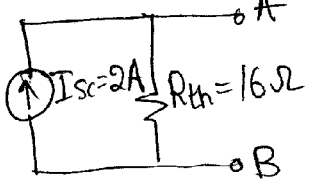
For Rth, Short 20V and open 4A current source



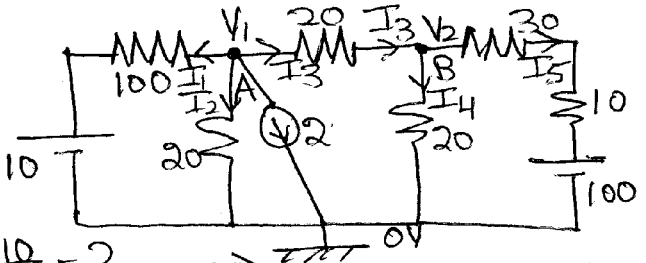


$\therefore R_{th} = 16\,\Omega$

Norton's Equivalent circuit is :-



Q59) By KCL to node A:-



$$I_1 + I_2 + I_3 + 2 = 0$$

$$\frac{V_1 - 10 - 0}{100} + \frac{V_1 - 0}{20} + \frac{V_1 - V_2}{20} + 2 = 0$$

$$V_1\left(\frac{1}{100} + \frac{1}{20} + \frac{1}{20}\right) + V_2\left(\frac{-1}{20}\right) = \frac{10}{100} - 2 \quad \text{— (I)}$$

By KCL at node B:-

$$I_3 = I_4 + I_5$$

$$\therefore \frac{V_1 - V_2}{20} = \frac{V_2 - 0}{20} + \frac{V_2 - 100 - 0}{30 + 10}$$

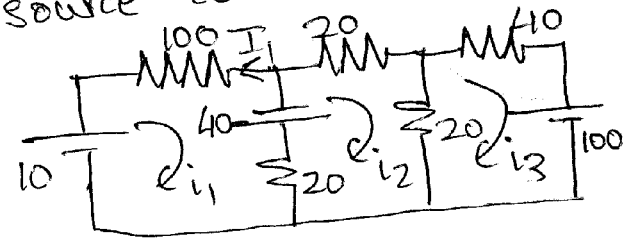
$$\therefore V_1\left(\frac{1}{20}\right) + V_2\left(\frac{-1}{20} - \frac{1}{20} - \frac{1}{40}\right) = \frac{-100}{40} \quad \text{— (II)}$$

$$V_1 = -10V$$

$$V_2 = 16V$$

$$I_1 = \frac{V_1 - 10}{100} = -0.2A$$

NOTE: For Verification, we source convert and use mesh analysis



By KVL to loop I:-

$$120i_1 - 20i_2 + 0i_3 = 50 \quad \text{— (I)}$$

By KVL to loop II:-

$$-20i_1 + 60i_2 - 20i_3 = -40 \quad \text{— (II)}$$

By KVL to loop III:-

$$0i_1 - 20i_2 + 60i_3 = -100 \quad \text{— (III)}$$

$$\therefore i_1 = 0.2$$

$$i_2 = -1.3$$

$$i_3 = -2.1$$

$$\therefore I_1 = -i_1$$

$$= -0.2A$$

Q60) By KCL at middle node,

$3 + I_x = 5 + I_y + I_z$ — (I)

i) $I_y = 2, I_z = 0 \quad \therefore I_x = 4A$

ii) $I_x = 2, I_z = 2I_y \quad \therefore I_y = 0A$

iii) $I_x = I_y = I_z \quad \therefore I_z = -2A$

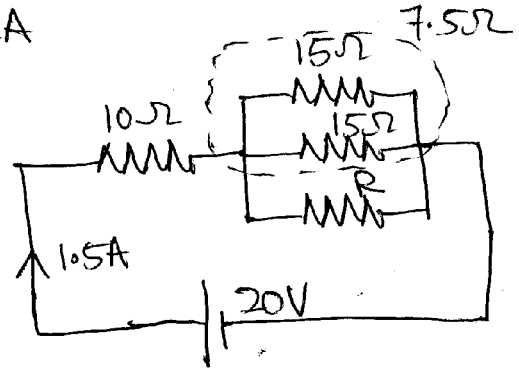
Q61) $R_{parallel} = \frac{7.5R}{7.5+R}$

$\text{Total } R = 10 + \frac{7.5R}{7.5+R}$

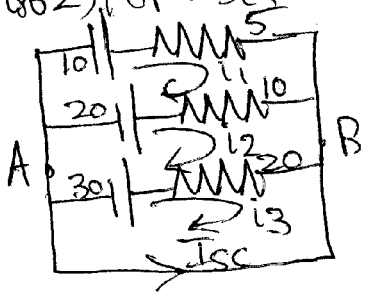
By KVL,

$20 = 1.5\left(10 + \frac{7.5R}{7.5+R}\right)$

$\therefore R = 6\Omega$



Q62) For I_{sc}, short 25Ω resistance



By KVL to loop I:-

$15i_1 - 10i_2 + 0i_3 = -10$

By KVL to loop II:-

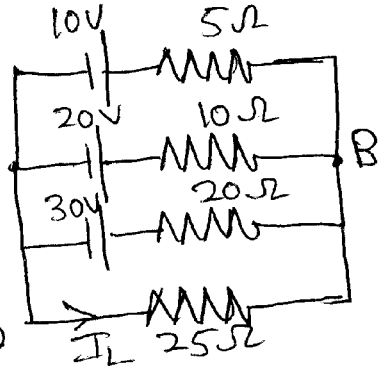
$-10i_1 + 30i_2 - 20i_3 = -10$

By KVL to loop III:-

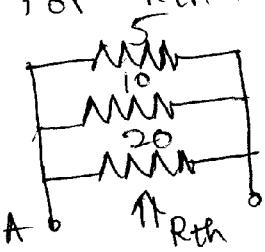
$0i_1 - 20i_2 + 20i_3 = 30$

$\therefore i_1 = 2A, i_2 = 4A, i_3 = 5.5A$

$I_{sc} = -i_3 = -5.5A$

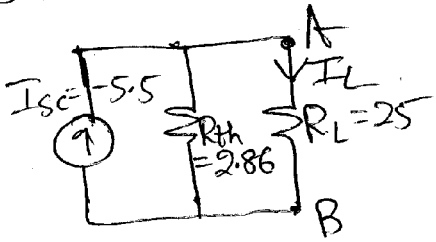


For R_{th}, short 10V, 20V, 30V Batteries



$\therefore R_{th} = 2.86\Omega$

Norton's Eq. ckt. is



$\therefore I_L = -0.57A$

NOTE: For Verification use mesh analysis

$15i_1 - 10i_2 + 0i_3 = -10$

$-10i_1 + 30i_2 - 20i_3 = -10$

$0i_1 - 20i_2 + 45i_3 = 30$

$\therefore I_L = -i_3 = -0.56A$

Q63) By KVL to loop I:-

$3.5i_1 - 2i_2 - 1.5i_3 = -6$

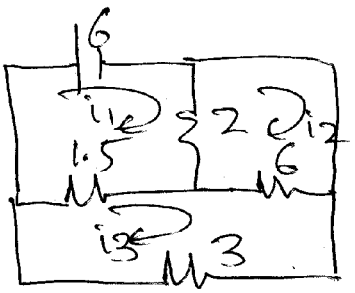
By KVL to loop II:-

$-2i_1 + 8i_2 - 6i_3 = 0$

By KVL to loop III:-

$-1.5i_1 - 6i_2 + 10.5i_3 = 0$

$\therefore i_1 = -4A$

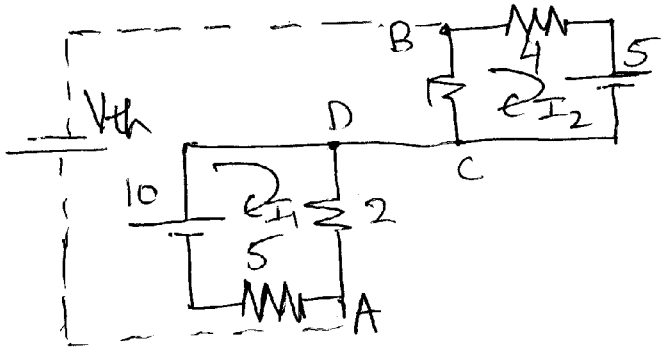


Q64) By KVL to loop I:-

$7I_1 = 10 \quad \therefore I_1 = 1.43A$

By KVL to loop II:-

$5I_2 = -5 \quad \therefore I_2 = -1A$



By KVL to loop A-B-C-D-A:-

$-I_2 + 2I_1 = -Vth$

$\therefore Vth = -3.86V$

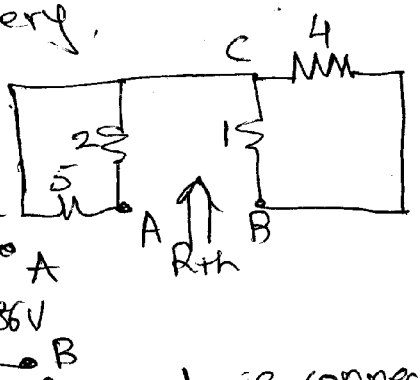
For Rth, short 10V & 5V Battery.

$2\Omega // 5\Omega = 1.43\Omega$

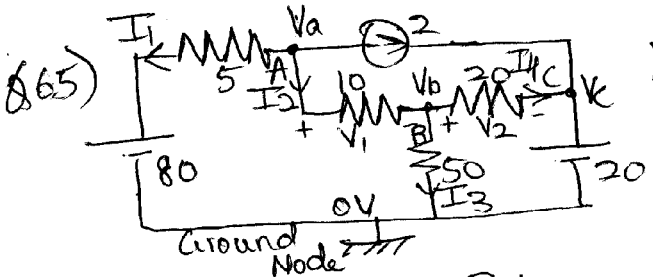
$1\Omega // 4\Omega = 0.8\Omega$

$Rth = 1.43 + 0.8 = 2.23\Omega$

Thevenin's Eq. ckt. is



Q65)



[NOTE: If a node is connected to a battery without any resistor between node and ground then KCL cannot be applied and nodal voltage = Battery voltage with polarity = nearest Battery nodal polarity]

$\therefore$ At Node C:-

$V_c = +20V$

KCL at node A:-

$I_1 + I_2 + 2 = 0$

$\therefore \frac{Va - 80 - 0}{5} + \frac{Va - Vb}{10} + 2 = 0$

$$\therefore V_a\left(\frac{1}{5}+\frac{1}{10}\right)+V_b\left(\frac{-1}{10}\right)=\frac{80}{5}-2 \quad \text{—(I)}$$

KCL at node B:-

$$I_2 = I_3 + I_4$$

$$\frac{V_a - V_b}{10} = \frac{V_b - 0}{50} + \frac{V_b - V_c}{20}$$

$$\therefore V_a\left(\frac{1}{10}\right)+V_b\left(-\frac{1}{10}-\frac{1}{50}-\frac{1}{20}\right)+V_c\left(\frac{1}{20}\right)=0 \quad \text{—(II)}$$

$V_a = 60.49\,V$

$V_b = 41.46\,V$

[Polarity of V_a & V_b depends on signs of V_1 close to V_a & V_b]

$V_1 = +V_a - V_b$

$\therefore V_1 = 19.03\,V$

$V_2 = +V_b - V_c$

$\therefore V_2 = 21.46\,V$

[NOTE: Verify using Mesh Analysis:-

KVL to loop I:-

$65I_1 - 10I_2 - 50I_3 = 80$ — (I)

In loop II:-

$I_2 = 2A$ — (II)

KVL to loop III:-

$-50I_1 - 20I_2 + 70I_3 = -20$ — (III)

$\therefore I_1 = 3.9\,A$

$I_2 = 2\,A$

$I_3 = 3.07\,A$

[Polarity of current depends on terminal of V_1 it enters]

$V_1 = 10(+I_1 - I_2)$

$\therefore V_1 = 19\,V$

$V_2 = 20(+I_3 - I_2)$

$\therefore V_2 = 21.4\,V$