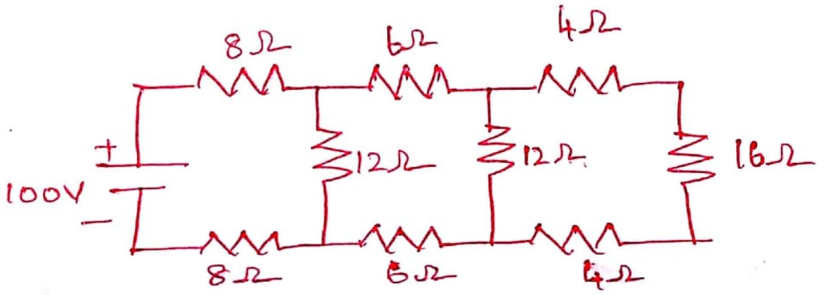
Part - B

1. Calculate

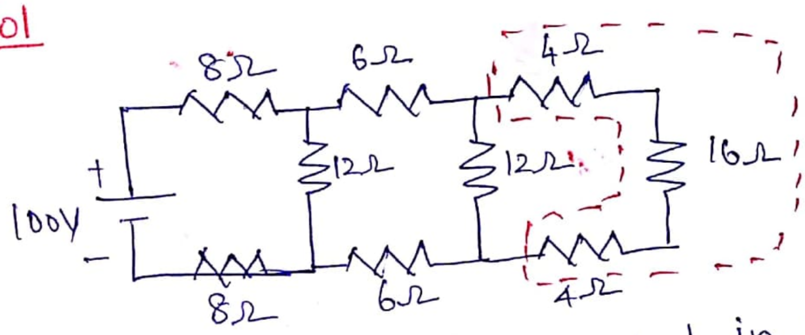
(i) Equivalent resistance across the terminal of the supply

(ii) Total current supplied by the source

(iii) Power delivered to 16Ω resistor in the circuit shown below

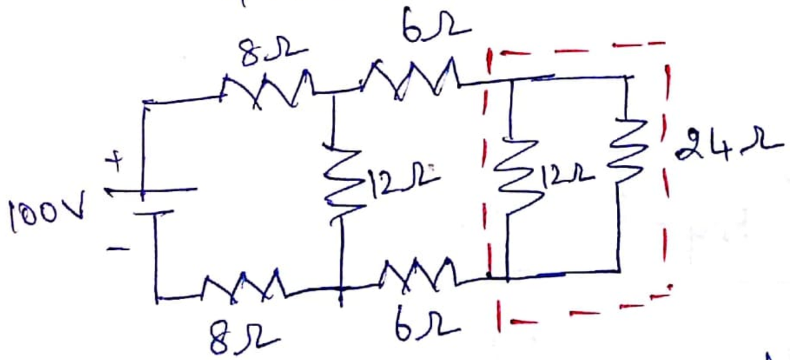


Sol



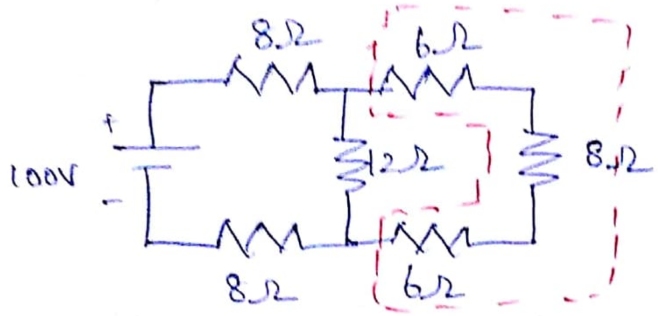
4Ω, 16Ω, 4Ω are connected in series

$$4+16+4 = 24\,\Omega$$



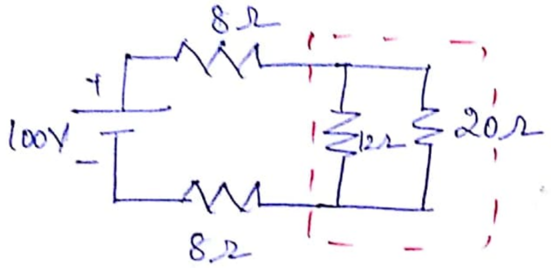
12Ω and 24Ω are connected in parallel

$$\frac{12 \times 24}{12+24} = 8\,\Omega$$



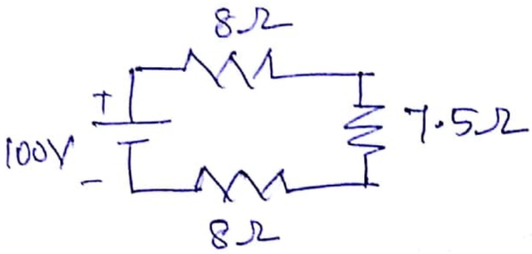
6Ω, 8Ω, 6Ω are connected in series

$6+8+6 = 20\Omega$



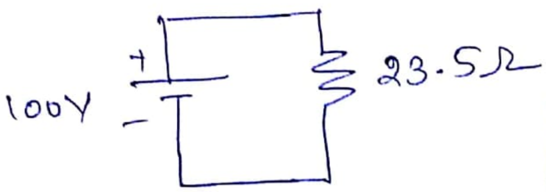
12Ω and 20Ω are connected in parallel

$$\frac{12 \times 20}{12+20} = 7.5\Omega$$



8Ω, 8Ω, & 7.5Ω are connected in series

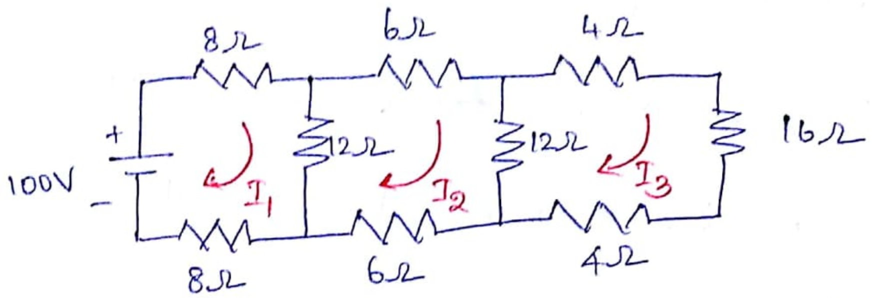
$8+8+7.5 = 23.5\Omega$



$$\boxed{R_{eq} = 23.5\Omega}$$

$$I_T = \frac{V}{R} = \frac{100}{23.5} = 4.25A$$

Power delivered by 16Ω is $P_{16\Omega} = I_{16\Omega}^2 R = I_3^2 R$



By KVL

loop1

$$8I_1 + 8I_1 + 12(I_1 - I_2) = 100$$

$$28I_1 - 12I_2 = 100 \rightarrow (1)$$

loop2

$$6I_2 + 6I_2 + 12(I_2 - I_1) + 12(I_2 - I_3) = 0$$

$$-12I_1 + 36I_2 - 12I_3 = 0 \rightarrow (2)$$

loop3

$$4I_3 + 4I_3 + 12(I_3 - I_2) + 16I_3 = 0$$

$$0I_1 - 12I_2 + 36I_3 = 0 \rightarrow (3)$$

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

$I_1 = 4.25A$

$I_2 = 1.59A$

$I_3 = 0.5A$

Power delivered by 16Ω is $P_{16\Omega} = I_3^2 R = (0.5)^2 = 16$

$$\boxed{P_{16\Omega} = 4W}$$

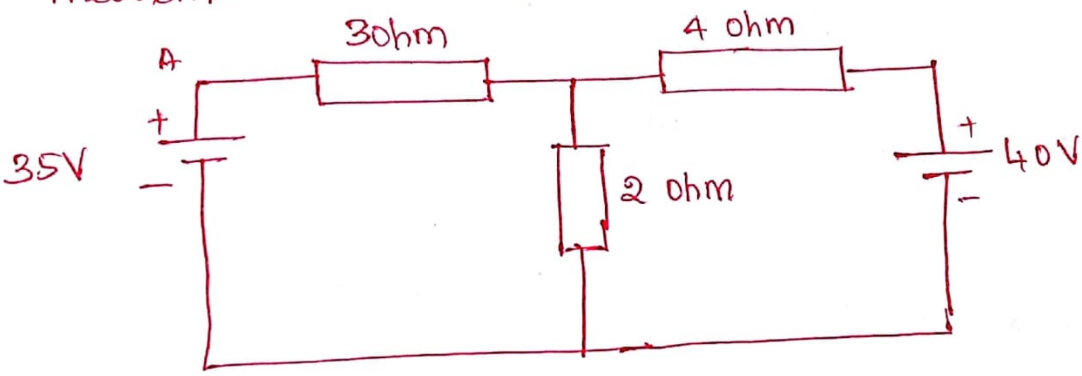
Result :

(i) Equivalent resistance $R_{eq} = 23.5\Omega$

(ii) Total current supplied by the battery $I_T = 4.25A$

(iii) Power delivered by 16Ω resistor $P_{16\Omega} = 4W$

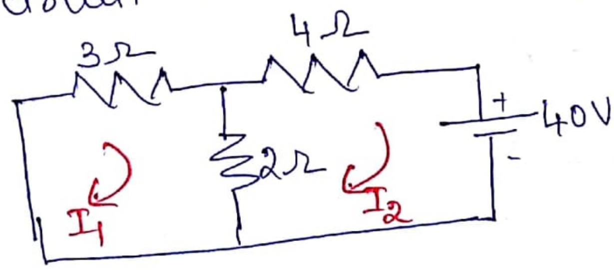
2. Find the current in each branch using superposition theorem.



Sol

Case(i)

Short circuit the 35V battery and calculate I_1, I_2



By KVL

loop 1 $3I_1 + 2(I_1 - I_2) = 0$

$5I_1 - 2I_2 = 0 \rightarrow (1)$

loop2,

$$4I_2 + 2(I_2 - I_1) = -40$$

$$-2I_1 + 6I_2 = -40 \rightarrow (2)$$

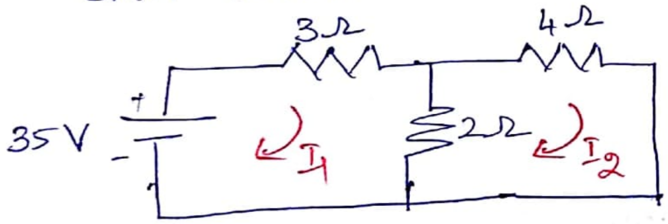
Solve the equations (1) & (2)

$$I_1 = -3.076\,A$$

$$I_2 = -7.69\,A$$

case(ii)

Short circuit the 40V battery & calculate I_1 & I_2



By KVL

loop 1

$$3I_1 + 2(I_1 - I_2) = 35$$

$$5I_1 - 2I_2 = 35 \rightarrow (1)$$

loop 2

$$4I_2 + 2(I_2 - I_1) = 0$$

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

Solve eqn (1) & (2) & calculate I_1 & I_2

$$I_1 = 8.07\,A$$

$$I_2 = 2.69\,A$$

From both case (i) & case (ii)

$I_1 = I_1$ in case (i) + I_1 in case (ii)

$= -3.706 + 8.076$

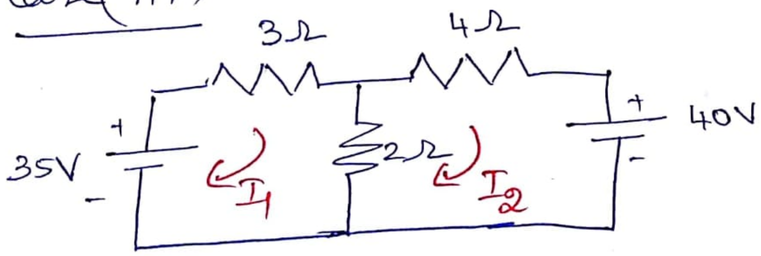
$\boxed{I_1 = 4.37A} \simeq 5A \rightarrow (A)$

$I_2 = I_2$ in case (i) + I_2 in case (ii)

$= -7.69 + 2.69$

$\boxed{I_2 = -5\,A} \rightarrow (A)$

Case (iii)



Apply KVL,

loop 1 $5I_1 - 2I_2 = 35 \rightarrow (1)$

loop 2 $-2I_1 + 6I_2 = -40 \rightarrow (2)$

Solve eqn (1) & (2) we get

$\left.\begin{array}{l} I_1 = 5A \\ I_2 = -5A \end{array}\right\} \rightarrow (B)$

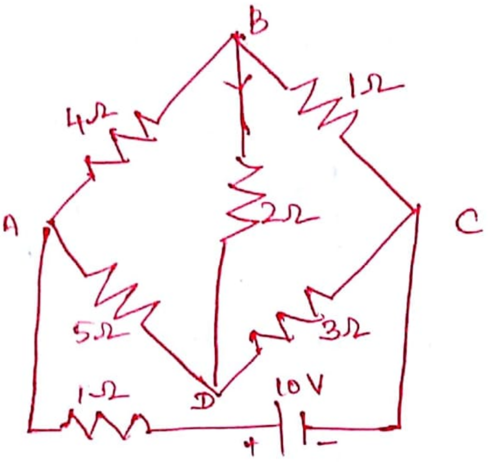
Eqn. (A) = Eqn. (B)

Hence the superposition theorem is verified

3. Use Kirchoff's laws and find

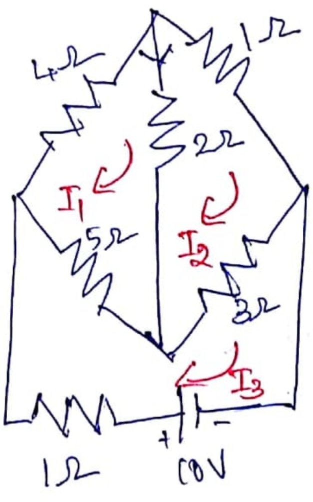
(i) Calculate the current through 1Ω resistor (6)

(ii) Calculate the current through 1Ω resistor which is connecting series with battery (7)



Sol

Assume current direction



By KVL

loop1 $\quad 11I_1 - 2I_2 - 5I_3 = 0 \quad \rightarrow (1)$

loop2 $\quad -2I_1 + 6I_2 - 3I_3 = 0 \quad \rightarrow (2)$

loop3 $\quad -5I_1 - 3I_2 + 9I_3 = 10 \quad \rightarrow (3)$

Solving equation (1), (2) & (3) we get

$I_1 = 1.45 A$

$I_2 = 1.73 A$

$I_3 = 2.49 A$

(i) Current through 2Ω resistor is $I_{2\Omega} = I_2 - I_1$

$= 1.73 - 1.45$

$\boxed{I_{2\Omega} = 0.28 A}$

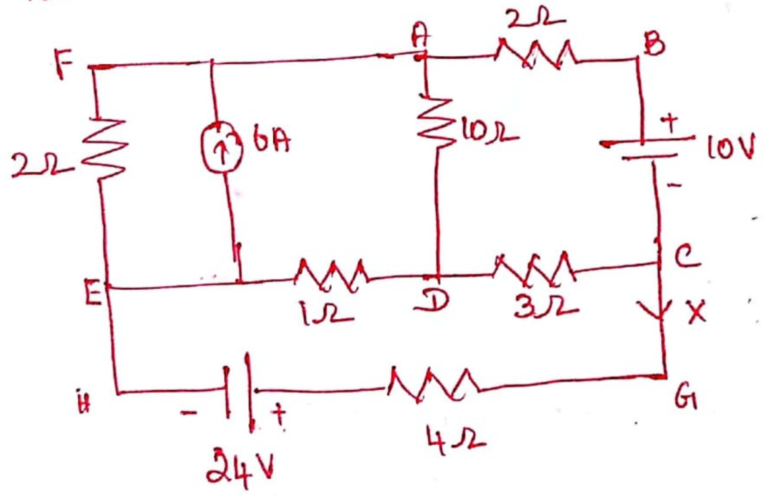
(ii) Current through 1Ω resistor connecting series with the battery is I_3

$\therefore \boxed{I_3 = I_{1\Omega} = 2.49 A}$

4. For the following circuit find

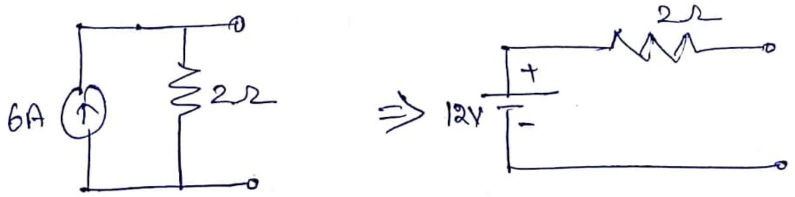
(i) the current 'x' (10)

(ii) Power across 4Ω resistor (3)



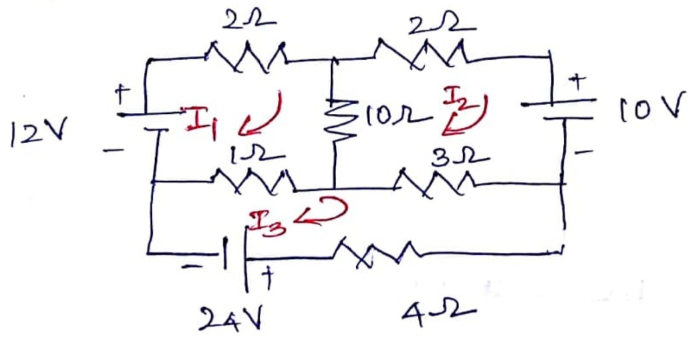
Sol

Transforming current source into equivalent voltage source,



$$V = IR = 6(2) = 12\,V$$

After source transformation,



Apply KVL,

At loop 1,

$$13I_1 - 10I_2 - I_3 = 12 \longrightarrow (1)$$

At loop 2,

$$-10I_1 + 15I_2 - 3I_3 = -10 \longrightarrow (2)$$

loop 3, $$-I_1 - 3I_2 + 8I_3 = -24 \longrightarrow (3)$$

Solving eqn (1), (2) & (3) we get

$I_1 = -1.02\,A$

$I_1 = 1.02A$ (Assume opposite direction)

$I_2 = -2.13A$, $I_3 = -3.9\,A$

(i) Current 'x' is I_3

$\therefore I_3 = x = -3.9\,A$ [direction is opposite to flow of current]

(ii) Power across 4Ω resistor

$$P_{4\Omega} = (I_{4\Omega})^2 R = (I_3)^2 R = (-3.9)^2 \times 4$$

$$\boxed{P_{4\Omega} = 60.8\,W}$$

5. Explain Kirchoff's current and voltage laws with suitable ~~or~~ examples (13)

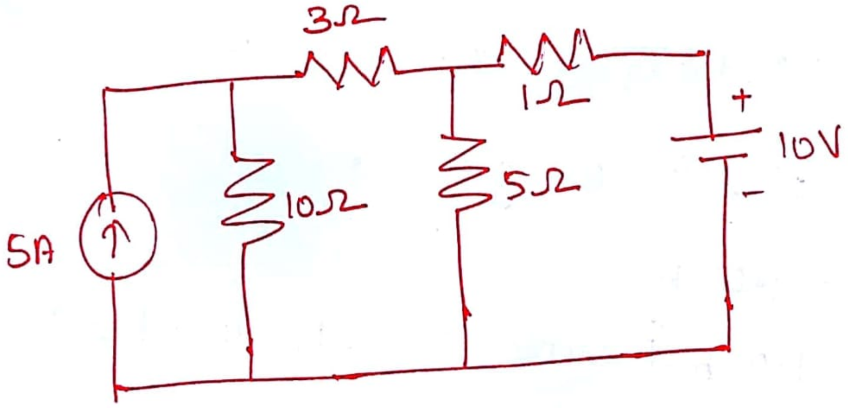
(1) KVL - definition

Eg. problem - Find the solution

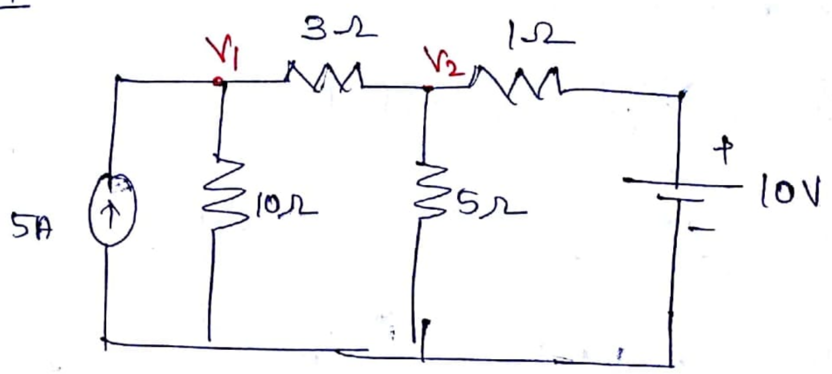
(2) KCL - definition

Eg - Problem - find the solution

6. Write the node voltage equations & determine the currents in each branch for the network shown (13)



Sol



Apply KVL, at node V_1

$$\frac{V_1 - 0}{10} + \frac{V_1 - V_2}{3} = 5 \longrightarrow (1)$$

$$\frac{V_1}{10} + \frac{V_1}{3} - \frac{V_2}{3} = 5$$

$$0.433V_1 - 0.33V_2 = 5 \longrightarrow (2)$$

At node V_2

$$\frac{V_2 - V_1}{3} + \frac{V_2}{5} + \frac{V_2 - 10}{1} = 0$$

$$\frac{-V_1}{3} + \frac{V_2}{3} + \frac{V_2}{5} + V_2 = 10$$

$$-0.33V_1 + 1.53V_2 = 10 \longrightarrow (3)$$

Solving equations (2) & (3) we get

$V_1 = 19.77V$

$V_2 = 10.8V$

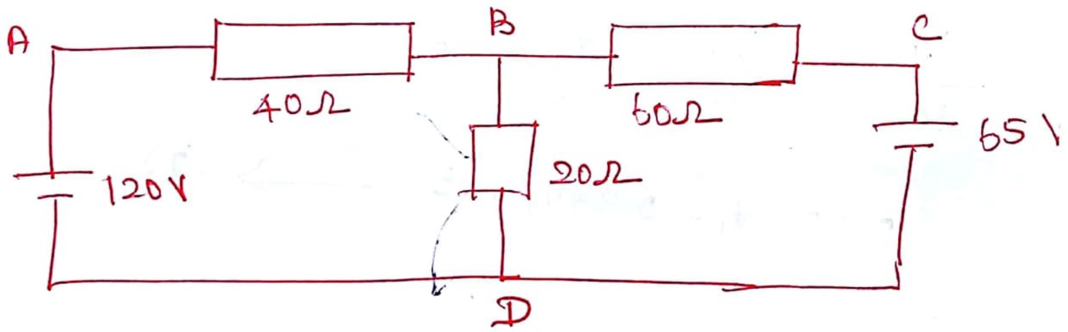
Currents in each branch are

$$I_{10\Omega} = \frac{V_1 - 0}{10} = \frac{19.95}{10} = 1.995\ A$$

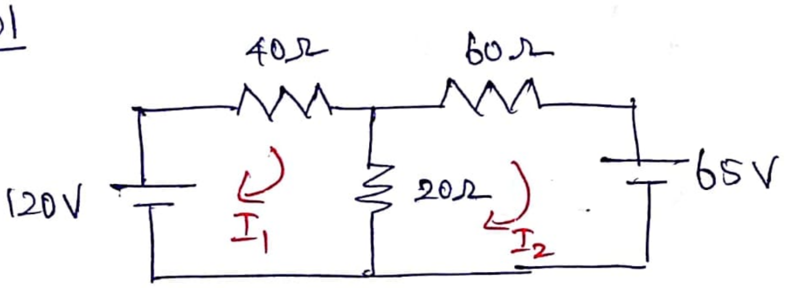
$$I_{3\Omega} = \frac{V_1 - V_2}{3} = \frac{19.95 - 10.84}{3} = 3.04A$$

$$I_{1\Omega} = \frac{V_2 - 10}{1} = 10.08 - 10 = 0.84A$$

7. In the circuit shown in figure, find the current in each branch using mesh analysis (13)



Sol



Apply KVL

loop 1 $\quad 40I_1 + 20(I_1 - I_2) = 120$

$$60I_1 - 20I_2 = 120 \longrightarrow (1)$$

loop 2 $\quad 60I_2 + 20(I_2 - I_1) = -65$

$$-20I_1 + 80I_2 = -65 \longrightarrow (2)$$

Solving equations (1) & (2)

$$\cancel{I_1 = 1.886\,A} \qquad \cancel{\Delta =}$$

$$\cancel{I_2 = -3.4\,A}$$

$$\begin{bmatrix} 60 & -20 \\ -20 & 80 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 120 \\ -65 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 60 & -20 \\ -20 & 80 \end{vmatrix} = (60)(80) - (-20)(-20) = 4400$$

$$\Delta_1 = \begin{vmatrix} 120 & -20 \\ -65 & 80 \end{vmatrix} = (120)(80) - (-65)(-20)$$

$$= 8300$$

$$\Delta_2 = \begin{vmatrix} 60 & 120 \\ -20 & -65 \end{vmatrix} = (60)(-65) - (120)(-20) = -1500$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{8300}{4400} = 1.886\,A$$

$$I_2 = \frac{\Delta_2}{\Delta} = \cancel{1580}\ \frac{-1500}{4400} = \cancel{-3.4\,A}\ -0.34\,A$$

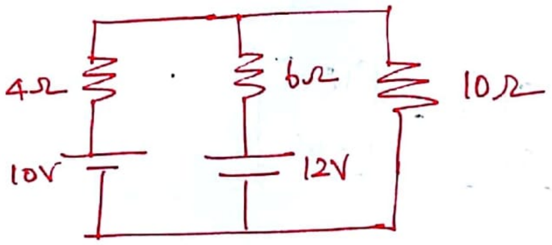
<u>Result</u>

$I_1 = 1.886\,A$

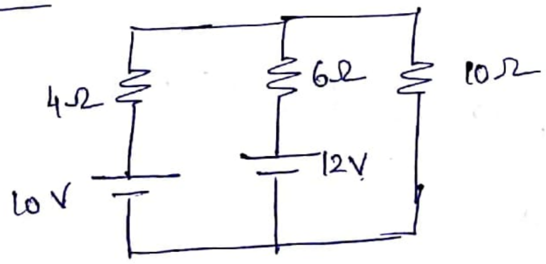
$I_2 = -0.34\,A$

8. Determine the current in 10Ω resistor using thevenin's theorem (13).

~~Sol~~

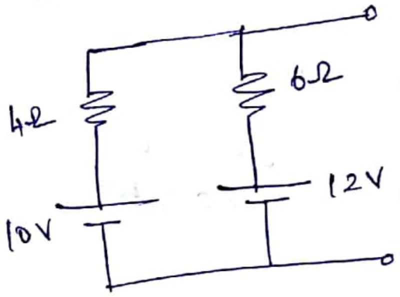


Sol



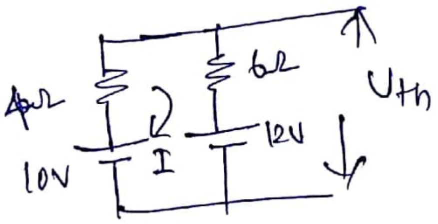
Step 1

Remove the load resistor 10Ω



Step 2

Determine thevenin's voltage (V_{th})

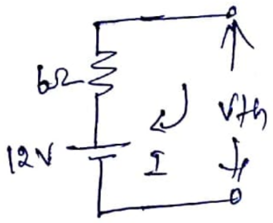


By KVL, $4I + 6I = 10 - 12$

$10I = -2$

$\boxed{I = -0.2\,A}$

Current in 6Ω resistor is −0.2 A



By KVL,

$6I = 12 - V_{th}$

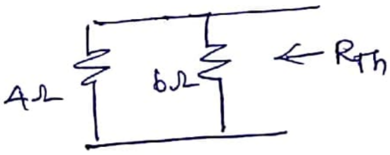
$V_{th} = 12 - 6I = 12 - 6(0.2)$

$\boxed{V_{th} = 10.8\ V}$

Step 3 :

~~To~~ find R_{Th}

- open circuit the ~~ckt the~~ current source
- Short circuit the voltage source



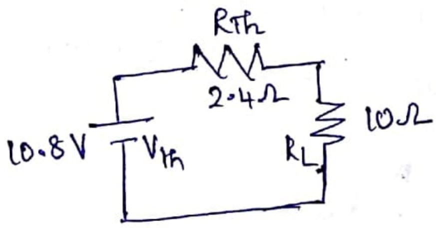
4Ω & 6Ω are connected in parallel

$\frac{4 \times 6}{4+6} = 2.4\ Ω$

Step 4

Thevenin's equivalent circuit,

Connect R_{Th} in series with V_{th} & reconnect the load resistor

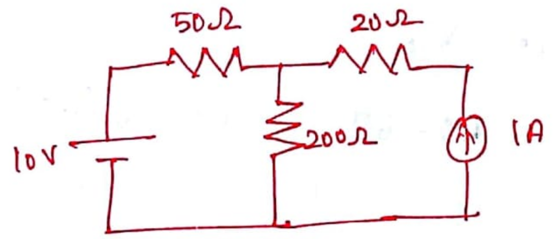


Step 5 To find load current

$I_L = \frac{V_{th}}{R_{Th} + R_L} = \frac{10.8}{2.4+10} = 0.871 A$

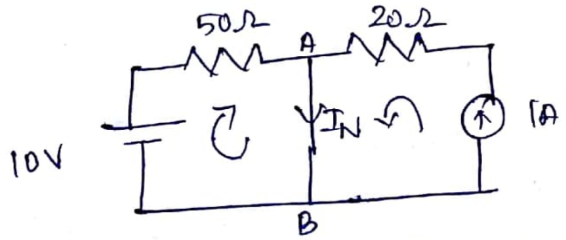
$V_L = I_L \times R_L = 0.871 \times 10 = 8.7 V$

9. Determine the voltage across 200Ω resistor in the circuit, using norton's theorem (13)



Sol

Step1 short the load resistor 200Ω & find the norton's current (I_N)



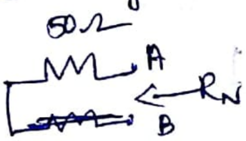
Due to 10V source $I_{10V} = \frac{V}{R} = \frac{10}{50} = 0.2A$

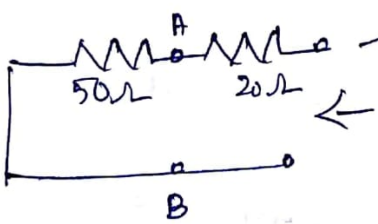
Due to 1A source $I_{1A} = 1A$

Total current through $I_N = I_{10V} + I_{1A} = 0.2 + 1$

$$\boxed{I_N = 1.2A}$$

Step2 Find R_N — open circuit the current source & Short circuit the voltage source & remove load resistor

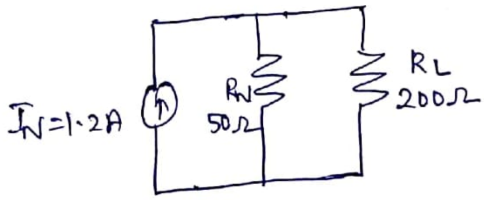




$R_N = R_{th} = 50Ω$

Step 3

Norton's equivalent circuit



Step 4

$$I_L = \frac{I_N R_N}{R_N + R_L} = \frac{1.2 \times 50}{50 + 200}$$

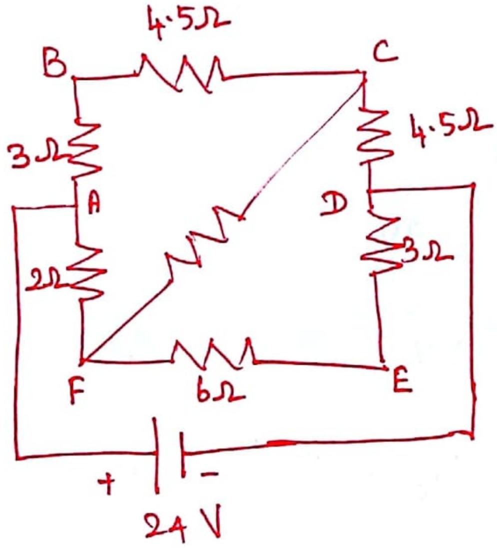
$$\boxed{I_L = 0.24A}$$

$$V_L = I_L R_L = 0.24 \times 200$$

$$\boxed{V_L = 48V}$$

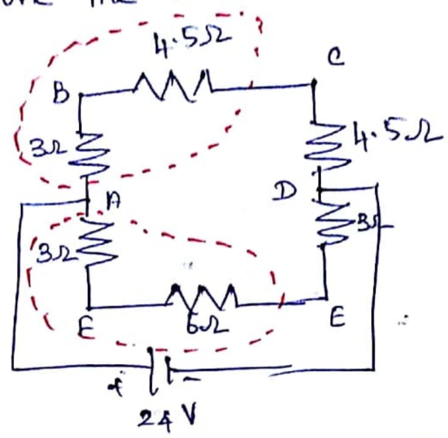
10(i) Draw the thevenin's equivalent circuit for the following circuit (7)

(ii) Determine the current through the branch FC (6)



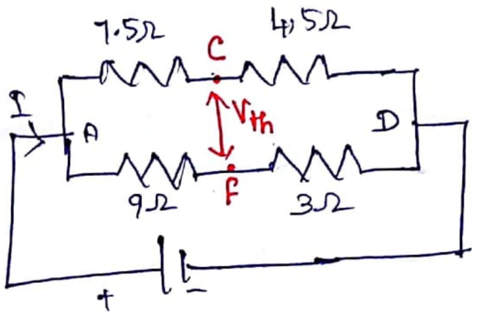
Step 1

Romove the load resistor 5Ω



4.5Ω & 3Ω are connected in series $4.5 + 3 = 7.5\Omega$

6Ω & 3Ω are " " " $3 + 6 = 9\Omega$



Step 2

Potential at point C & F ~~with~~ w.r.t. the negative terminal of the battery

Apply voltage division rule,

$$V_C = \frac{24 \times 4.5}{4.5 + 7.5} = 9V$$

$$V_F = \frac{24 \times 9}{9 + 3} = 18V$$

$$V_{Th} = V_{FC} = V_F - V_C = 18 - 9$$

$$\boxed{V_{Th} = 9V}$$

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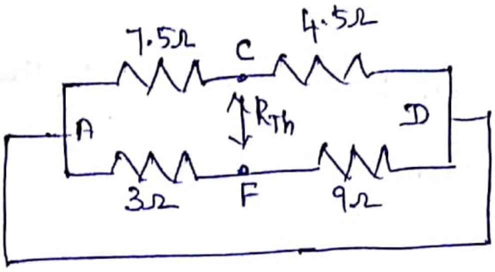
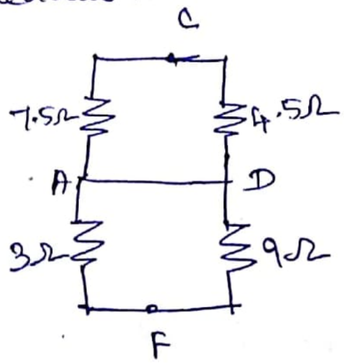
Step 3

To find R_{Th}

Open the current source, short the voltage source & remove the load resistor



Redraw the above circuit

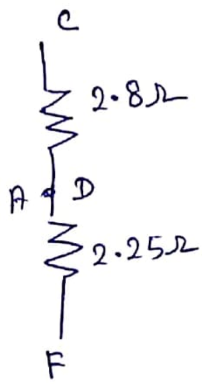


7.5Ω & 4.5Ω are in parallel

$$\frac{7.5 \times 4.5}{7.5 + 4.5} = 2.8\,\Omega$$

3Ω & 9Ω are in parallel

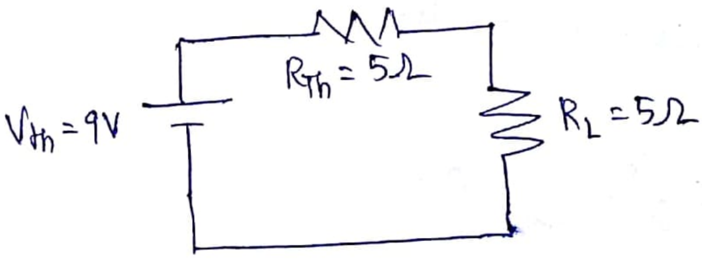
$$\frac{3 \times 9}{3 + 9} = 2.25\,\Omega$$



2.8Ω, 2.25Ω are in series

$$2.8 + 2.25 = 5.06\,\Omega$$

Step 4 Thevenin's equivalent circuit



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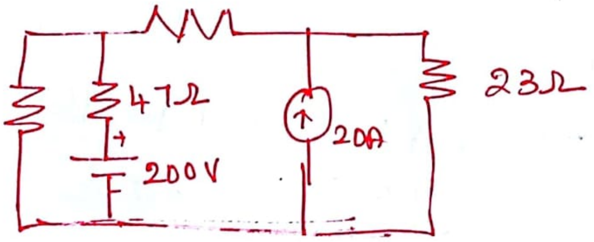
Step5

$$I_L = \frac{V_{th}}{R_{th}+R_L} = \frac{9}{5.06+5} = 0.9\,A$$

$$V_L = I_L R_L = 0.9 \times 5 = 4.5V$$

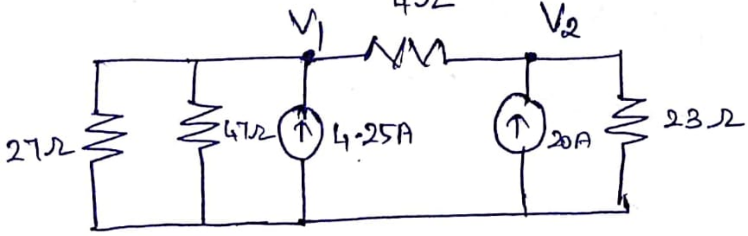
11. Compare the current through 23Ω resistor of the figure below using superposition theorem.



Sol

Using node voltage analysis

Convert the voltage source to current source



At node V_1

$$\frac{V_1}{27} + \frac{V_1}{47} + \frac{V_1 - V_2}{4} = 4.25$$

$$0.308V_1 - 0.25V_2 = 4.25 \longrightarrow (1)$$

At node V_2

$$\frac{V_2}{23} + \frac{V_2 - V_1}{4} = 20$$

$$-0.25V_1 + 0.29V_2 = 20 \longrightarrow (2)$$

Solving eqn. (1) & (2)

$$V_1 = 232.38\ V$$

$$V_2 = 269.29\ V$$

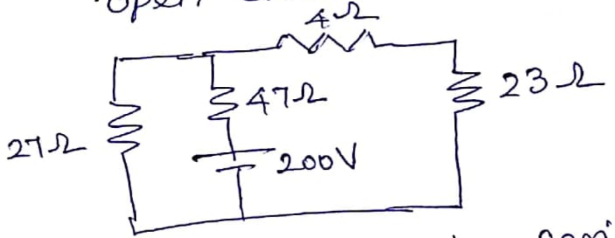
Current through 23Ω resistor $I_{23\Omega} = \frac{V_2}{R} = \frac{V_2}{23}$

$$= \frac{269.29}{23}$$

$$\boxed{I_{23\Omega} = 11.708\ A} \longrightarrow (1)$$

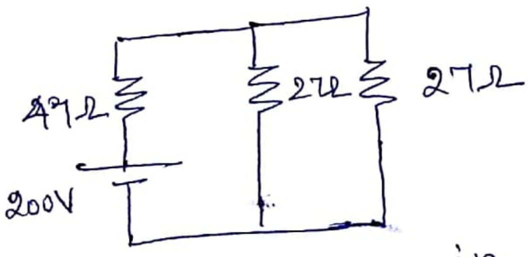
Case(i)

· open circuit the current source



→ (A)

23Ω & 4Ω are in series $23+4 = 27\Omega$

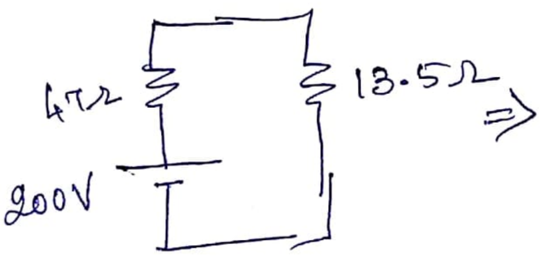


27Ω & 27Ω are in parallel

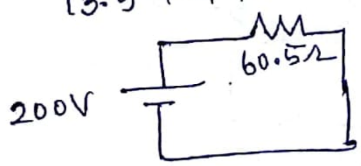
$$\frac{27\times27}{27+27} = 13.5\Omega$$

13.5Ω & 47Ω are in series

$$13.5 + 47 = 60.5\Omega$$



$\Rightarrow$



$\therefore$ Total current $I_T = \frac{V}{R} = \frac{200}{60.5} = 3.3\,A$

For the circuit (A)

Current through 23Ω resistor is

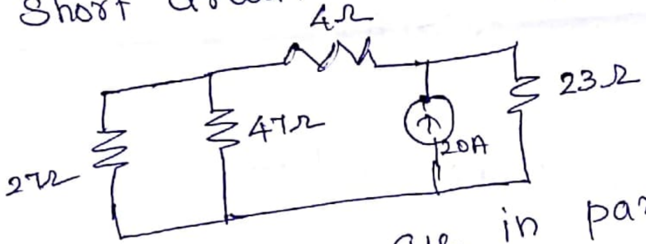
Apply current division rule

$$I_{23\Omega} = \frac{3.3 \times 27}{23+4+23} =$$

$\boxed{I_{23\Omega} = 1.65\,A}$ due to 200V source

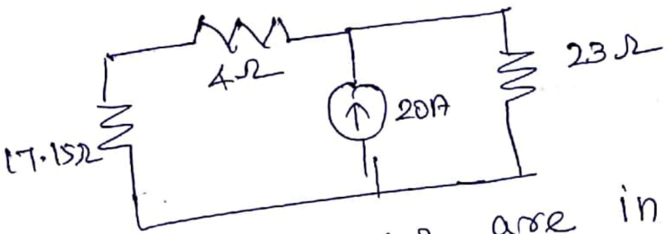
Case ii

Short circuit the voltage source

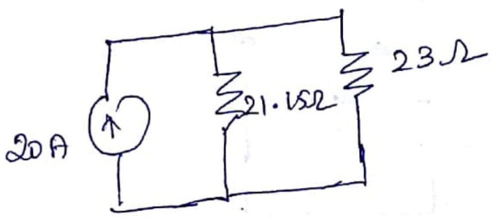


47Ω & 27Ω are in parallel

$$\frac{27 \times 47}{27+47} = 17.15\Omega$$



17.15Ω and 4Ω are in series $\quad \cancel{17.5} + \; 17.15 + 4 = 21.15\Omega$



Current through 23Ω resistor due to 20A current source is

$$I_{23\Omega} = \frac{20 \times 21.15}{21.15 + 23}$$

$$\boxed{I_{23\Omega} = 9.58A}$$ due to current source.

Total current through 23Ω resistor

= current through 23Ω resistor ~~by~~ due to voltage source + Current source

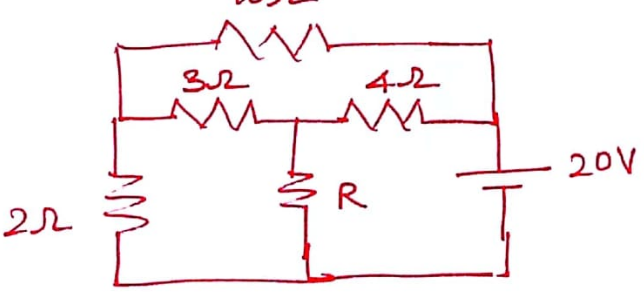
$= 1.65 + 9.58$

$$\boxed{I_{23\Omega} = 11.23\ A} \longrightarrow (2)$$

eqn (1) = (2)

Hence superposition theorem is verified.

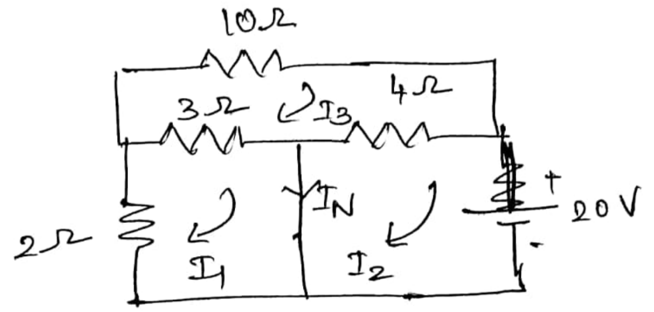
12. Obtain the Norton's equivalent circuit across the unknown resistor 'R'. (13)



Sol

Step 1

Remove load resistor



To find I_N

By KVL

Loop 1 $2I_1 + 3(I_1 - I_3) = 0$

$2I_1 - 3I_3 = 0 \rightarrow (1)$

Loop 2 $4(I_2 - I_3) = -20$

$4I_2 - 4I_3 = -20 \rightarrow (2)$

Loop 3 $10I_3 + 3(I_3 - I_1) + 4(I_3 - I_2) = 0$

$-3I_1 - 4I_2 + 17I_3 = 0 \rightarrow (3)$

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

$I_1 = -1.07A$

$I_2 = -6.78A$

$I_3 = -1.78A$

$$I_N = I_1 - I_2$$

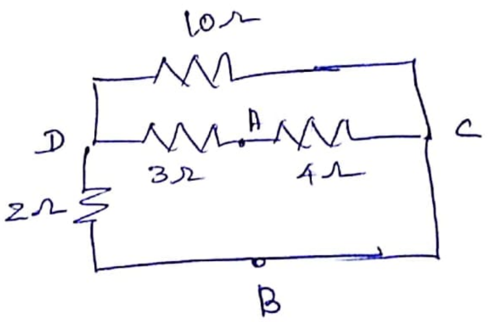
$$= -1.07 - (-6.78)$$

$$\boxed{I_N = 5.72\ A}$$

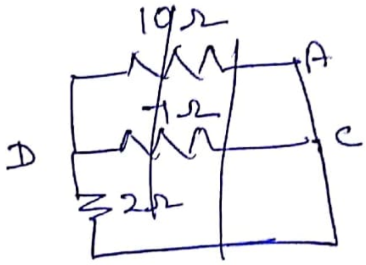
Step 2

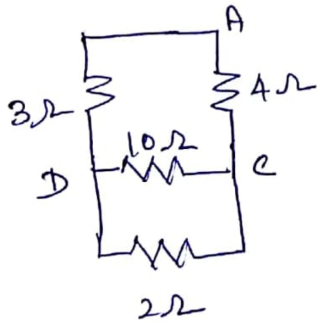
To find R_{Th}

Short circuit the voltage source, open circuit the current source and Remove load resistor.



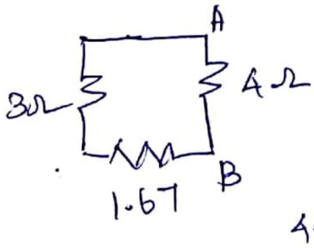
⇒





2Ω & 10Ω are in parallel

$$\frac{2 \times 10}{2 + 10} = 1.67\Omega$$



3Ω & 1.67Ω ⇒ Series

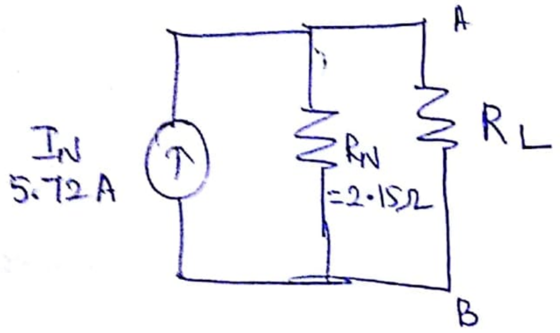
$$3 + 1.67 = 4.67\Omega$$

⇒ 4.67Ω & 4Ω ⇒ parallel

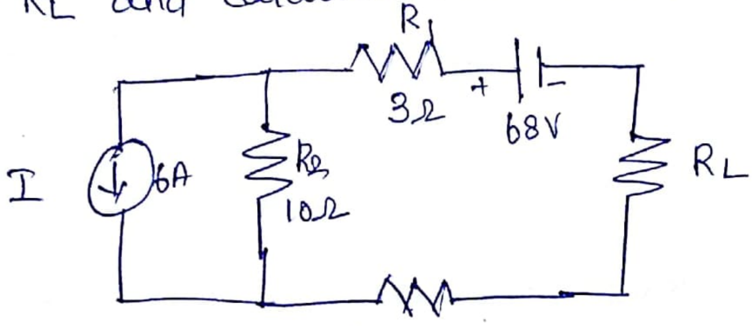
$$\frac{4.67 \times 4}{4.67 + 4} = 2.15\Omega$$

Step 3

Norton's equivalent circuit

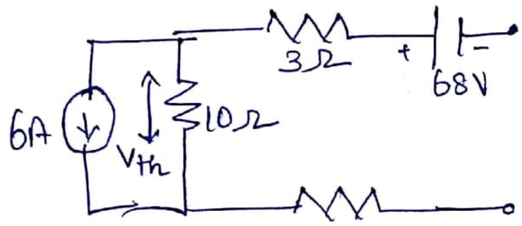


13) Find the value R_L in the fig. for maximum power to R_L and calculate the maximum power.



Sol

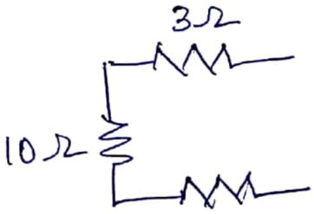
To find the V_{th}, Open the load resistance R_L.



$V_{th} = IR$

$V_{th} = 6(10) = 60V$

To find R_{th} : Open current source, short circuit the Voltage source and open R_L



$\Rightarrow$ 3Ω, 10Ω & 2Ω are connected in series

$3 + 10 + 2 = 15\Omega$

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

$$P_{max} = \frac{(V_{Th})^2}{4R_{Th}} = \frac{(60)^2}{4\times15} = \frac{3600}{60}$$

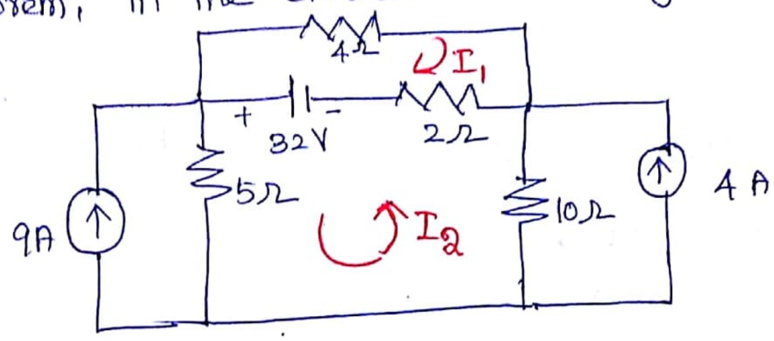
$$\boxed{P_{max} = 60W}$$

Result:

$R_L = 15\Omega$

$P_{max} = 60W$

14. Estimate the current through 5Ω resistor using superposition theorem, in the circuit shown in fig.



Sol

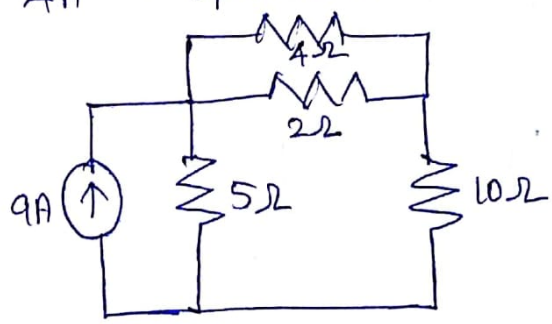
Case(i)

9A Current Source is active and

4A & 32V are inactive

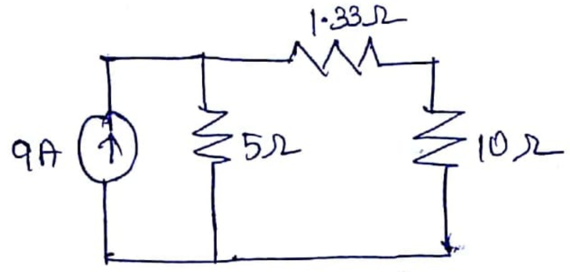
32V – Short circuit

4A – Open circuit



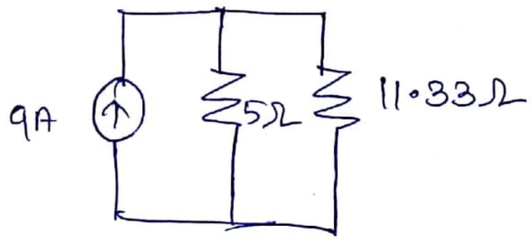
4Ω and 2Ω are connected in parallel

$$\frac{4\times2}{4+2} = \frac{8}{6} = 1.33\Omega$$



1.33Ω & 10Ω are connected in series

$$1.33 + 10 = 11.33\,\Omega$$



Current through 5Ω resistor ~~because~~ due to 9A source I'

Using current division rule,

$$I' = I_{5\Omega} = \frac{9 \times 11.33}{5 + 11.33}$$

$$= \frac{101.97}{16.33} = 6.24\text{ A}$$

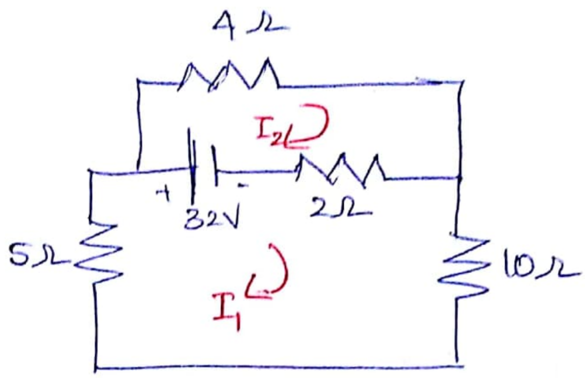
$$\boxed{I' = I_{5\Omega} = 6.24\text{A}}$$ Downwards

Case(ii)

32V Voltage source is active

9A & 4A Current sources are inactive

9A & 4A ⇒ open circuit



Apply KVL,

loop 1,

$$5I_1 + 10I_1 + 2(I_1 - I_2) = -32$$

$$17I_1 - 2I_2 = -32 \longrightarrow (1)$$

loop 2,

$$4I_2 + 2(I_2 - I_1) = 32$$

$$-2I_1 + 6I_2 = 32 \longrightarrow (2)$$

$$I_1 = -1.306\text{ A}$$

$$I_2 = 4.89\text{ A}$$

Current through 5Ω resistor is I_1

$$I_{5\Omega} = I_1 = -1.306\text{ A} \quad \text{upwards}$$

Current through 5Ω resistor due to 32V voltage source is I''

$$\boxed{I'' = I_{5\Omega} = -1.306\text{ A}} \text{ upwards.}$$

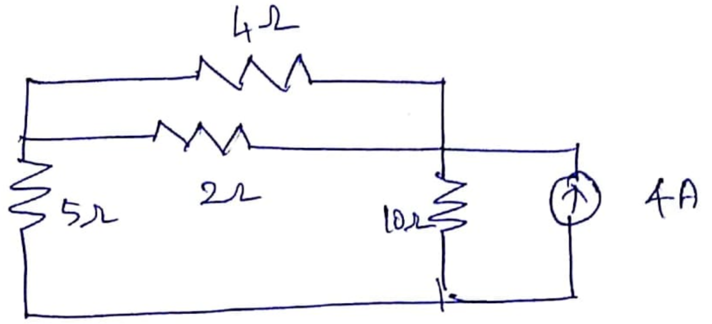
Case(iii)

4A current source is active

32V & 9A are inactive

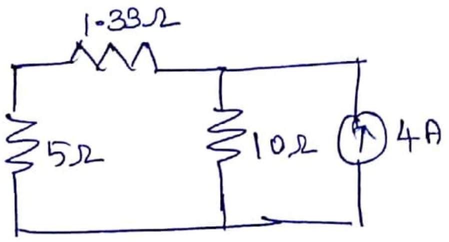
9A → open circuit

32V → Short circuit



4Ω & 2Ω are connected in parallel

$$\frac{4\times 2}{4+2} = \frac{8}{6} = 1.33\Omega$$



Using current division rule,

Current through 5Ω resistor due to 4A current source is I'

$$I''' = I_{5\Omega} = \frac{4\times 10}{5+10+1.33} = \frac{40}{16.33}$$

$$\boxed{I''' = I_{5\Omega} = 2.449A \text{ Downwards}}$$

Total current through 5Ω resistor $I = I' + I'' + I'''$

$$= 6.24 - 1.306 + 2.449$$

$$\boxed{I_{5\Omega} = 7.383A}$$

Result

Current through 5Ω resistor $I_{5\Omega} = 7.383\ A$