Sethupathi. K
212223040189

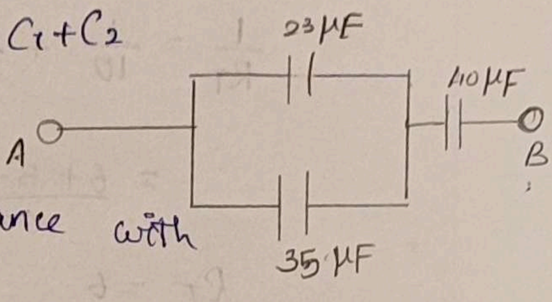
Part - A

1. Determine the equivalent capacitance of 23 μF, 35 μF and 40 μF are connected as shown below.

Step 1: Calculate the combined capacitance of the two capacitors in parallel

Capacitors in parallel - $C_{tot} = C_1 + C_2$

$C_{parallel} = 25 + 35 = 58 \mu F$



Step 2: Connect this combined capacitance with the final capacitor in series.

Capacitors in series: $\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$

$$\frac{1}{C_{tot}} = \frac{1}{58} + \frac{1}{40} = \frac{49}{1160}$$

Step 3: Rearrange for the total cappacitance

$$C_{tot} = \frac{1160}{49} = 23.673 = 24 \mu F \text{ (2s.f)}$$

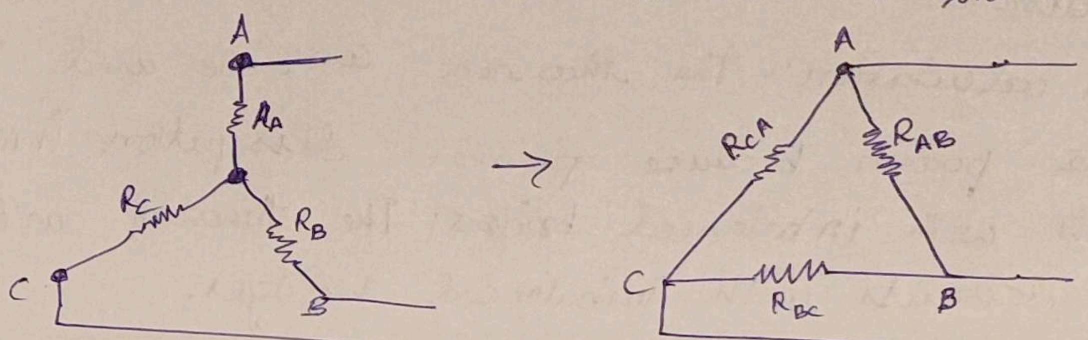
2. Express the equation to Convert star Connected resistances (R_1, R_2 and R_3) to delta connected resistances.

$$R_a = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

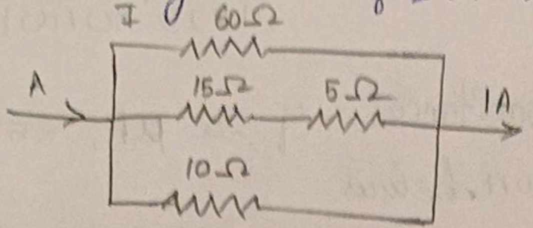
$$R_b = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

$$R_c = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3}$$

Three resistor R_A, R_B and R_C connected in star formation and its equivalent delta connection is shown below.



3. Find the magnitude of I in ampere.



When the Resistors 10, 15 and 60Ω are connected in parallel hence.

$$\frac{1}{R_T} = \frac{1}{10} + \frac{1}{20} + \frac{1}{60}$$

$$= \frac{6+3+1}{60} = \frac{1}{6}$$

$$R_T = 6$$

Current I_2 is

$$I = 1A \, \frac{6}{60}$$

$$= 0.1$$

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4. State Thevenin's theorem.

Thevenin's theorem is a fundamental principle in electrical circuit analysis. It state that any linear circuit regardless of its complexity, can be simplified into an equivalent circuit comprising a single voltage source and a series resistance.

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5. What is the limitation of the Superposition theorem?

Non-linear circuits: The theorem cannot be used for non linear circuits. which include those with diodes and transistors.

Power calculation:- The theorem can't be used to Calculate power because power dissipation is non linear

Circuits with inbalanced bridges: The theorem can't be used for circuits with imbalanced bridges.

6. Find the power consumption if 100 V is applied across a 200V, 100W bulb. ①

Solution

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

$$R = \frac{V^2}{P} = \frac{(200)^2}{100}$$

$$= 400\Omega$$

The power consumed is

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

$$R = \frac{V^2}{P} = \frac{100^2}{400}$$

$$R = 25W$$

7. Write down the expression of equivalent resistance for 'n' - the number of resistors in parallel connection.

For 'n' resistor connected in parallel, the equivalent resistance is given by,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$$

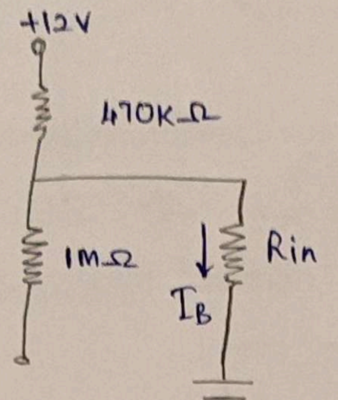
8. What is the conditions for maximum power transfer to the load?

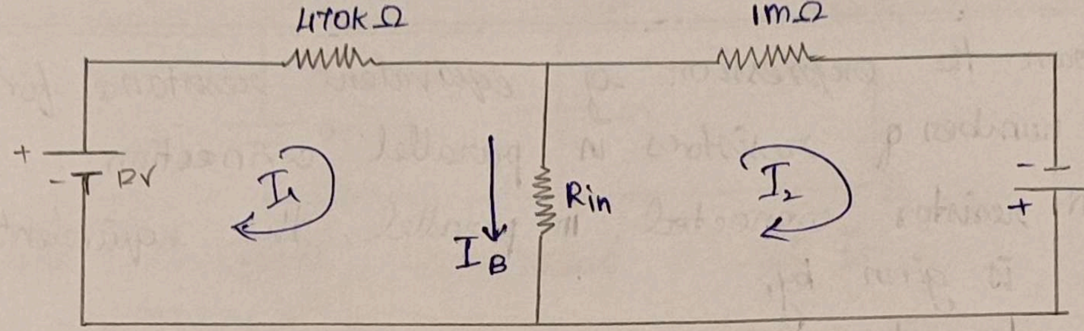
The maximum power transfer theorem states that to obtain maximum external power from a power source with internal resistance, the resistance of the load must equal the resistance of the source as viewed from its output terminal.

1

Part B - 13 Mark

1. In the circuit shown in the below, $I_B = 10\mu A$. Find the value of resistance Rin.





Assume that the loop current I_1, and I_2 are as indicated.

Given that $I_1 - I_2 = I_B = 10 \times 10^{-6}$ A

Applying KVL to the left loop, we get

$$12 - 470 \times 10^3 I_1 - (I_1 - I_2)\,Rin = 0$$

$$12 - 470 \times 10^3 I_1 - (10 \times 10^{-6})Rin = 0$$

$$10^{-5} Rin + 470 \times 10^3 I_1 = 12 \longrightarrow ②$$

Similarly, applying KVL to the right loop, we get

$$-1 \cdot \times 10^6 I_2 + I_2 + (I_1 - 12)\,Rin$$

$$-10^6 I_2 + 12 + 10 \times 10^{-6} Rin = 0$$

$$10^{-5} Rin - 10^6 I_2 = -12 \longrightarrow ③$$

① - ③

$$470 \times 10^3 I_1 + 10^6 I_2 = 24$$

$$0.47 I_1 + I_2 = 24 \times 10^{-6}$$

$$1.47 I_1 = 34 \times 10^{-6}$$

$$I_1 = 23.13 \times 10^{-6} A$$

From (2)

$$10^{-5} R_{in} = 12 - 470 \times 10^{3} I_1$$

$$= 12 - 470 \times 10^{3} \times 23.13 \times 10^{-6}$$

$$= 12 - 10.87$$

$$= 1.13$$

$$R_{in} = 113000\ \Omega$$

$$= 113\ k\Omega$$

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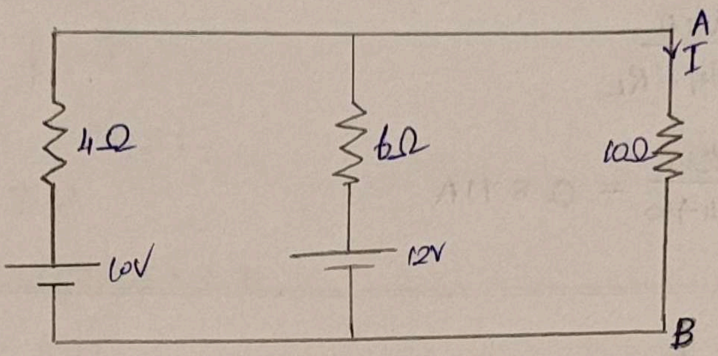
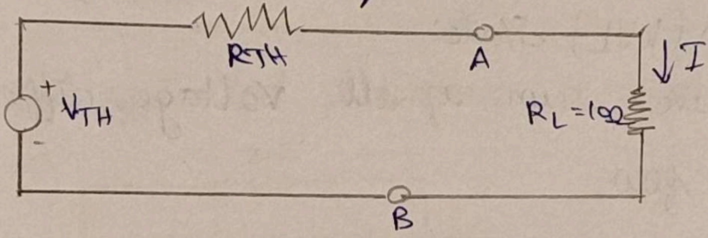
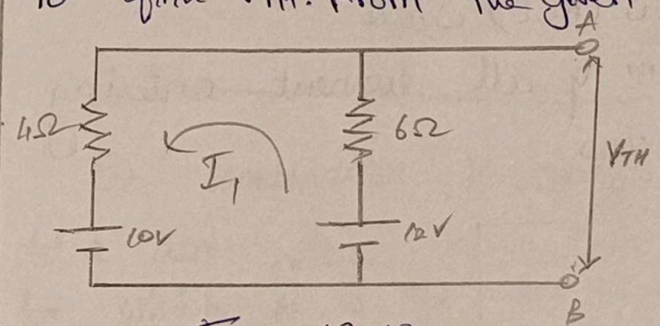
2. Calculate the current flowing through 10-ohm resistor using Thevenin's theorem.



The Thevenin's equivalent circuit is



To find V_{TH}. From the given circuit disconnect $R_L = 10\ \Omega$



$$I = \frac{12-10}{4+6} = 0.2\,A$$

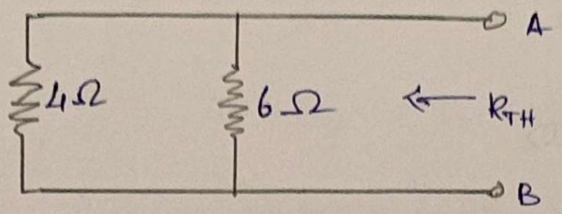
$$V_{TH} = V_{AB}$$

$$= 6I - 12$$

$$= 6 \times 0.2 - 12$$

$$= -10.8 \text{ volts}$$

To calculate R_{TH}: From the above circuit, remove the Source The resultant circuit is



$R_{TH} = R_{AB} = 4 \| 6$

$= \frac{4 \times 6}{4+6} = 2.4\Omega$

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

$= \frac{10.8}{2.4+10} = 0.871A$

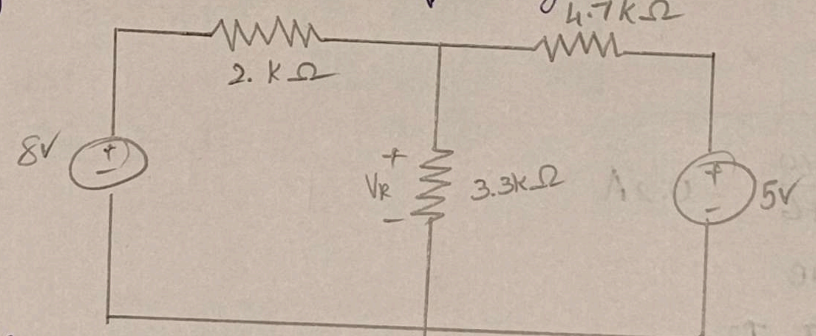
3.
(i) State Kirchoffs Laws

Kirchhoff's Voltage law (KVL) State:

* The algebraic sum of all voltage differences around any closed loop is zero.

Kirchhoff's ~~Voltage~~ Current Law (KCL) State

* The algebraic sum of all current entering and exiting a node must equal zero.



(ii) Calculate the voltage across a 33 kohm resistor (Vo)

$$-8+2I_1 \quad -3.3I_1 - 3.3I_2 = 0$$

$$5.3I_1 - 3.3I_2 = 8 \rightarrow ①$$

$$4.7I_2 + 5 + 3.3I_2 - 3.3I_1 = 0$$

$$-3.3I_1 + 8I_2 = -5 \rightarrow ②$$

$I_1 = 1.5\ mA$

$I_2 = -0.0031\ mA$

$I_R = I_1 - I_2$

$= 1.5031$

$V_R = IR$

$= 1.503 \times 3.3$

$= 4.9V$

$V_R \simeq 5V$

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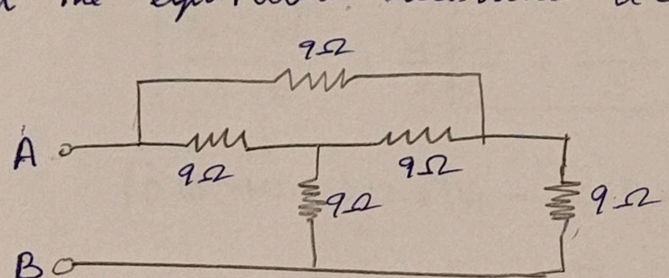
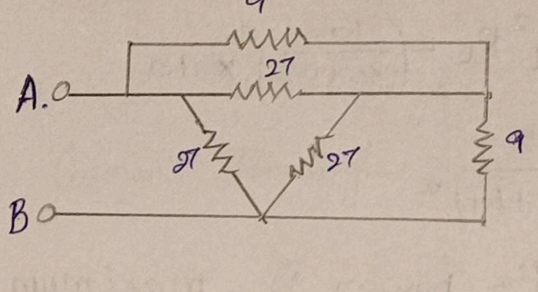
4. Find the equivalent resistance across A and B.

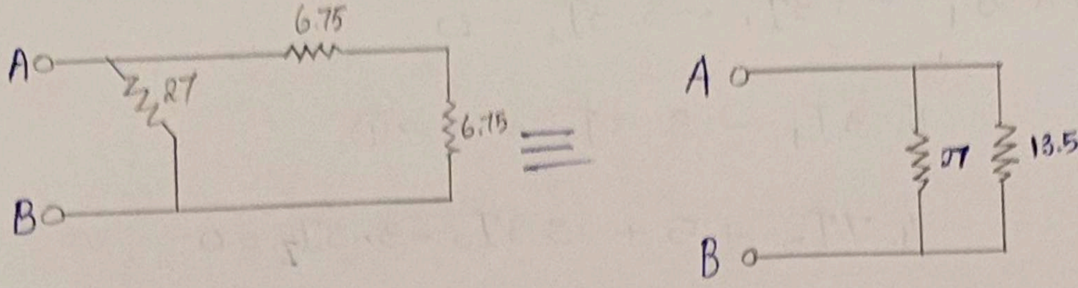


The combination is neither series nor parallel. There is delta and star connection. Converting the star connection for which N is the star point and redrawing the circuit, we get.



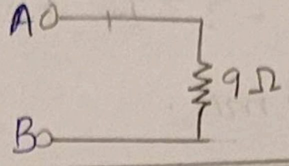
$$\frac{27 \times 9}{27+9} = \frac{27 \times 9}{36}$$

$$= 6.75\Omega$$

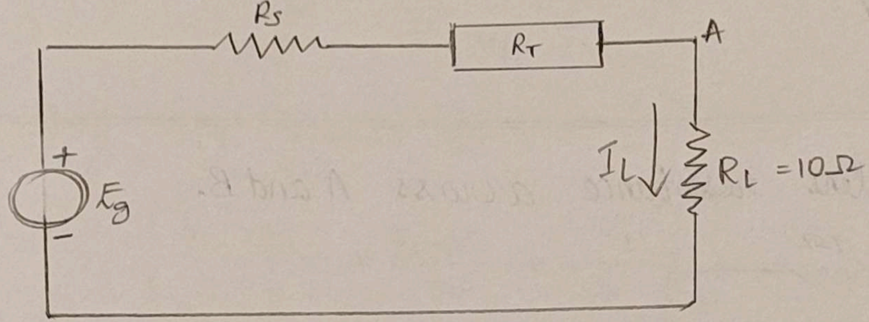


$$R_{AB} = 27 \| 13.5 = \frac{27 \times 13.5}{27 + 13.5}$$

$$= 9\Omega$$



5. A network having Thevenin's equivalent of voltage E_g in series with R_g supplies a load of R_L through a transmission line of resistance R_T. If $E_g = 100$ volts, $R_g = 20\Omega$ and $R_L = 10\Omega$, determine the value R_T and the power transferred to the load is the maximum.



$$I_L = \frac{E_g}{R_{total}}$$

$$= \frac{E_g}{R_g + R_L + R_T}$$

$$= \frac{100}{20 + 10 + R_T}$$

$$= \frac{100}{30 + R_T} \text{ Amps}$$

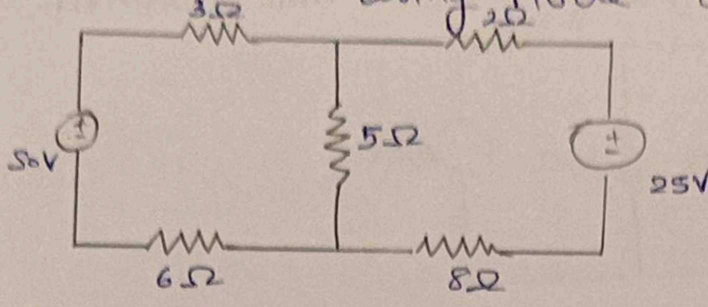
Power transferred to RL $= I_L^2 R_L = \left(\frac{100}{30 + R_T}\right)^2 \times 10$

$$P = \frac{10^5}{(30 + R_T)^2}$$

It is seen that when the power is maximum, RT must be equal to zero

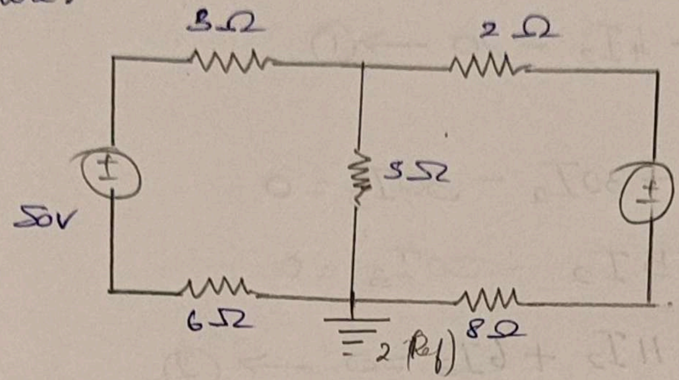
$$P_{max} = \frac{10^5}{(30+0)^2} = 111 \text{ watts.}$$

6. Determine all branch currents and the voltage across the 5Ω resistor using node analysis.



Solution

The circuit is labeled by nodes which is as shown in figure.



Apply KCL to node V_1

$$\left[\frac{V_1-50}{3+6}+\frac{V_1-25}{2+8}+\frac{V_1}{5}\right]=0$$

$$[0.111+0.1+0.2]V_1-5.556-2.5=0$$

$$[0.4111]V_1=8.056$$

$$V_1=19.59$$

Current through 3Ω and 6Ω resistor is

$$I_3=\frac{V_1-50}{3+6}=\frac{19.59-50}{3+6}=-3.37A$$

Current through 2Ω and 8Ω resistor is

$$I_5=\frac{V_1-25}{2+8}=\frac{19.59-25}{2+8}=-0.541A$$

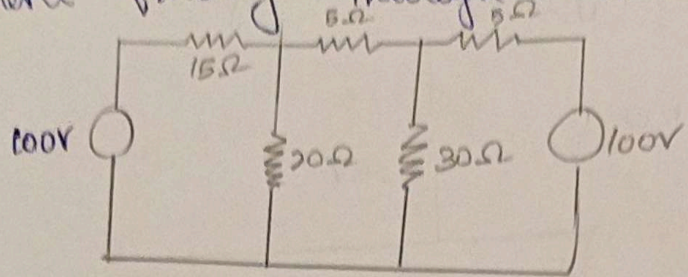
Current through 5Ω resistor is

$$I_5=\frac{8.056}{5}=3.918A$$

Voltage across 5Ω resistor is

$V=I_5\times5=3.918\times5=19.59V$

7. Using the mesh Current Method, how can you calculate the current flowing through a 30 - ohm resistor?



$$-100 + 15I_1 + 20I_1 - 20I_2 = 0$$

$$35I_1 - 20I_2 = 100$$

$$7I_1 - 4I_2 = 20 \longrightarrow ①$$

$$-20I_1 + 5I_2 + 30I_2 - 30I_3 = 0$$

$$20I_1 + 55I_2 - 30I_3 = 0$$

$$20I_1 - 11I_2 + 6I_3 = 0 \longrightarrow ②$$

$$30I_3 - 30I_2 + 5I_3 + 100 = 0$$

$$-30I_2 + 35I_3 + 100 = 0$$

$$30I_2 - 35I_3 = 100 \longrightarrow ③$$

$$\begin{bmatrix} 7 & -4 & 0 \\ 4 & -11 & 6 \\ 0 & 30 & -35 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \\ 100 \end{bmatrix}$$

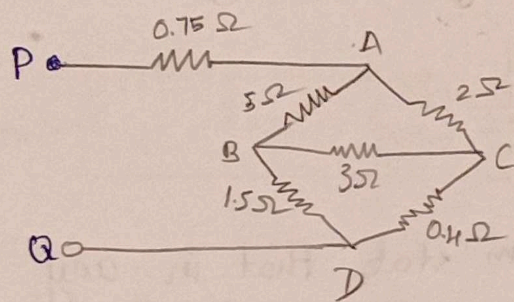
$$I_1 = 1.94$$

$$I_2 = -1.6$$

$$I_3 = -4.22$$

$$I_2 - I_3 = 2.62$$

8. Find the Effective Resistances between P and Q. Also Find the current supplied by a 10V battery connected to PQ.



To find P

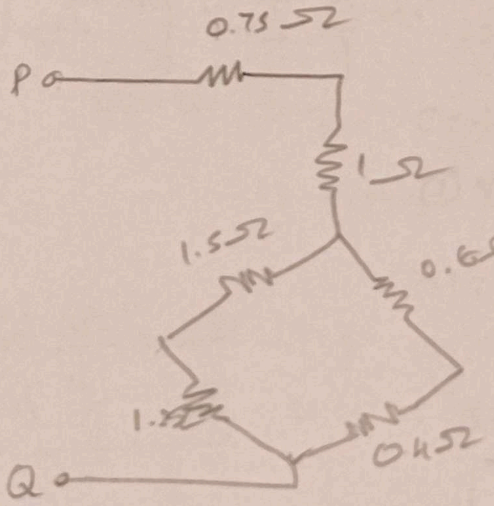
PQ

Delta → Star

$R_A = 1\Omega = \frac{10}{10} = 1$

$R_B = \frac{5\times3}{10} = \frac{15}{10} = \frac{3}{2} = 1.5\Omega$

$R_C = \frac{3\times2}{10} = \frac{6}{10} = 0.6\Omega$



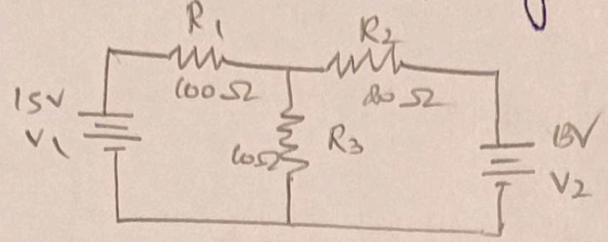
$\frac{1}{R} = \frac{1}{3} + \frac{1}{1} = \frac{1+3}{3} = \frac{3}{4} = 0.75\Omega$

$R_{PQ} = 0.7\cdot\Omega + 1 + 0.75 = 2.50\Omega$

$I = \frac{V}{R} = \frac{10}{25} = 4A$

Part - C

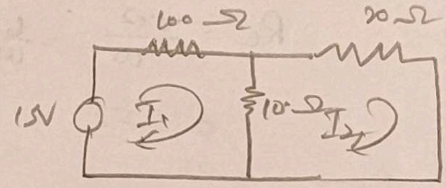
1. State Superposition Theorem. Using the Superposition theorem determine the current flowing through resistor R_1.



The Superposition theorem state that in any linear directional circuit having more than one independent source, the response in any one of the element is equal to algebric sum of the response caused by individual source while rest of the sources are replaced by their internal resistance.

Considering 15V source alone.

loop I_1



$$100 I_1 + 10 (I_1 - I_2) = 15$$

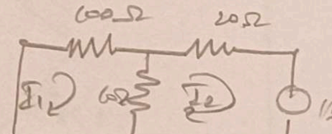
$$100 I_1 + 10 I_1 - 10 I_2 = 15$$

$$110 I_1 - 10 I_2 = 15 \rightarrow ①$$

loop I_2

$$20 I_2 + 10 (I_2 - I_1) = 0$$

$$-I_1 + 30 I_2 = 0 \rightarrow ②$$



$$\begin{bmatrix} 110 & -10 \\ -10 & 30 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 15 \\ 0 \end{bmatrix}$$

$I_1 = 0.14 A$ $\quad I_2 = 0.046 A$

loop I_2 :-

$$20 I_2 + 10 (I_2 - I_1) = 13$$

$$20 I_2 + 10 I_2 - 10 I_1 = 13$$

$$-10 I_1 + 30 I_2 = 13 \rightarrow ②$$

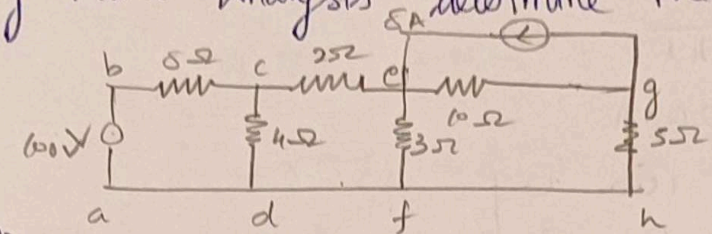
$$\begin{bmatrix} 110 & -10 \\ -10 & 30 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 13 \end{bmatrix}$$

$I_1 = 0.0406$ $\quad I_2 = \cancel{0.0}\ 0.4408$

When 15 and 13V active

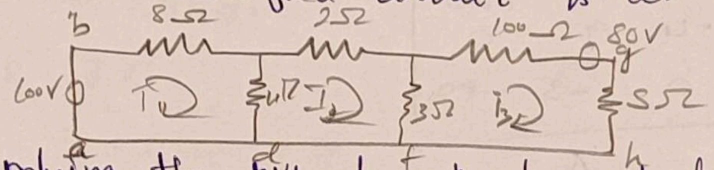
$$I_{R100\Omega} = I_{15V} - I_{13V} = (0.14 - 0.04)\,A = 0.1\,A$$

2. Using Mesh Analysis determine the current I_x.



Solution

For the given circuit there is current source to apply KVL current Source has to be converted into voltage source, the modified circuit is as shown in Figure 58.



Applying the KVL for the loop abeda

$$8i_1 + 4(i_1 - i_2) - 100 = 0$$

$$12i_1 - 4i_2 = 100$$

for the loop eefdc

$$2i_2 + 3(i_2 - i_3) + 4(i_2 - i_1) = 0$$

$$-4i_1 - 9i_2 - 3i_3 = 0$$

for the loop eghfc

$$10i_3 + 5i_3 + 3(i_3 - i_2) + 80 = 0$$

$$0i_1 - 3i_2 + 18i_3 = -80$$

The three mesh equations are

$$12i_1 - 4i_2 + 0i_3 = 100$$

$$-4i_1 + 9i_2 - 3i_3 = 0$$

$$0i_1 - 3i_2 + 18i_3 = -80$$

$$\Delta = \begin{vmatrix} 12 & -4 & 0 \\ -4 & 9 & -3 \\ 0 & -3 & 18 \end{vmatrix}$$

$$= 1836 - 288 = 1548$$

$$i_1 = \frac{\begin{vmatrix} 100 & -4 & 0 \\ 0 & 5 & -3 \\ -80 & -3 & 18 \end{vmatrix}}{\Delta}$$

$$= \frac{14340}{1548}$$

$$= 9.26\ A$$

$$i_2 = \frac{\begin{vmatrix} 12 & 100 & 0 \\ -4 & 0 & -3 \\ 0 & -80 & 18 \end{vmatrix}}{\Delta}$$

$$= \frac{4320}{1548} = 2.79A$$

$$i_3 = \frac{\begin{vmatrix} 12 & -4 & 100 \\ -4 & 9 & 0 \\ 0 & -3 & -80 \end{vmatrix}}{\Delta}$$

$$= \frac{-6160}{1548} = -3.97A$$

$\therefore i_1 = 9.26A \quad i_2 = 2.79A \quad i_3 = -3.97A$