Ohm's Law

Relation between V, I & R (ohm's law)

All the electrical Elements are satisfy this ohm's law

use of ohm's law → provide the relation between V, I, & R.

Statement:

At Constant temperature, the ratio between potential difference (V) across the two ends of the conductor and current through it, is constant.

$$\boxed{R = \frac{V}{I}}$$ @ Constant temperature.

Other forms of law,

$$\boxed{R = \frac{V}{I}, \quad I = \frac{V}{R} \quad (or) \quad V = IR}$$

@ Constant temperature

Kirchoff's Law

1) Kirchoff's current law (KCL)

2) Kirchoff's Voltage law (KVL)

KCL [Kirchoff's Current Law]

→ Mesh current law

K: Current cannot be stored at any point in a circuit

Current → Move (or) flow of charges.

Entering current (or) incoming current } = { leaving current (or) outgoing current.

(+) (-)

$$\boxed{\Sigma \text{ of incoming current} + \Sigma \text{ of outgoing current} = 0}$$

* The Amount of current entering to a point must leave the point.

Statement:

The Algebraic sum of the current meeting at a point is equal to zero.

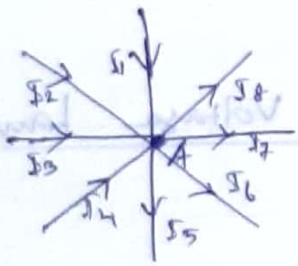
$\boxed{\Sigma I = 0} \Rightarrow \Sigma I_{EC} = \Sigma I_{LC}$

$$\boxed{\Sigma I_{EC} + \Sigma_{LC} = 0}$$

EC = Entering current

LC = Leaving current.

Explanation:



I_1, I_2, I_3 & I_4 = Entering current.

I_5, I_6, I_7, I_8 = Leaving current.

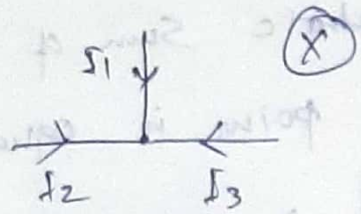
$$I_1 + I_2 + I_3 + I_4 = I_5 + I_6 + I_7 + I_8$$

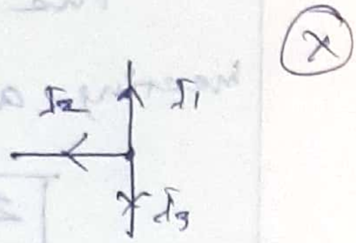
$$I_1 + I_2 + I_3 + I_4 - (I_5 + I_6 + I_7 + I_8) = 0$$

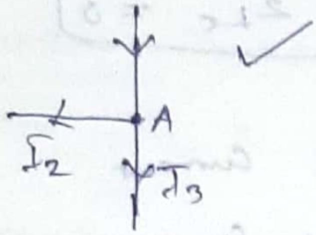
$$\Sigma I_{E.C} - \Sigma_{L.C} = 0$$

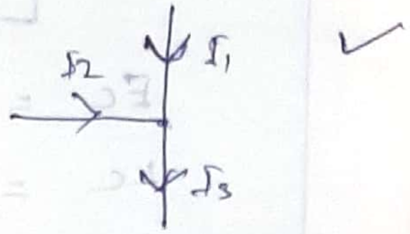
Condition:

* at least one path must be incoming current and at least one path must be leaving current.









Kirchhoff's Voltage Law.

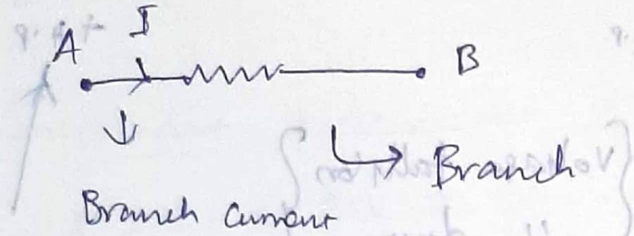
Statement:

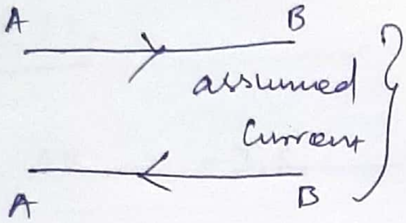
In a closed circuit, the Algebric Sum of product of current(I) and Resistance (R) (ΣIR) + Algebric sum of Voltage (ΣV) is equal to Zero.

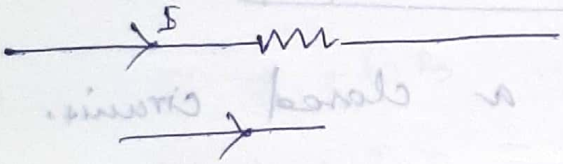
$$\boxed{\Sigma IR + \Sigma V = 0}$$

Sign of IR

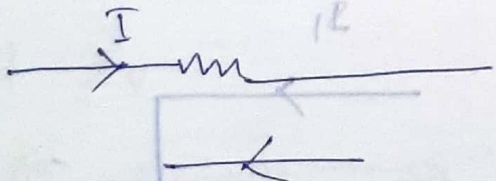
The Electric path between two point is called branch → current passing through branch is called Branch current.







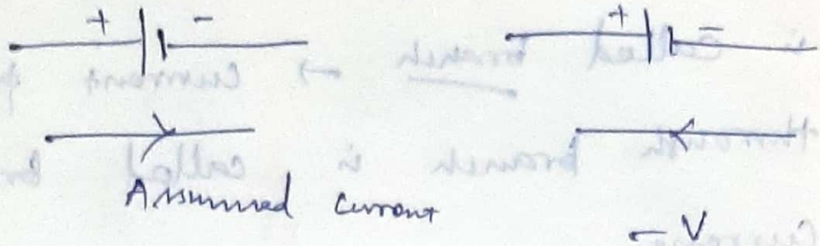
IR → positive sign (+) → (Voltage falls or drop.)



IR → Negative sign (−) → (Voltage Raise)

∴ IR sign is based on the assumed current.

Sign of V



−V

+V

+V (H.P)
↓
−V (L.P) { Voltage fall (or) '' drop. }

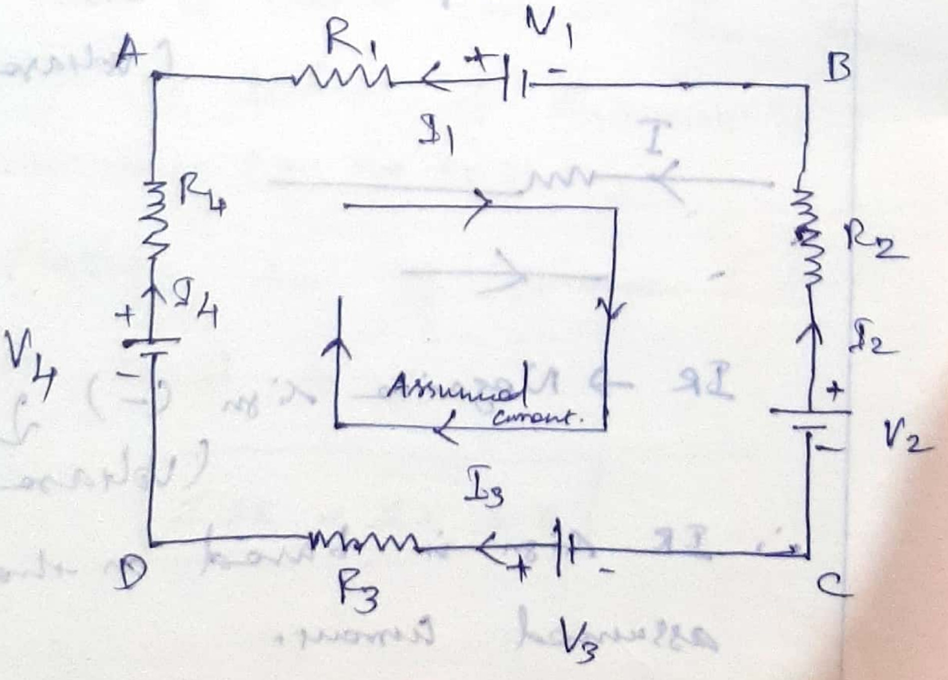
+ H.P
↑
− L.C

Voltage Raise

Explanation (or) proof:

Consider a closed circuit.

→ ABCDA.



Branches → AB, BC, CD, DA.

$\underbrace{I_1, I_2, I_3, I_4}$ → Branch current due to
↓ V_1, V_2, V_3 & V_4.

Direction of the current from positive of Battery.

* Important parameter of KVL are
$$\boxed{\sum IR \;\&\; \sum V}$$

Find $\underline{\sum IR}$

Branch AB → $-I_1R_1$ → Voltage Rise
" BC → $-I_2R_2$ → Voltage "
" CD → $+I_3R_3$ → " drop
" DA → $+I_4R_4$ → " "

$$\boxed{\sum IR = -I_1R_1 - I_2R_2 + I_3R_3 + I_4R_4}$$

Find $\sum V$

Branch AB → $+V_1$ → voltage drop
" BC → $+V_2$ → " "
" CD → $-V_3$ → " Rise
" DA → $-V_4$ → " "

$$\boxed{\Sigma V = V_1 + V_2 - V_3 - V_4}$$

KVL,

$$\Sigma IR + \Sigma V = 0$$

$$-I_1R_1 - I_2R_2 + I_3R_3 + I_4R_4 + V_1 + V_2 - V_3 - V_4 = 0$$

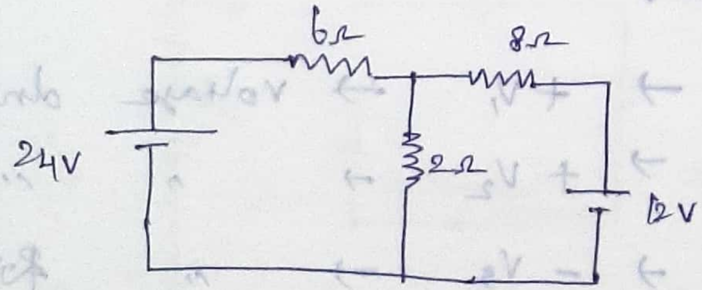
$$\boxed{I_3R_3 + I_4R_4 + V_1 + V_2 = I_1R_1 + I_2R_2 + V_3 + V_4}$$

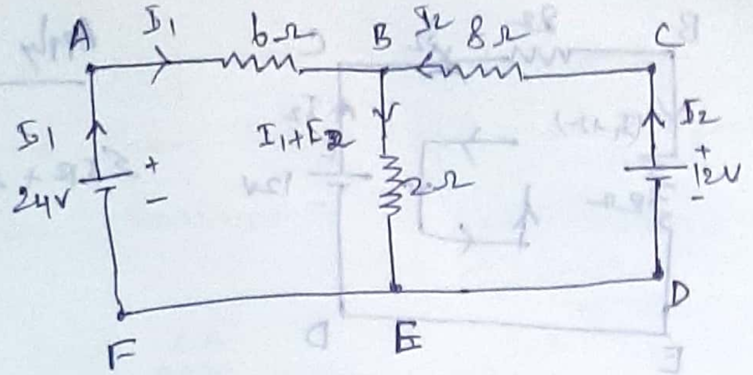
Sum of Voltage drop = Sum of Voltage Rise

$$\boxed{\Sigma V.D = \Sigma V.R}$$

Problem No: 1

By using Kirchoff's law, find the current supplied by the Batteries, and the current through 2Ω Resistor for the given circuit.





At point B ⇒ $I_1 + I_2 = I_3$

To find I_1 & I_2 we need two equations.

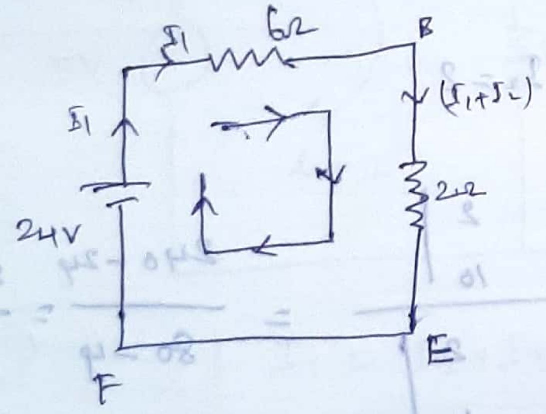
Divide the circuit in two.

1) ABEFA

2) BCDEB

3) ABCDEFA

Closed ckt



Apply KVL,

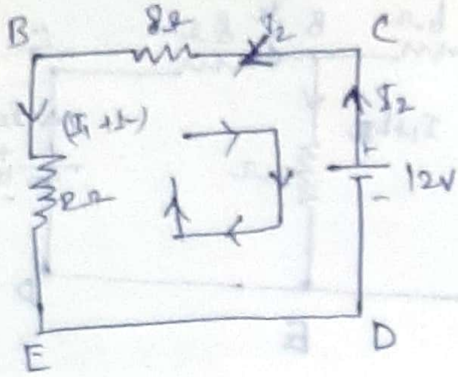
$$\boxed{\Sigma IR + \Sigma V = 0}$$

$$6I_1 + 2(I_1+I_2) + (-24) = 0$$

$$6I_1 + 2I_1 + 2I_2 = 24$$

$$8I_1 + 2I_2 = 24 \rightarrow (1)$$

closed ckt BCDEB



Apply KVL

$\Sigma IR + \Sigma V = 0$

$$-8I_2 + [-2(I_1+I_2)] + 12V = 0$$

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

$$-2I_1 - 10I_2 = -12V$$

$$2I_1 + 10I_2 = 12 \rightarrow ②$$

$$8I_1 + 2I_2 = 24$$

$$2I_1 + 10I_2 = 12$$

$I_1 = ?$ $I_2 = ?$

$$I_1 = \frac{\begin{vmatrix} 24 & 2 \\ 12 & 10 \end{vmatrix}}{\begin{vmatrix} 8 & 2 \\ 2 & 10 \end{vmatrix}} = \frac{240-24}{80-4} = \frac{216}{76} = 2.842\text{ A}$$

$\boxed{I_1 = 2.842\text{ A}}$

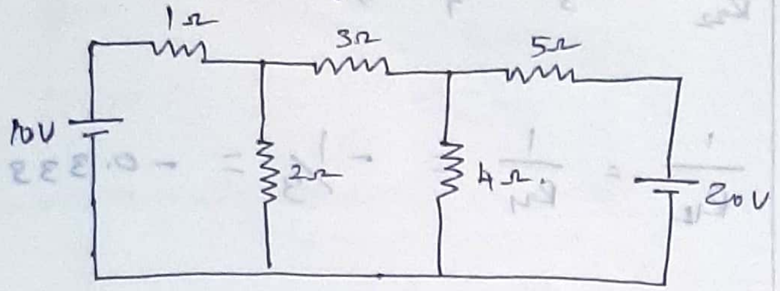
$$I_2 = \frac{\begin{vmatrix} 8 & 24 \\ 2 & 12 \end{vmatrix}}{\begin{vmatrix} 8 & 2 \\ 2 & 10 \end{vmatrix}} = \frac{96-48}{80-4} = \frac{48}{76} = 0.631\text{ A}$$

$\boxed{I_2 = 0.631\text{ A}}$

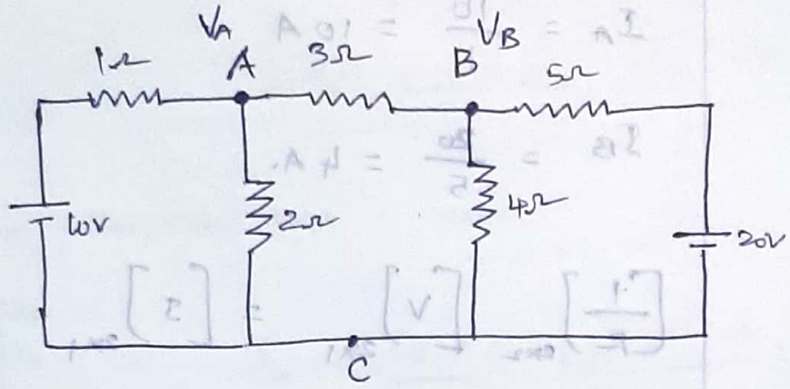
$\boxed{I_1 + I_2 = 3.473\text{ A}}$

Nodal Analysis

① Find the current through each resistors using nodal analysis method.



Solution:



$V_c = 0$

Number of Nodes = 3 = N.

$$\left[\frac{1}{R}\right]_{(N-1)\times(N-1)} \left[V\right]_{(N-1)\times 1} = I_{[(N-1)\times 1]}$$

$$\left[\frac{1}{R}\right]_{2\times 2} = \begin{bmatrix} \frac{1}{R_{11}} & \frac{1}{R_{12}} \\ \frac{1}{R_{21}} & \frac{1}{R_{22}} \end{bmatrix}$$

$$[V]_{2\times 1} = \begin{bmatrix} V_A \\ V_B \end{bmatrix} ; [I]_{2\times 1} = \begin{bmatrix} I_A \\ I_B \end{bmatrix}$$

$$\frac{1}{R_{11}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = 1 + 0.5 + 0.333 = 1.833$$

$$\frac{1}{R_{22}} = \frac{1}{3} + \frac{1}{4} + \frac{1}{5} = 0.333 + 0.25 + 0.2 = 0.783$$

$$\frac{1}{R_{12}} = \frac{1}{R_{21}} = -\frac{1}{3} = -0.333$$

$$I_A = \frac{10}{1} = 10\,A$$

$$I_B = \frac{20}{5} = 4\,A.$$

$$\left[\frac{1}{R}\right]_{2\times 2} [V]_{2\times 1} = [I]_{2\times 1}$$

$$\begin{bmatrix} 1.833 & -0.333 \\ -0.333 & 0.783 \end{bmatrix} \begin{bmatrix} V_A \\ V_B \end{bmatrix} = \begin{bmatrix} 10 \\ 4 \end{bmatrix}$$

Apply cramer's rule,

$V_A = 6.918\,V$

$V_B = 8.05\,V$

Current through $1\,\Omega$

$10 \xrightarrow{I_1} V_A$

$$I_1 = \frac{10 - V_A}{1} = \frac{10 - 6.918}{1} = 3.08\,A$$

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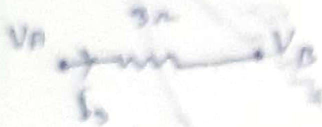
Current through 2Ω

$$I_2 = \frac{V_A - V_C}{2} = \frac{6.918}{2} = 3.459\,A$$

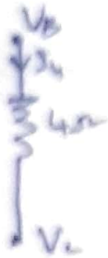
Current through 3Ω



$$I_3 = \frac{V_A - V_B}{3} = \frac{6.918 - 8.05}{3}$$

$\boxed{\cancel{V_{3} = 0.382A}}$ $\boxed{I_3 = -0.37A}$

Current through 4Ω



$$I_4 = \frac{V_B - V_C}{4} = \frac{8.05 - 0}{4} = 2.01A$$

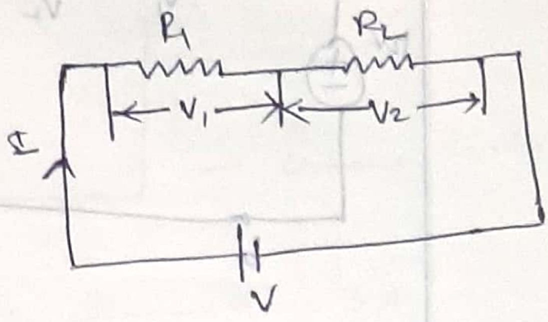
$\boxed{I_4 = 2.012A}$

Current through 5Ω

$$I_5 = \frac{V_B - 20}{5} = \frac{8.05 - 20}{5} = 2.389$$

Voltage + current division Rule

Voltage division Rule

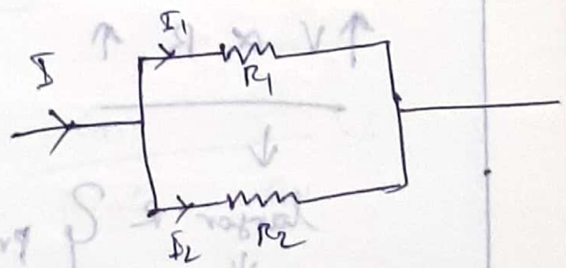


$$V_1 = \frac{\text{Total voltage} \times \text{corresponding Resistance}}{\text{Sum of the resistance}}$$

$$V_1 = \frac{V \times R_1}{R_1 + R_2}$$

$$V_2 = \frac{V \times R_2}{R_1 + R_2}$$

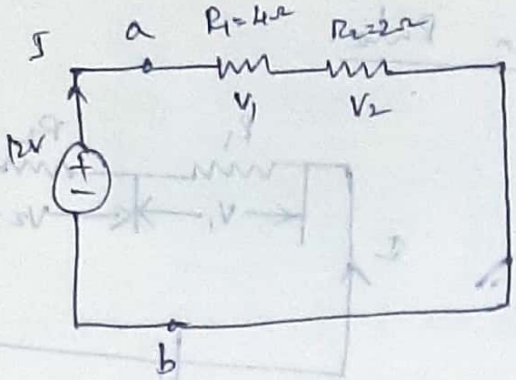
Current division Rule.



$$I_1 = \frac{\text{Total current} \times \text{opposite Resistance}}{\text{Sum of the resistance}}$$

$$I_1 = \frac{I \times R_2}{R_1 + R_2} \quad ; \quad I_2 = \frac{I\,R_1}{R_1 + R_2}$$

Series Resistors & Voltage Division:



→ Current same
voltage different

→ Voltage divider

$$V_1 = \frac{R_1}{R_1+R_2} \times V = \frac{4}{4+2} \times 12 = 8V$$

$$V_2 = \frac{R_2}{R_1+R_2} \times V = \frac{2}{4+2} \times 12 = 4V$$

For N - Resistors.

$$V_n = \frac{R_n}{R_1+R_2+\dots R_N} \times V$$

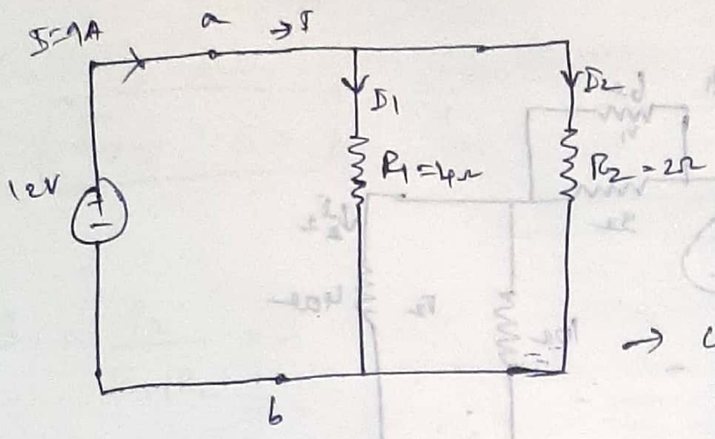
$$\uparrow V \propto R \uparrow$$

↓

larger R
↓
larger V

} principle of Voltage Division.

parallel Resistors & current Divisions



Current different

Voltage same

→ current divider

$$I_1 = \frac{R_2}{R_1+R_2} \times I = \frac{2}{4+2} \times 9 = 3A$$

$$I_2 = \frac{R_1}{R_1+R_2} \times I = \frac{4}{4+2} \times 9 = 6A$$

$$R_{eqn} = \frac{R_1 R_2}{R_1+R_2} = \frac{4\times 2}{4+2} = \frac{8}{6} = 1.333\Omega$$

$$V = IR \Rightarrow I = V/R = \frac{12}{1.333} = 9A$$

$$\boxed{I = \frac{Q}{t}, \quad V = \frac{J}{Q}}$$

$$\boxed{1/R = G}$$

$$I_n = \frac{G_1}{G_1+G_2+\dots G_N} \times I$$

$$\downarrow I \propto \frac{1}{R\uparrow}$$

↓

larger R

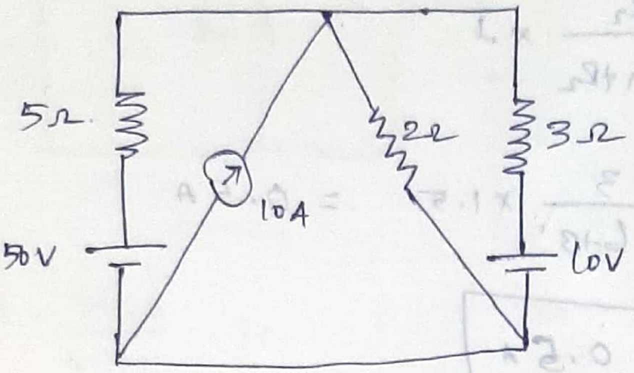
↓

smaller I

} Principle of current division

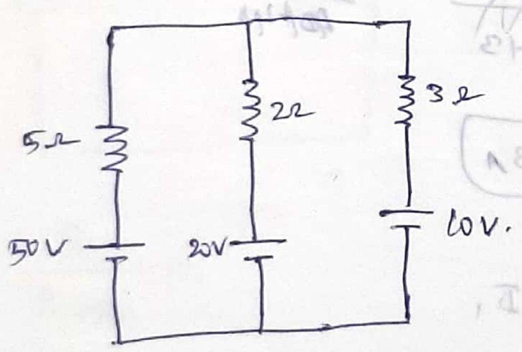
Source Transformation

1) Using source transformation, find the power delivered by the 50V voltage source.



Solution:

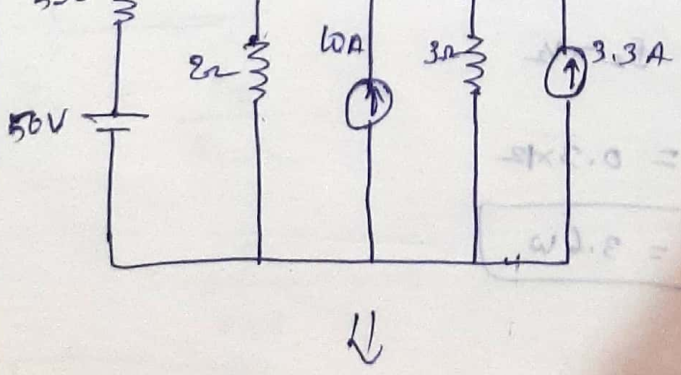
→ Convert the current source into voltage source.



$V = IR$

$= 10 \times 2$

$= 20\,V$

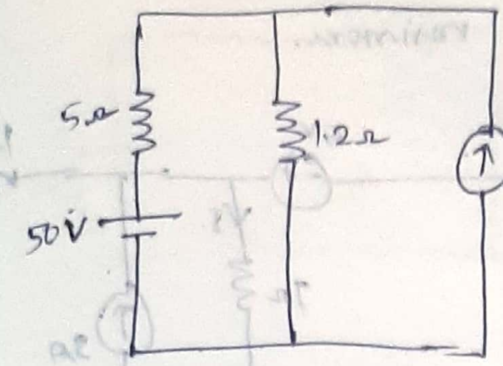


$I = V/R$

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

$I = \frac{10}{3} = 3.33$

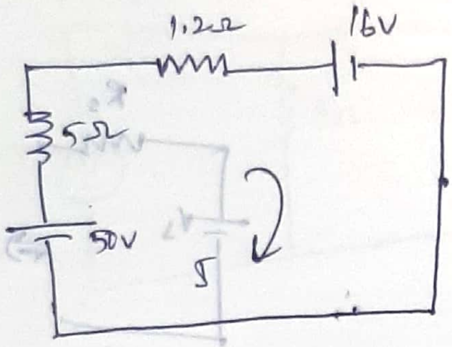
$10 + 3.33A = 13.33A$



$R_{eq} = \frac{10 \times 3}{10 + 3}$

$= 1.2\Omega$

⇓



$V = IR$

$= 13.33 \times 1.2$

$= 16V$

Apply KVL to the loop.

$50 - 5I - 1.2I - 16 = 0$

$34 - 6.2I = 0$

$34 = 6.2I$

$I = \frac{34}{6.2} = 5.483A$

$\boxed{I = 5.483A}$

Power delivered by the 50V Source $= VI$

$= 50 \times 5.483$

$\boxed{P = 274.19\,W}$

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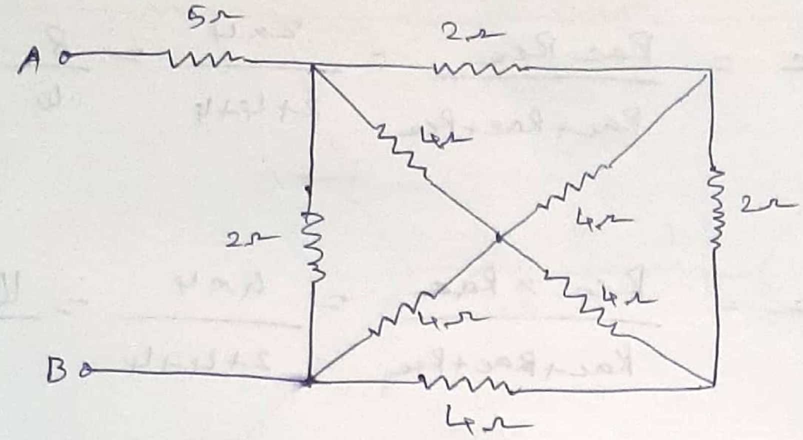
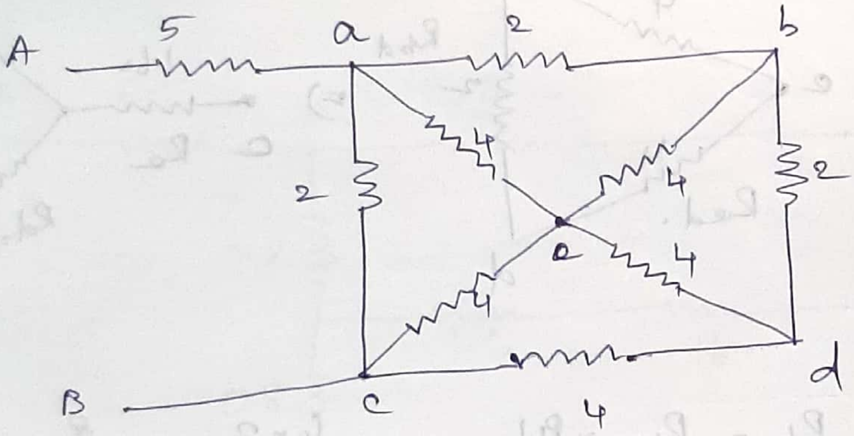
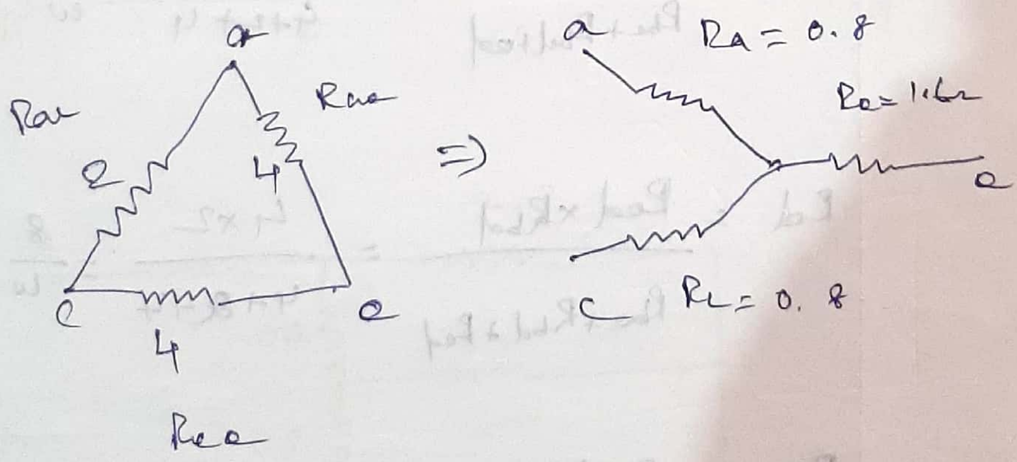
8 Use delta - star conversion, find resistance between terminal A & B.



Solution.





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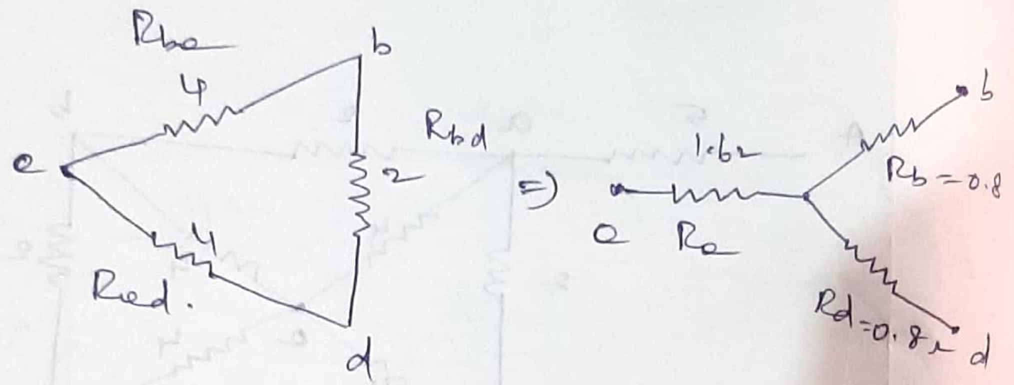
$$R_a = \frac{R_{ac} \times R_{ae}}{R_{ac} + R_{ae} + R_{ce}} = \frac{2 \times 4}{2+4+4} = \frac{8}{10} = 0.8\,\Omega$$

$$R_c = \frac{R_{ac} R_{ce}}{R_{ac} + R_{ae} + R_{ce}} = \frac{2 \times 4}{2+4+4} = \frac{8}{10} = 0.8\,\Omega$$

$$R_e = \frac{R_{ce} \times R_{ae}}{R_{ac} + R_{ae} + R_{ce}} = \frac{4 \times 4}{2+4+4} = \frac{16}{10} = 1.6\,\Omega$$

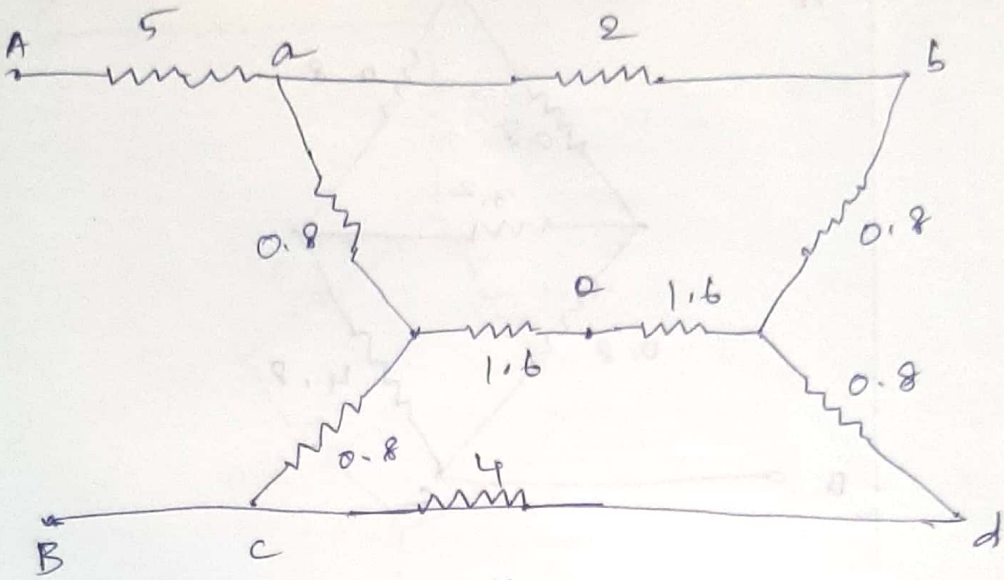


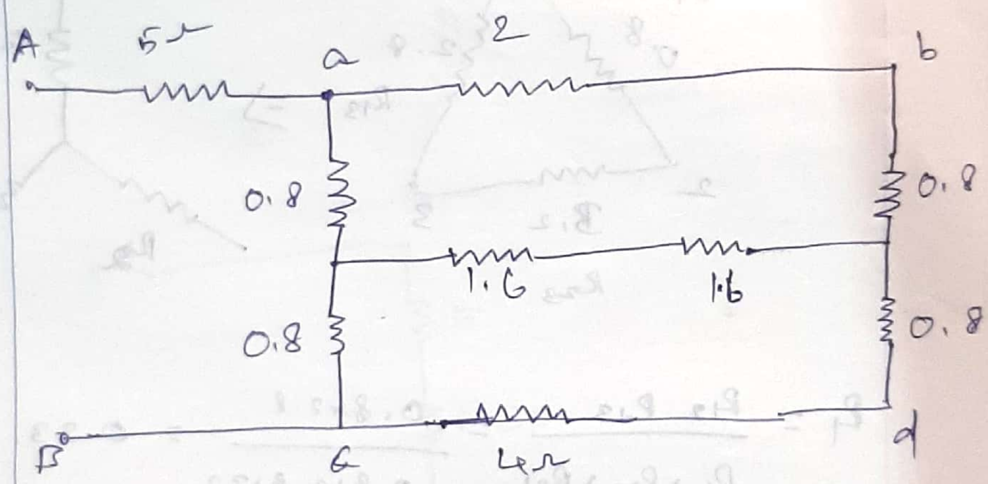
$$R_b = \frac{R_{be} \times R_{bd}}{R_{be} + R_{bd} + R_{ed}} = \frac{4 \times 2}{4+2+4} = \frac{8}{10} = 0.8\,\Omega$$

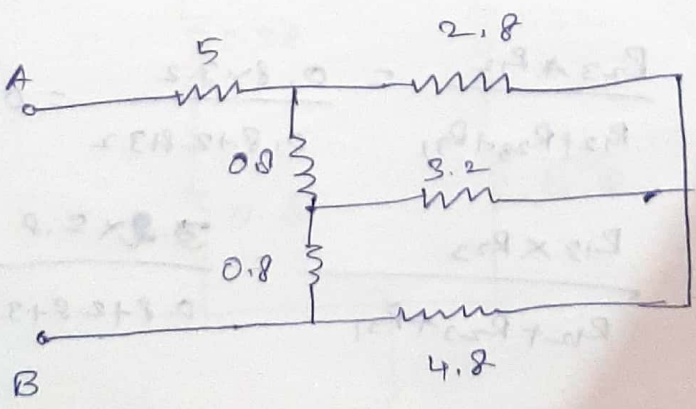
$$R_d = \frac{R_{ed} \times R_{bd}}{R_{be} + R_{bd} + R_{ed}} = \frac{4 \times 2}{4+2+4} = \frac{8}{10} = 0.8\,\Omega$$

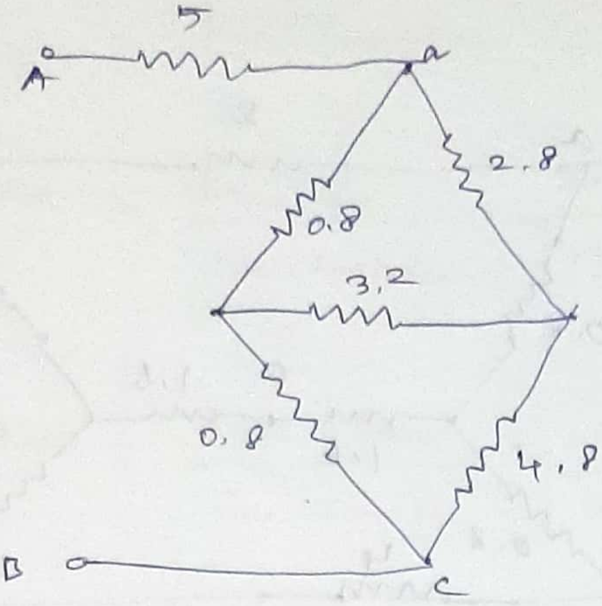
$$R_e = \frac{R_{ed} \times R_{be}}{R_{be} + R_{bd} + R_{ed}} = \frac{4 \times 4}{4+2+4} = \frac{16}{10}$$

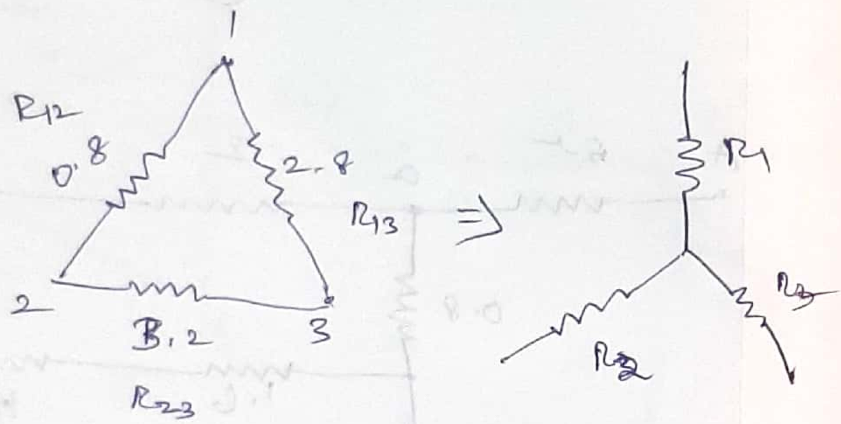
$$= \frac{1.6}{10}$$


A
5
a
2
b
0.8
0.8
0
1.6
1.6
0.8
0.8
4
B
c
d


A
5Ω
a
2
b
0.8
0.8
1.6
1.6
0.8
0.8
B
c
4Ω
d


5
2.8
A
0.8
3.2
0.8
4.8
B

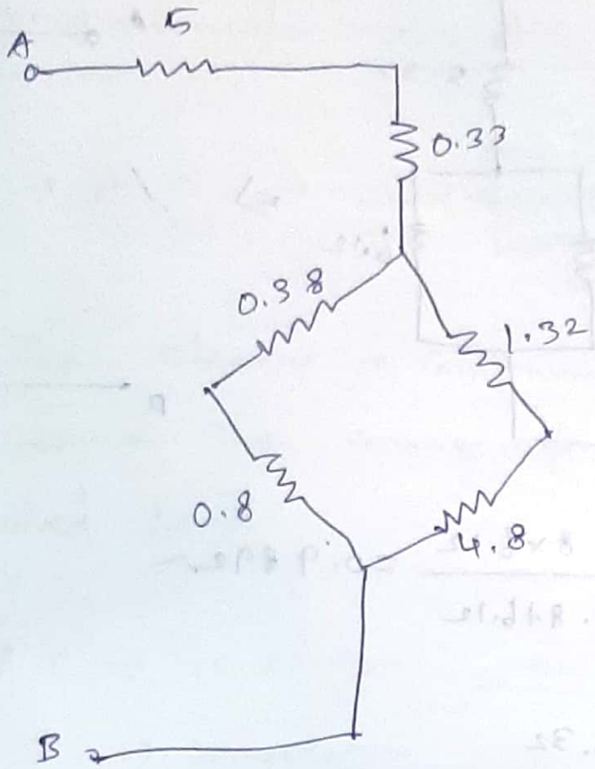


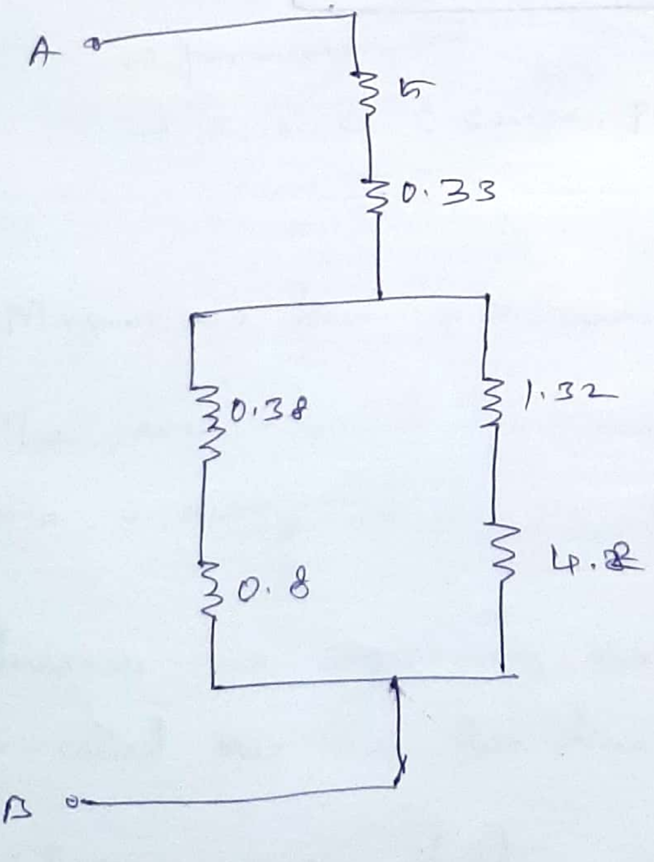


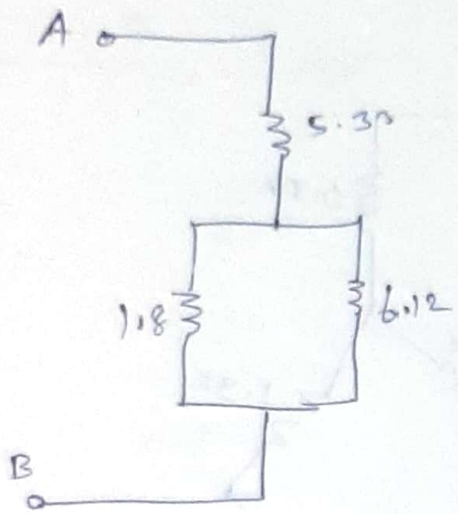
$$R_1 = \frac{R_{12}\, R_{13}}{R_{12}+R_{23}+R_{31}} = \frac{0.8\times 2.8}{0.8+2.8+3.2} = 0.33.$$

$$R_2 = \frac{R_{23} \times R_{12}}{R_{12}+R_{23}+R_{31}} = \frac{0.8\times 3.2}{0.8+2.8+3.2} = 0.38$$

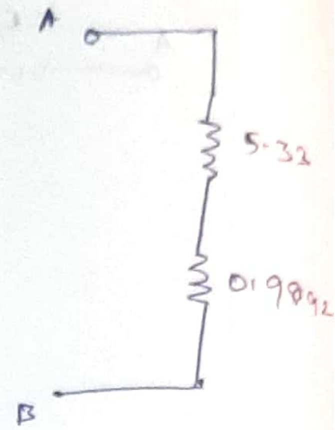
$$R_3 = \frac{R_{13} \times R_{23}}{R_{12}+R_{23}+R_{31}} = \frac{3.2\times 2.8}{0.8+2.8+3.2} = 1.32$$


A
5
0.33
0.38
1.32
0.8
4.8
B

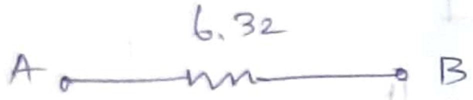

A
5
0.33
0.38
1.32
0.8
4.8
B



$\Rightarrow$



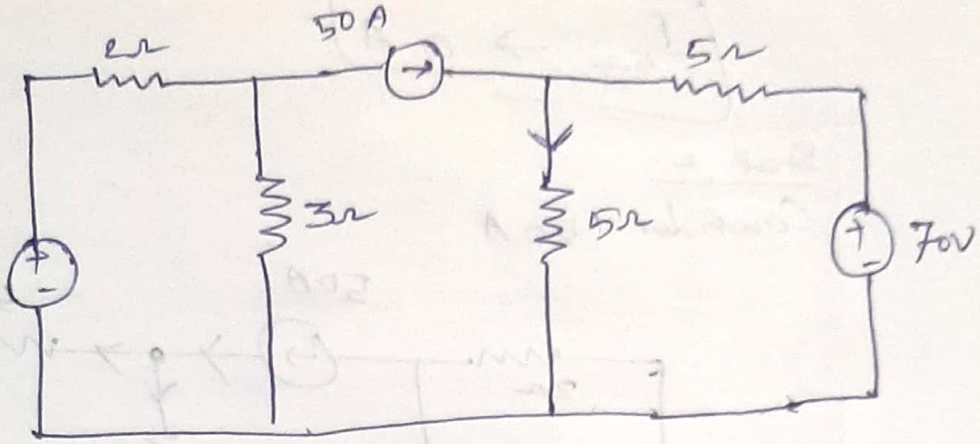
$$R = \frac{1.8 \times 6.12}{1.8 + 6.12} = 0.9892\,\Omega$$



$$\boxed{R_{AB} = 6.32\,\Omega}$$

1

(2) Find current through 5Ω using Superposition theorem.



Solution.

→ Consider one source at a time

→ Neglect remaining sources.

→ while Neglecting,

make Voltage Source → S.C

Current " → O.C

Making the value of voltage & current source Zero

In S.C

$R \to 0,\ I \to \infty$

$V \to 0$

$V = IR$

$I = V/R$

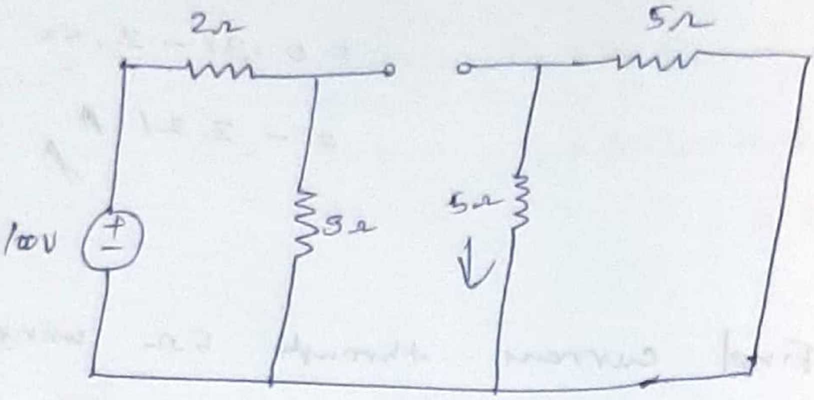
In O.C

$R \to \infty$

$I \to 0$

$V \to \infty$

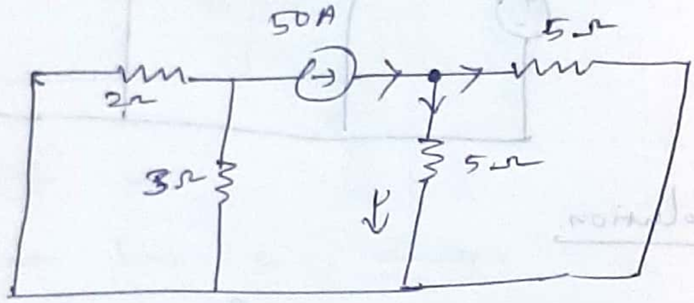
Step : 1 Consider 100V



$$\boxed{I'_{5\Omega} \rightarrow 0\,A}$$

Step : 2

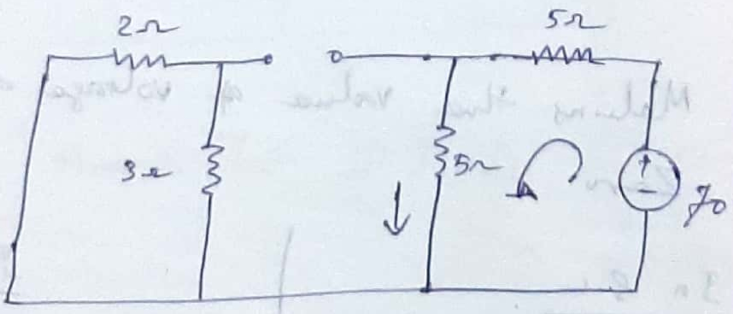
Consider 50 A



$$\boxed{I''_{5\Omega} = 25\,A}$$

Step : 3

Consider 70 V



$5+5 = 10\,\Omega$

$$\boxed{I'''_{5\Omega} = 7A}$$

$I = \frac{70}{10} = 7A$

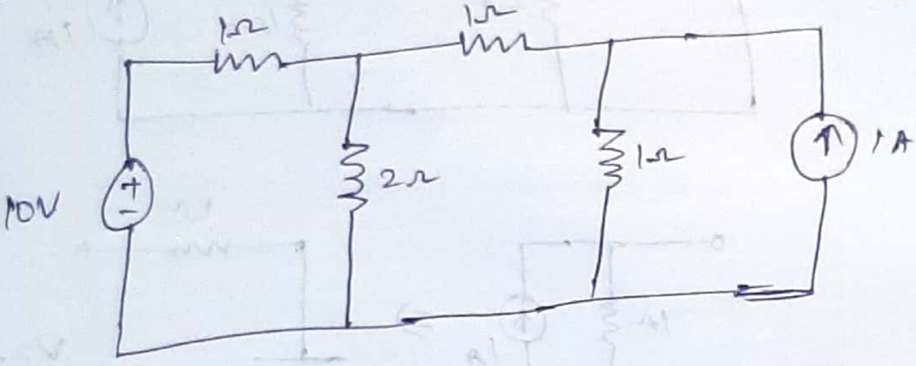
Step : 3

total current $= I'_{5\Omega} + I''_{5\Omega} + I'''_{5\Omega}$

$= 0 + 25A + 7A$

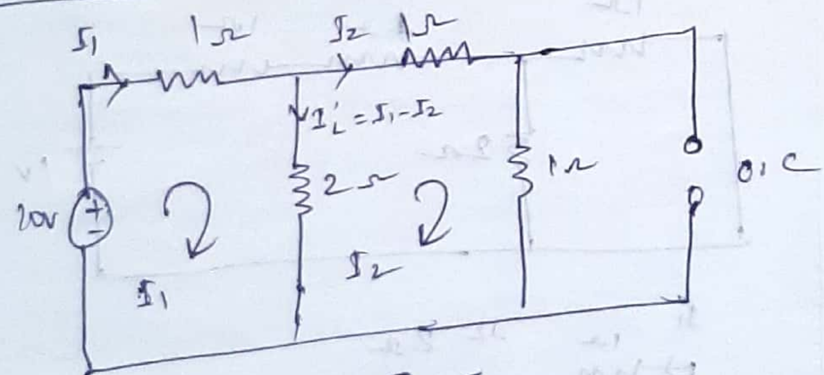
$$\boxed{I = 32A}$$

(3) Calculate the current through 2Ω resistor by using Superposition theorem.



Solution:

Step 1: Consider 10V,



$$[R]\,[I] = [V]$$

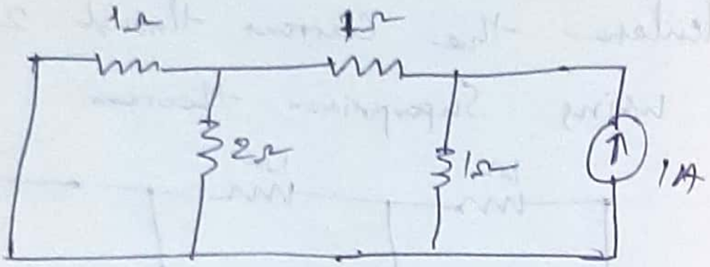
$$\begin{bmatrix} 3 & -2 \\ -2 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \end{bmatrix}$$

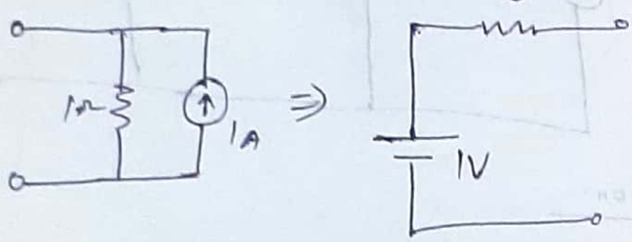
$I_1 = 5A, \; I_2 = 2.5A$

$I_L' = I_1 - I_2 = 5 - 2.5$

$\boxed{I_L' = 2.5A}$

Step: 2: Consider 1 A Source.

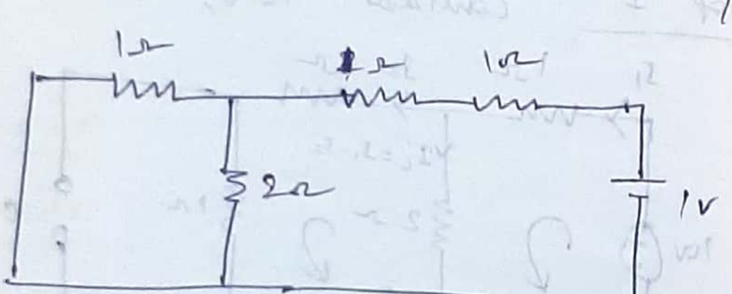


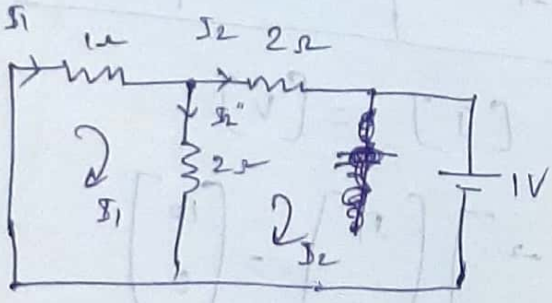


$V = IR$

$= 1 \times 1$

$\boxed{V = 1V}$





$$\begin{bmatrix} 3 & -2 \\ -2 & 4 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}$$

$I_1 = -0.25$, $I_2 = -0.375$

$$I_L'' = I_1 - I_2$$

$$= -0.25 - (-0.37) = -0.25 + 0.375$$

$$\boxed{I_L'' = 0.125A}$$

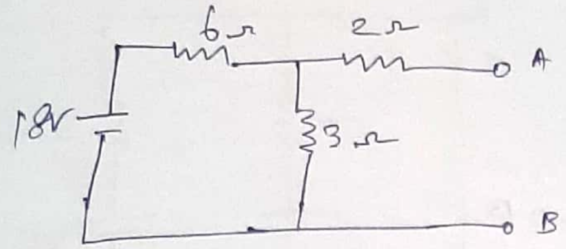
Step 3: Consider both Sources

$$I_L = I_L' + I_L''$$

$$= 2.5 + 0.125$$

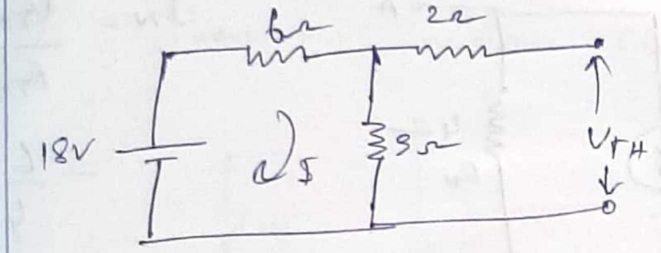
$$\boxed{I_L = 2.625A}$$

(2) Draw the Norton's equivalent ckt across A & B for the given circuit.



Solution:

Find V_{th}.



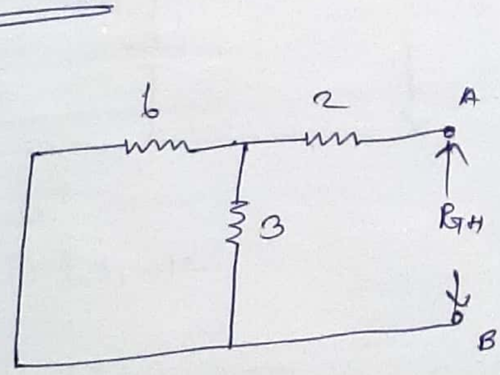
$V_{AB} = I \times 3 = V_{th}$.

$I = \frac{18}{6+3} = \frac{18}{9} = 2\,A$

$V_{th} = 2 \times 3 = 6V$

$\boxed{V_{th} = 6V}$

Find R_{TH}



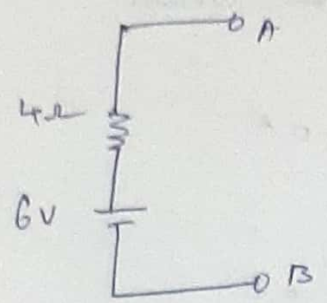
$R_{TH} = \frac{6 \times 3}{6+3} + 2$

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

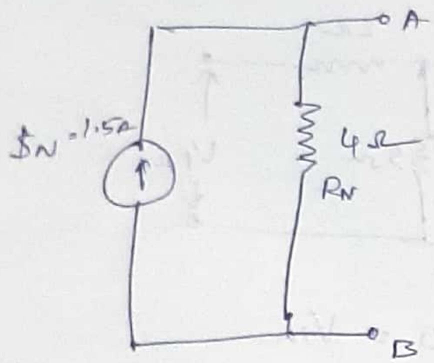
$= 2 + 2$

$\boxed{R_{TH} = 4\Omega}$

Draw thevenin's equivalent circuit.



Norton's equivalent ckt



$I_N = \frac{V_{TH}}{R_{TH}}$

$= \frac{6}{4} = 1.5A$

$\boxed{I_N = 1.5A}$

$\boxed{R_N = R_{TH}}$

$R_N = 4\Omega$