# Chapter 2 : Basic Laws

01/07/2024

*** Page 34 (Exercise) Odd numbers

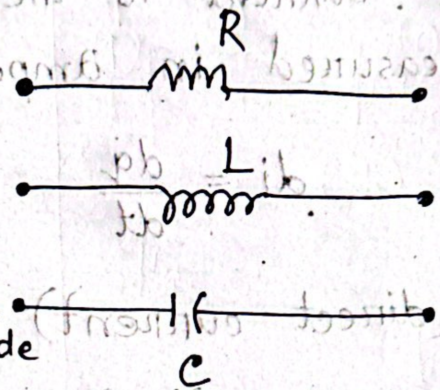
## Ohm's Law

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

$$V = IR$$

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

## Passive elements




Resistance

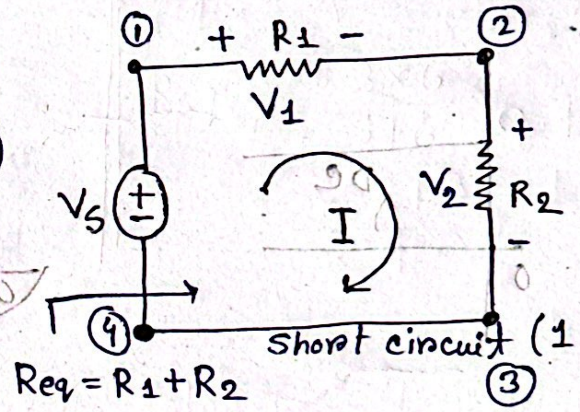
Inductor

Capacitor

## Circuit

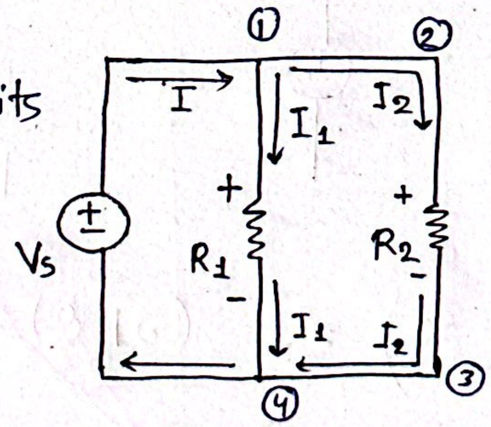
(I) Series (1st start = 2nd start)

(II) Parallel (1st start = 2nd start, 1st end = 2nd end)




Series circuit

* Here both series and parallel circuits are close loop circle




Parallel circuit

(P)

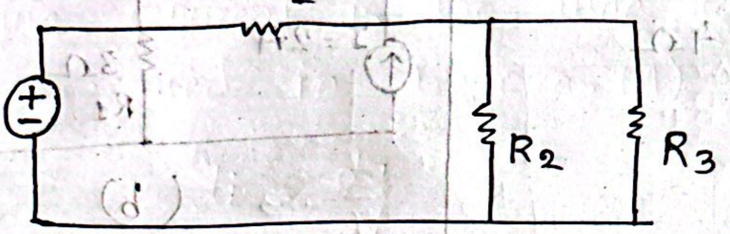
$$V = V_1 = V_2$$

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

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

- Short circuit is a circuit element with resistance approaching zero.

S-P




Series-Parallel circuit

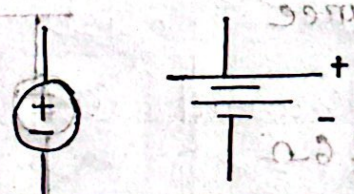
|   | Series | Parallel |
|---|---|---|
| V | Divided Voltage | Same Voltage |
| I | Same Current | Divided Current |

**Open circuit:**

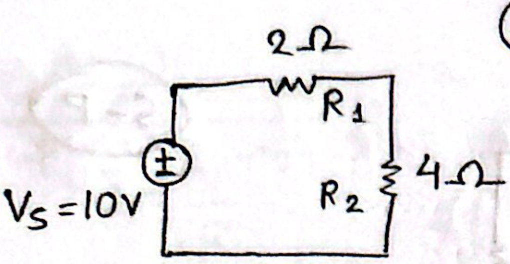
V = max
I = 0

**Short circuit:**

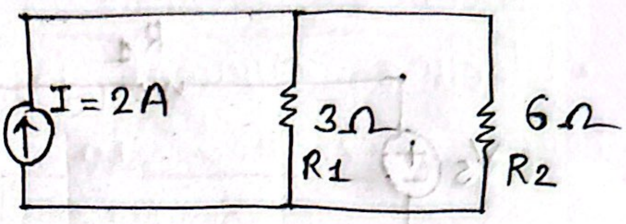
I = max ; V = 0

|   | Voltage Source | Current Source |
|---|---|---|
| Independent |  |  |
| Dependent |  |  |

Determine the equivalent resistance

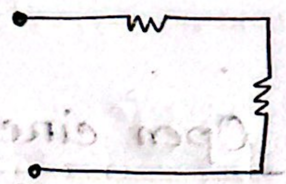



(a)




(b)

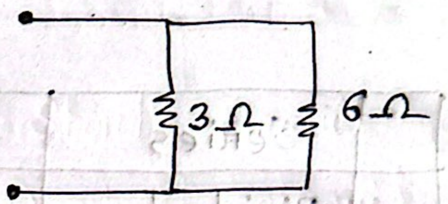
Soln:



$R_{eq} = (2+4)\ \Omega$

$= 6\ \Omega$

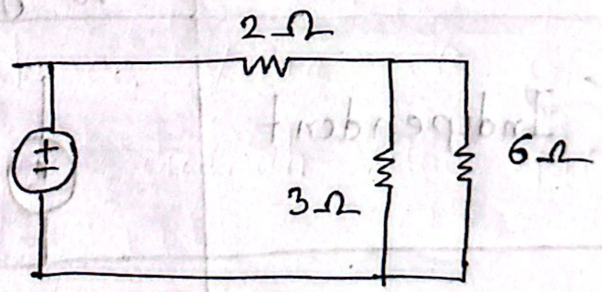
Soln:



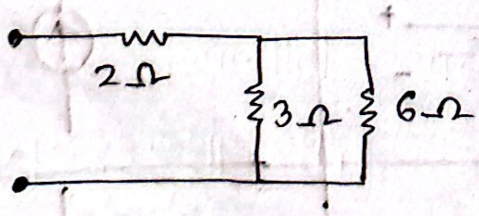

$R_{eq} = \frac{3 \times 6}{3+6}\ \Omega$

$= 2\ \Omega$

Find Req:



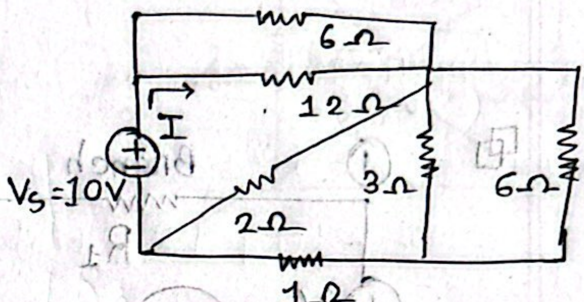

Step 1: Open Source



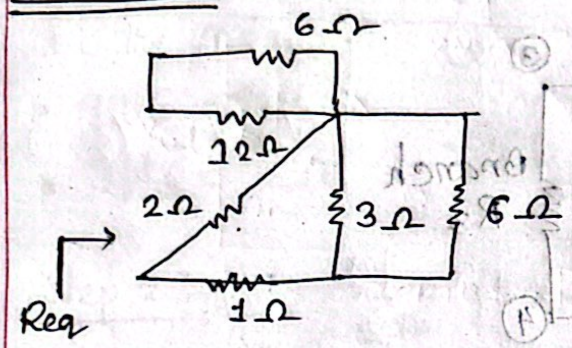

$R_{eq} : \quad 2 + (3 \| 6) = \left(2 + \frac{3 \times 6}{3+6}\right) \Omega$

$\therefore R_{eq} = 2 + 2 = 4\ \Omega$

[4] Determine the equivalent resistance and curre

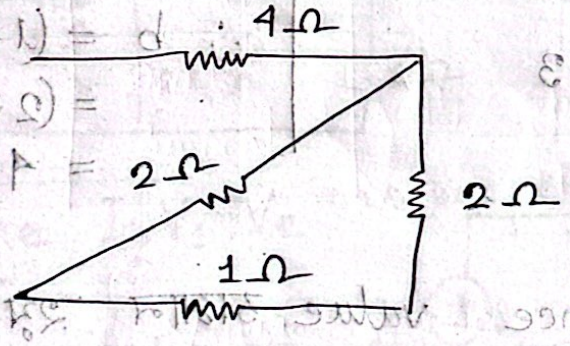



• **Step : 1 :**




• **Step 2 :** if source is from left to right then solve from right to left.

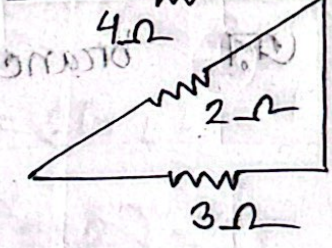
• **Step 3 :**




$6 \| 12 = 4\,\Omega$

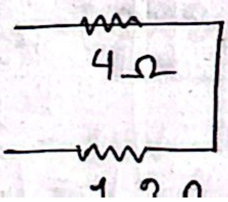
$3 \| 6 = 2\,\Omega$

• **Step 4 :**




$1 + 2 = 3\,\Omega$

• **Step 5 :**




**Step 6 :** $4 + 1.2 = 5.2\,\Omega$

$\therefore R_{eq} = 5.2\,\Omega$

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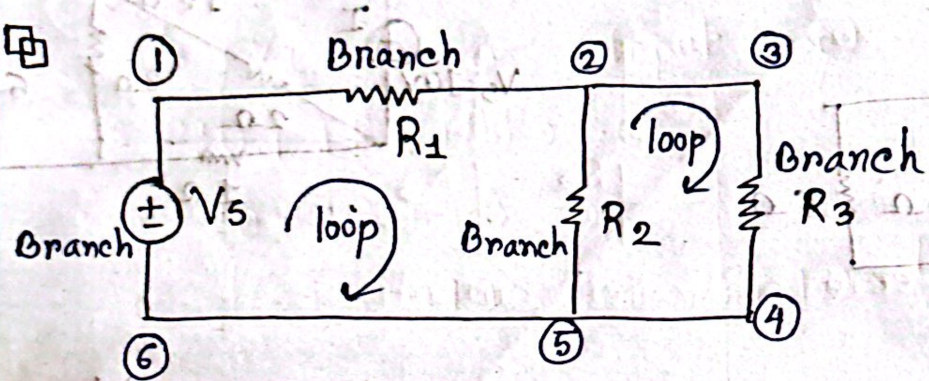
Using Ohm's Law: $I = \frac{V_s}{R_{eq}} = \frac{10}{5.2} = 1.92A$




Branch, $b = 4$

Loop, $l = 2$

Nodes, $n = 3$

(2, 3) Short circuit

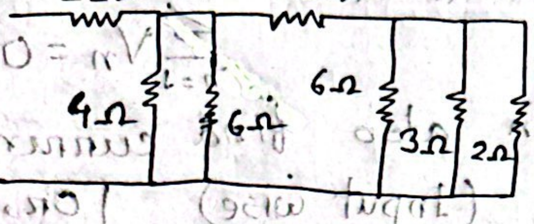
(4, 5, 6) Short circuit

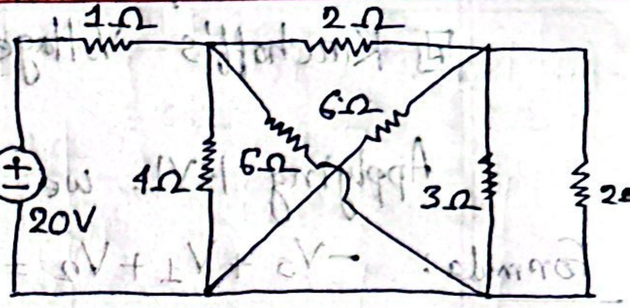
$$\therefore b = (l+n) - 1$$
$$= (2+3) - 1$$
$$= 4$$

* যদি Resistance value সমান হয় parallel circuit এর ক্ষেত্রে তাহলে Resistance Value কে অই ~~branc~~ parallel circuit এর branch value দিয়ে ভাগ দেওয়া হয়।

# Determine the equivalent resistance:

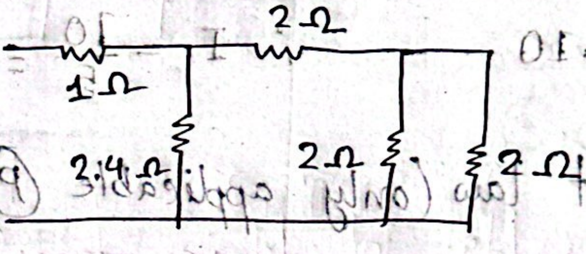
**Step 1:**



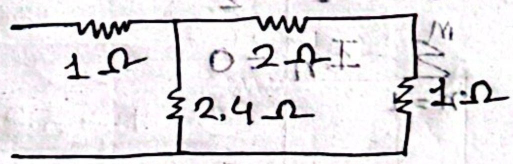




- $4 \parallel 6 = 2.4\,\Omega$
- $3 \parallel 6 = 2\,\Omega$
- $3 \parallel 2 = 1.2\,\Omega$

**Step 2:**




**Step 3:**




**Step 4:**

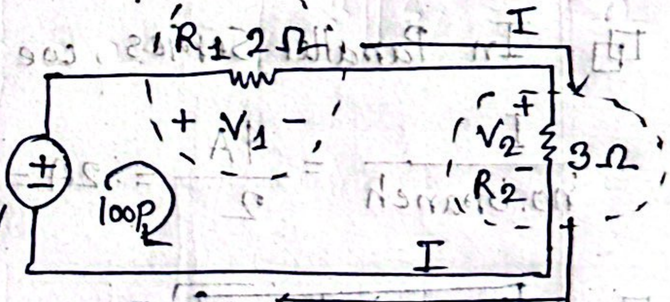
$R_{eq} = 1 + 2.4 \parallel (2+1)$

$= 1 + 2.4 \parallel 3$

$= 2.33\,\Omega$

(Ans)

# Determine I, $V_1$, $V_2$




$R_{eq} = R_1 + R_2 = 2 + 3 = 5$

Using Ohm's law, $I = \frac{V_s}{R_{eq}}$

$= \frac{10}{5}\,A = 2A$

$V_1 = IR_1 = (2 \times 2) = 4V$

$V_2 = IR_2 = (2 \times 3) = 6V$

} Distributed Voltage

$V_s = 4 + 6 = 10V$ (source Voltage)

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only applicable for (S) circuit

## Kirchoff's Voltage Law (KVL) $\sum_{n=1}^{N} V_n = 0$

Applying KVL we can also find current I,

Formula: $-V_S + V_1 + V_2 = 0$ (Input wise) | Or, Output wise $V_S - V_1 - V_2 = 0$

$\Rightarrow -10 + IR_1 + IR_2 = 0$

$\Rightarrow -10 + I2 + I3 = 0$

$\Rightarrow I(2+3) = 10$ $\therefore I = \frac{10}{5} = 2A$

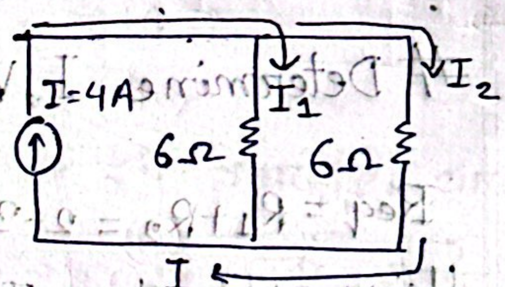
## Kirchoff's Current Law (only applicable (P) circuit)

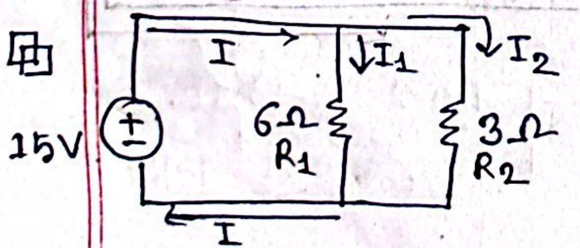

$I = I_1 + I_2$

$\sum_{n=1}^{M} I_n = 0$

## In Parallel Series we can use

$\frac{I}{\text{no. branch}} = \frac{4A}{2} = 2A = I_1 = I_2$




Since Source || $R_1$ || $R_2$

$V_1 = V_2 = V_S = 15V$

$I_1 = \frac{V_1}{R_1} = \frac{15}{6} = 2.5A$

$I_2 = 5A$

Using KCL we can find I

$I = I_1 + I_2 = 2.5 + 5 = 7.5A$ (Ans)

Another way to find I

$Req = \frac{6 \times 3}{6+3} = 2\Omega$

Ohm's law $I = \frac{V_s}{Req} = \frac{15V}{2\Omega}$

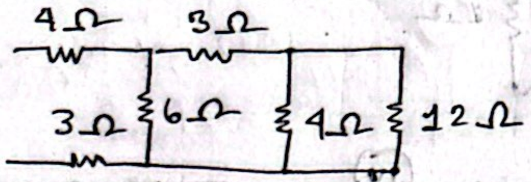
$\therefore I = 7.5A$ (Ans)

# Practise

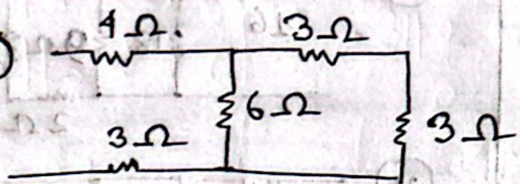
Ans: 10Ω

## Prac. Prob 2.9

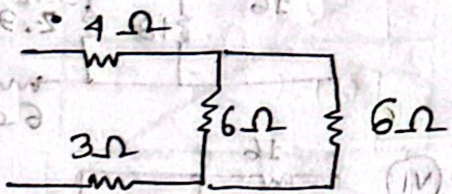
(I)




(II)

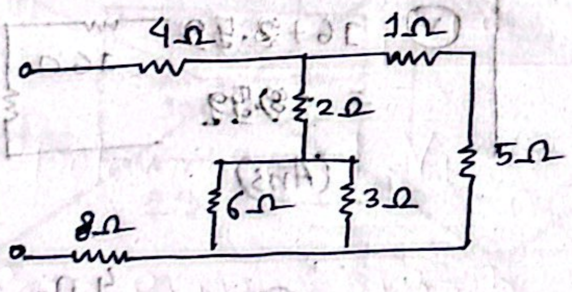



(III)

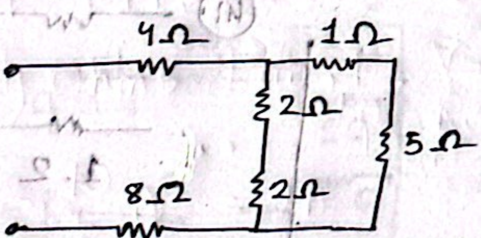



## Prob. 2.9

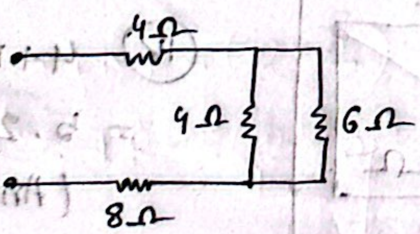
Q:



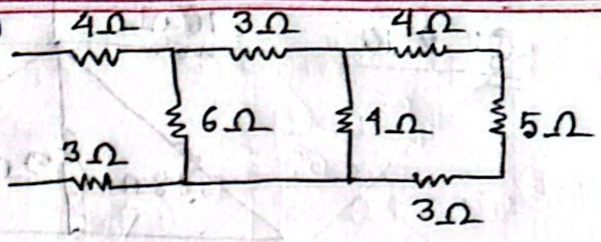

(I)



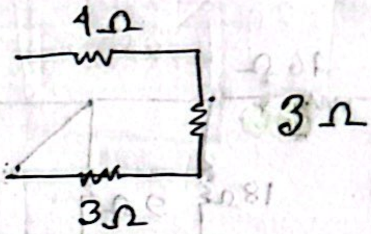

(II)




Q: #



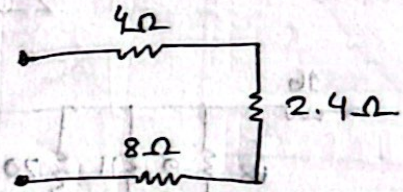

(IV)




(V) 4 + 3 + 3

= 10Ω (Ans)

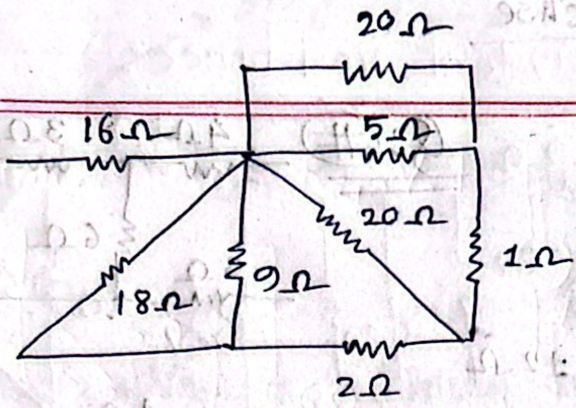
(III)



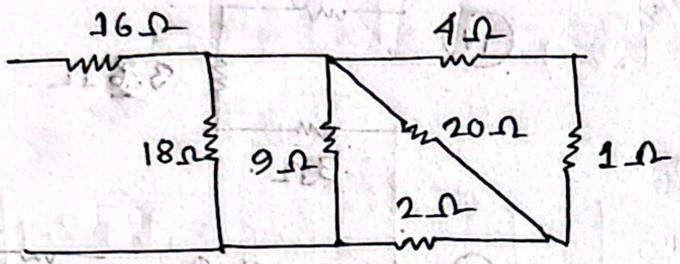

(IV) 2.4 + 4 + 8

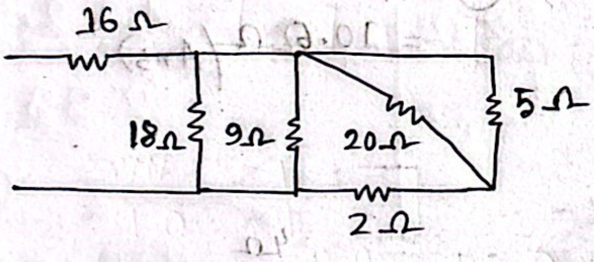
= 14.4 Ω (Ans)

Q: 2.10




Ans: 19

(I)



(II)
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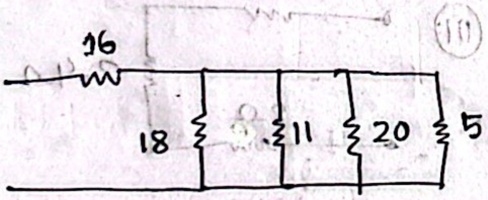
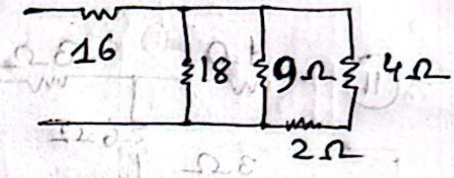
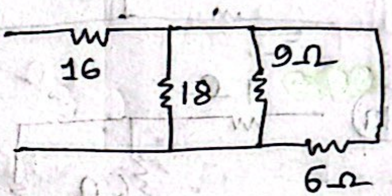
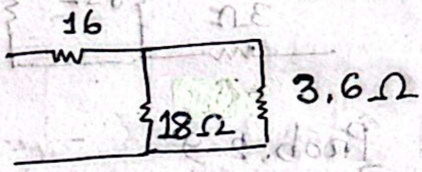



(IV)


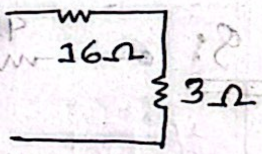

(V)



(VI)


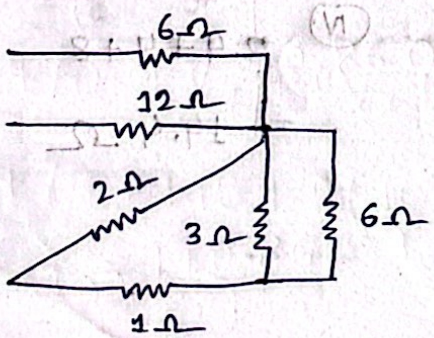

(V) 16 + 3

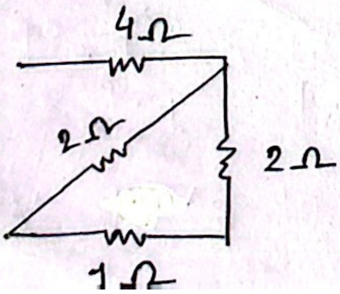
= 19 Ω

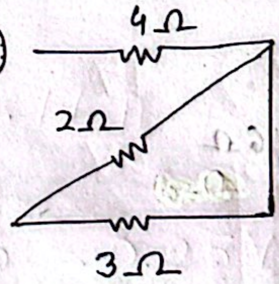
(Ans)

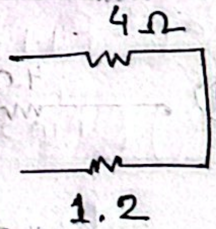



Q:




(I)



(II)


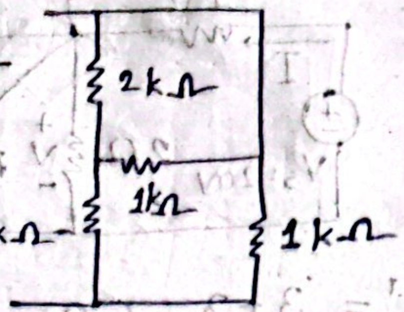

(III)



(IV) 4 + 1.2

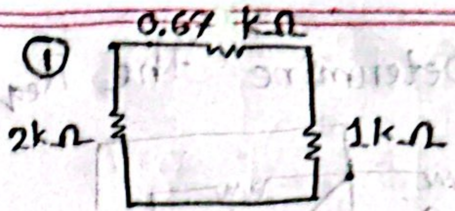
= 5.2

(Ans)

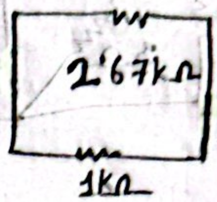
Q:2.39




(I)




(II)

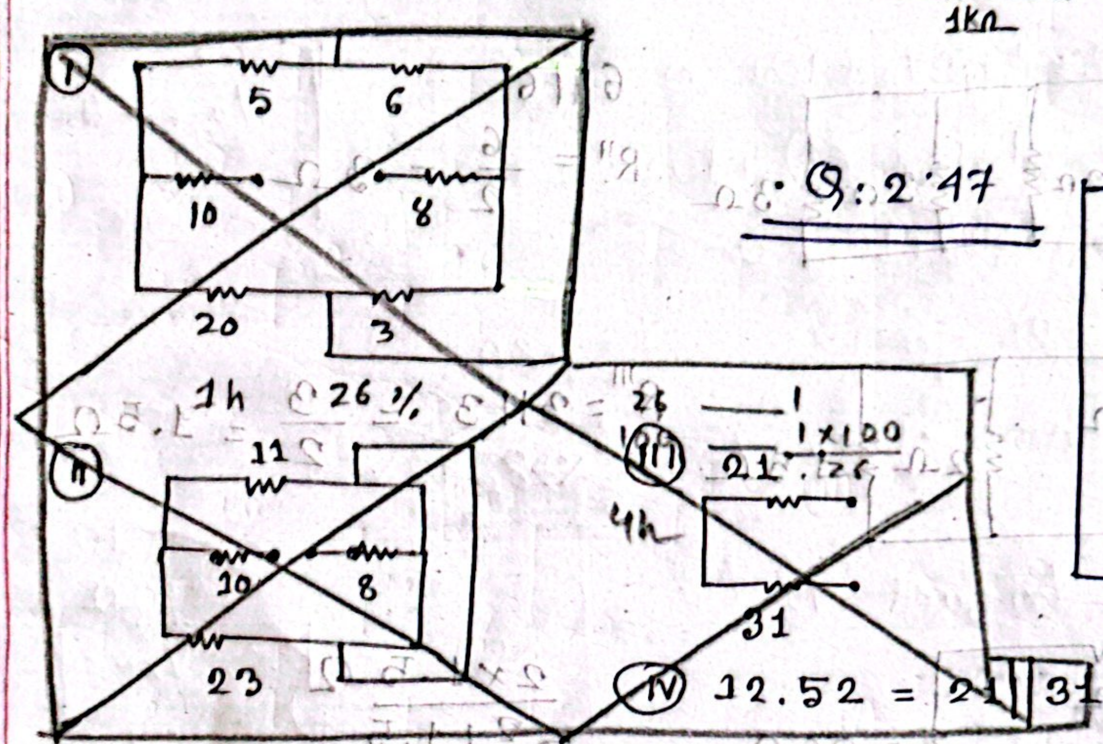



(III) $\frac{2.67\times1}{2.67+1}$ kΩ

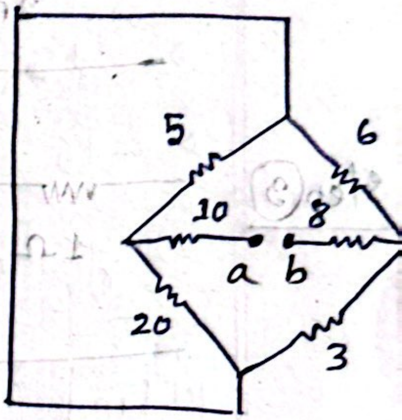
$= 0.727$ kΩ

$= 727.5\ \Omega$

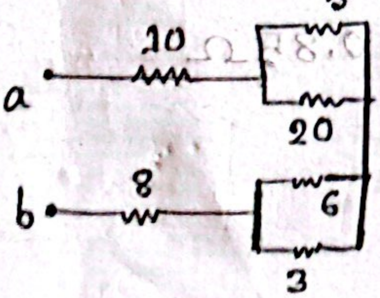
(Ans)



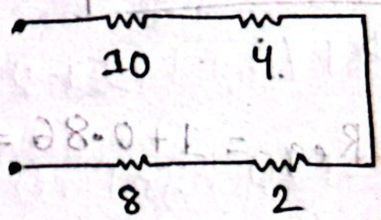
Q:2.47




(I)



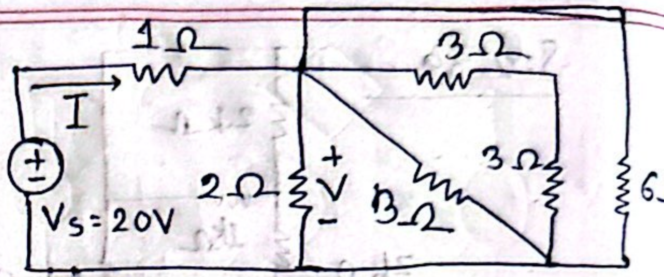

(II)



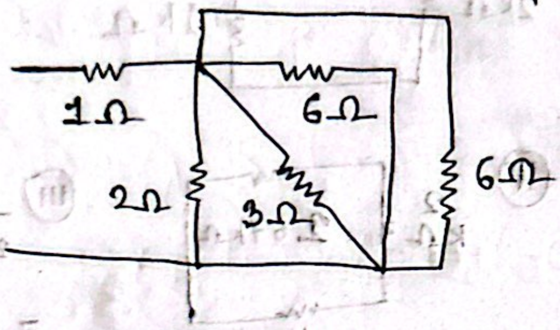

(III) $10+4+8+2 = 24$ (Ans)

C.W
03/07/21

Determine the $R_{eq}$, V, I

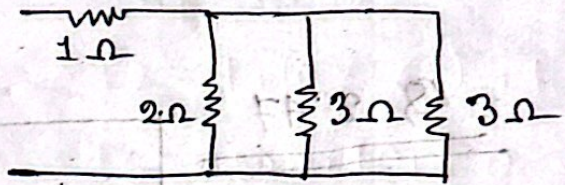



Step ①




$R' = 3 + 3 = 6\Omega$

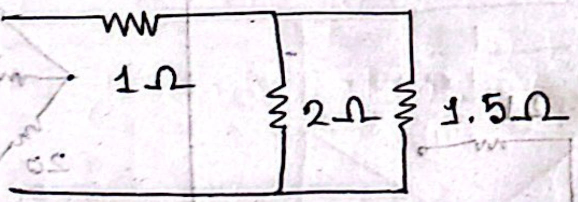
Step ②




$6 \| 6$

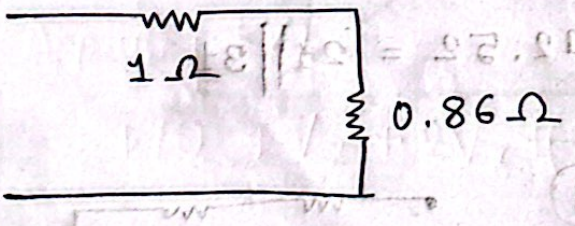
$R'' = \frac{6}{2} = 3\Omega$

Step ③




$R''' = 3 \| 3 = \frac{3}{2} = 1.5\Omega$

Step ④




$\frac{2 \times 1.5\Omega}{2 + 1.5}$

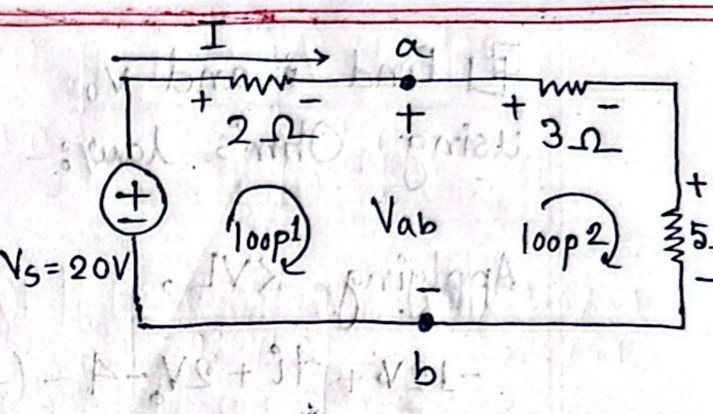
$R^{IV} = 0.85\Omega$

Step ⑤ $\therefore R_{eq} = 1 + 0.86 = 1.86\Omega$

$\therefore I = \frac{20}{R_{eq}} = \frac{20}{1.86\Omega} = 10.77\ A$

$\therefore V = IR^{IV} = 10.77 \times 0.85 = 9.25V$

Determine $V_{ab}$




KVL: $-V_s + 2I + 3I + 5I = 0$

$\Rightarrow -20 + 10I = 0$

$\Rightarrow 10I = 20 \quad \therefore I = 2A$

Applying KVL in loop 1, $-20 + 2I + V_{ab} = 0$

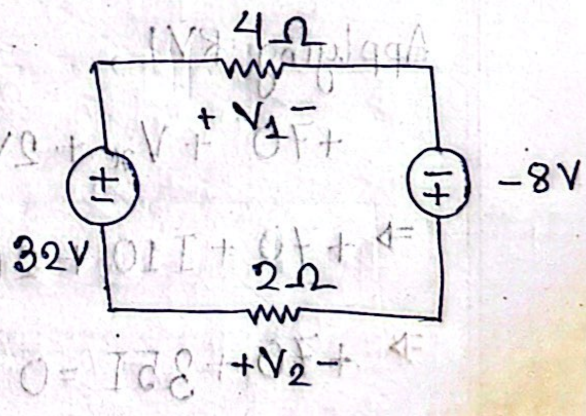
$V_{ab} = 20 - 2\times 2 = 16V$

Applying KVL in loop 2, $-V_{ab} + 3I + 5I = 0$

$\Rightarrow -V_{ab} = -8I$

$\therefore V_{ab} = 8\times 2 = 16V$

Find $V_1, V_2$




Using KVL,

$-32 + V_1 - (-8) - V_2 = 0$

$\Rightarrow -32 + 8 + IR_1 - (-I2) = 0$

$\Rightarrow -24 + 4I + 2I = 0$

$\Rightarrow -24 + 6I = 0$

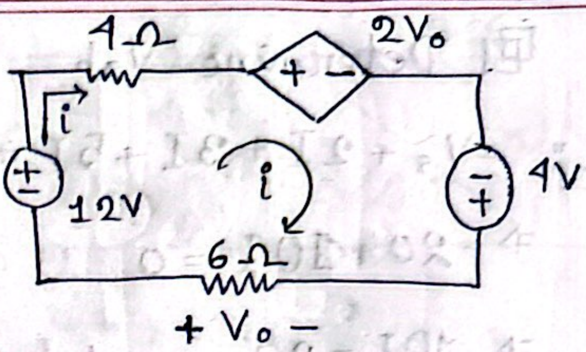
$\Rightarrow 6I = 24$

$\therefore I = 4A$

$V_1 = IR_1 = 4\times 4 = 16V$

$V_2 = -IR_2 = -4\times 2 = -8V$

Find $i$ and $v_o$ using Ohm's law:-




Applying KVL,

$$-12 + 4i + 2V_o - 4 - (-6i) = 0$$

$V_o = -6i$

$$\Rightarrow -12 - 4 + 2V_o + 10i = 0$$

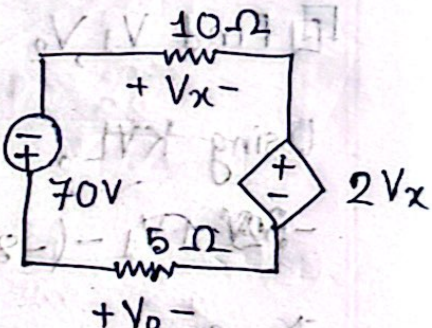
$$\Rightarrow -12 - 4 + (2 \times -6i) + 10i = 0$$

$$\Rightarrow -16 - 12i + 10i = 0$$

$$\Rightarrow -16 - 2i = 0 \qquad \therefore i = -8A$$

using Ohm's law, $V_o = -6 \times -8 = 48V$

Find $V_x$ and $V_o$




Applying KVL,

$$+70 + V_x + 2V_x - (-V_o) = 0$$

$$\Rightarrow +70 + I10 + 2(10I) + 5I = 0$$

$$\Rightarrow +70 + 35I = 0$$

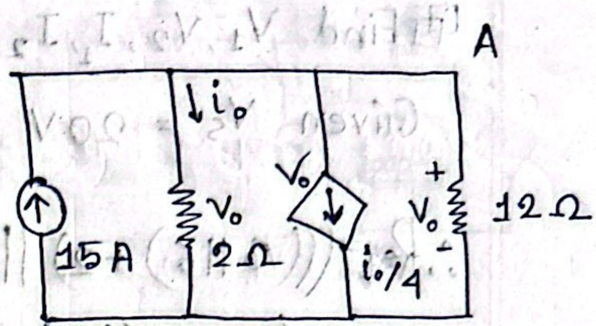
$$\Rightarrow I = -2A$$

$\therefore V_x = 10 \times -2 = -20\ V$

$\therefore V_o = -5 \times -2 = 10\ V$

Scanned with CamScanner

Find $V_o$ and $i_o$




Applying KCL at node A,

$$15 = i_o + \frac{i_o}{4} + i_1$$

$$\Rightarrow 15 = \frac{V_o}{2} + \frac{V_o/2}{4} + \frac{V_o}{12}$$

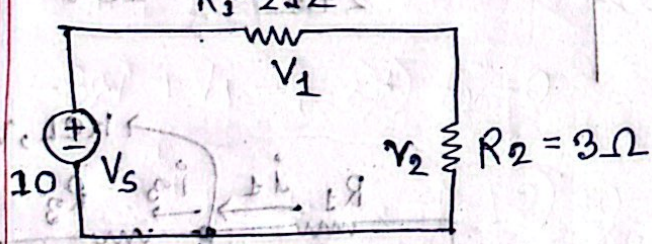
$$\Rightarrow 15 = \frac{17V_o}{24}$$

$$\therefore V_o = \frac{24 \times 15}{17} = 21.176$$

$$i_o = \frac{V_o}{2} = \frac{21.176}{2} = 10.58A \quad \text{(Ohm's Law)}$$

Voltage divider rule

(S) circuit

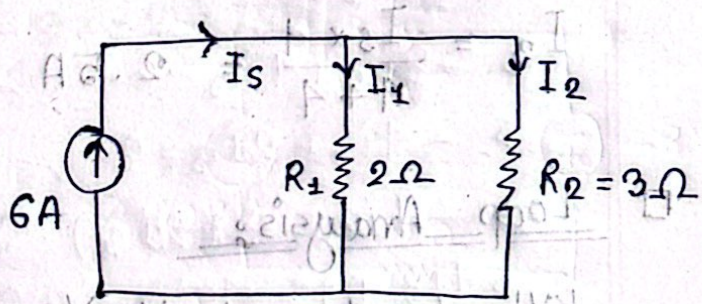



$$V_1 = \frac{V_s R_1}{R_1+R_2} = \frac{10 \times 2}{5} = 4V$$

$$V_2 = \frac{V_s R_2}{R_1+R_2} = \frac{10 \times 3}{5} = 6V$$

Current divider rule

(P) circuit




$$I_1 = \frac{I_s R_2}{R_1+R_2}$$

$$I_2 = \frac{I_s R_1}{R_1+R_2}$$

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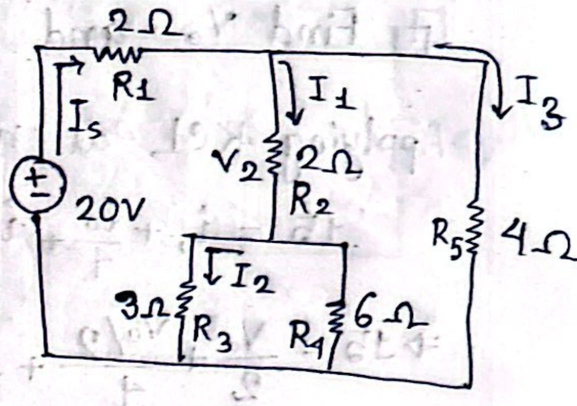
$$I_1 = \frac{I_s \times (R_2||R_3)}{R_1+R_2+R_3}$$

□ Find $V_1, V_2, I_1, I_2, I_3$




Given $V_s = 20V$

$\therefore R_{eq} = (((3 \| 6) + 2) \| 4) + 2$

$= (2 + 2 \| 4) + 2$

$= (4 \| 4) + 2 = 2 + 2 = 4\Omega$

$\therefore I_s = \dfrac{V_s}{R_{eq}} = \dfrac{20}{4} = 5A$

$I_1 = \dfrac{I_s \times 4}{4+4} = 2.5A$

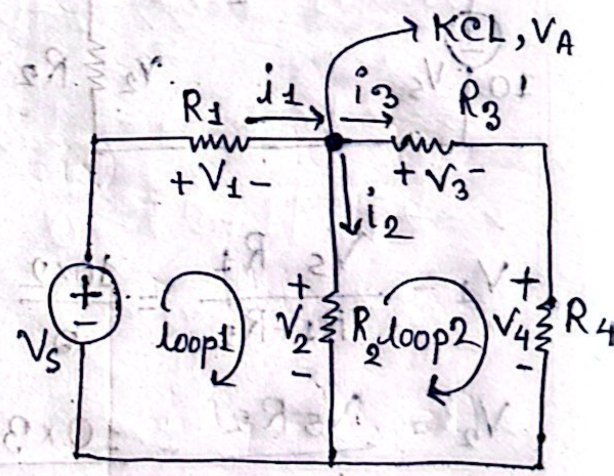
$I_2 = \dfrac{I_1 6}{3+6} = 1.67A$

$I_3 = \dfrac{I_s \times 4}{4+4} = 2.5A$

$V_1 = \dfrac{20 \times 2}{2+2} = 10V$

$V_2 = \dfrac{20 \times 2}{2+2} = 10V$

□ **Loop Analysis:**




KVL loop 1, $-V_s + V_1 + V_2 = 0$

for loop 2, $-V_2 + V_3 + V_4 = 0$

Applying KCL in node A,

$i_1 = i_2 + i_3$

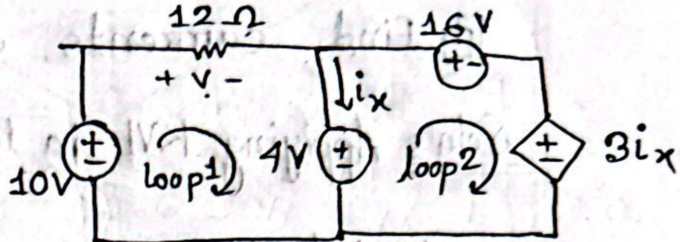
Ohm's Law apply, $i_1 = \dfrac{V_1}{R_1}, i_2 = \dfrac{V_2}{R_2}, \ldots\ldots$

$V_S - V_A = V_1$

# Practise

v? $i_x$?

(2.15) Applying KVL,




loop1, $-10+v+4=0$

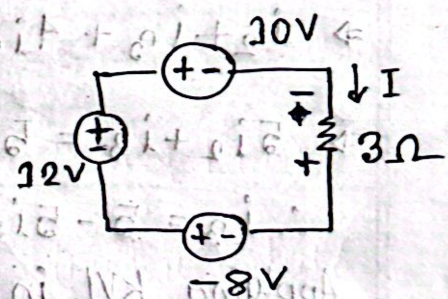
$\Rightarrow -6+v=0 \quad \therefore v=6V$

loop 2, $-4+16+3i_x=0$

$\Rightarrow +12+3i_x=0$

$\Rightarrow 3i_x=-12 \quad \therefore i_x=\frac{12}{-3}=-4A$

(2.19) $-12+10-(-3I)-(-8)=0$




$\Rightarrow 6+3I=0$

$\therefore I=-2A$

$P_1 = 12\times -2 = -24W$

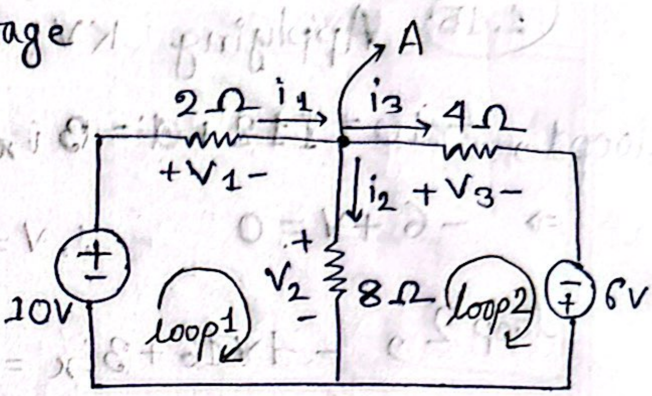
$P_2 = 10\times -2 = -20W$

$P_3 = -3\times -2 = 6$ W (wrong)

$P_4 = -8\times -2 = 16W$

Lecture-3
08/07/2024

Find currents and voltage




Soln: Applying KVL in loop 1,

$-10+V_1+V_2=0$

$\Rightarrow V_1+V_2=10$

$\Rightarrow 2i_1+8i_2=10$

$\Rightarrow i_1+4i_2=5$

$\Rightarrow i_2+i_3+4i_2=5$

$\Rightarrow 5i_2+i_3=5$ ------ (1)

$\therefore i_3=5-5i_2$

Applying KVL in loop 2,

$-V_2+V_3-6=0$

$\Rightarrow -8i_2+4i_3=6$

$\Rightarrow -4i_2+2i_3=3$

$\Rightarrow -4i_2+2(5-5i_2)=3$

$\Rightarrow -4i_2+10-10i_2=3$

$\Rightarrow -14i_2=-7$

$\Rightarrow i_2=\frac{-7}{-14}=0.5$ (Ans)

putting value $i_2$: $(5\times 0.5)+i_3=5$

$\therefore i_3=2.5A$ (Ans)

Applying KCL in node A

$i_1=i_2+i_3$

$\therefore i_1-i_2-i_3=0$

Using Ohm's law,

$V_1=2i_1$

$V_2=8i_2$

$V_3=4i_3$

$\Rightarrow i_1=0.5+2.5$

$\therefore i_1=3A$ (Ans)

$V_1 = 2i_1 = 2 \times 3 = 6V$ (Ans)

$V_2 = 8i_2 = 8 \times 0.5 = 4V$ (Ans)

$V_3 = 4i_3 = 4 \times 2.5 = 10V$ (Ans)

$\cancel{5i_2 = 5 - 3.18}$

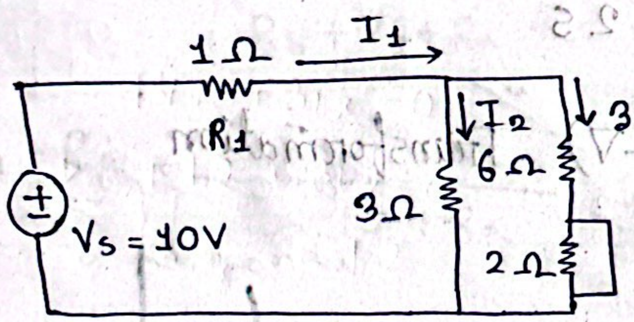
$\Rightarrow \cancel{5i_2 = 1.82}$

$\therefore \cancel{i_2 = 0.36A}$

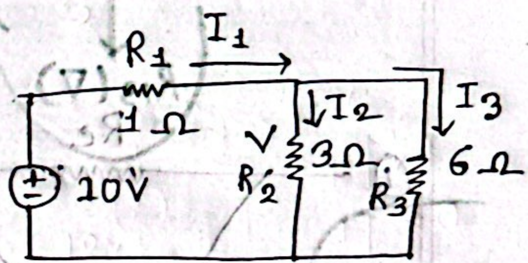
$\cancel{i_1 = i_2 + i_3}$

$\cancel{= 0.36 + 3.18}$

$\cancel{= 3.54A}$

□ 


Find $I_1, I_2, I_3$ & V.




$I_1 = \frac{V_s}{R_1} = \frac{10}{3} = 3.33A$

CDR, $I_2 = \frac{I_1 \times R_3}{R_2 + R_3} = 2.22A$

$Req = 1 + R' = 1 + 2 = 3\Omega$

CDR, $I_3 = \frac{I_1 \times R_2}{R_2 + R_3} = 1.11A$

$V = I_2 R'$

$\therefore V = 2.22 \times 2$

$= 4.44V$

$R' = R_2 \| R_3 = \frac{3 \times 6}{3+6} = 2\Omega$

Another way to solve: Applying KVL; $-10 + 1I_1 + 3I_2 = 0$ (loop 1)

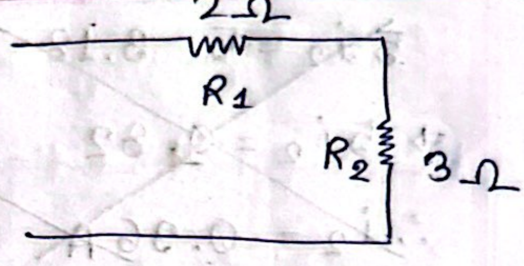
again KVL; $-3I_2 + 6I_3 = 0$ (loop 2)

KCL in node A, $I_1 = I_2 + I_3$

conductance, $G = \frac{1}{R}$ ($\mho$/S)

---

□ $R_{eq} = 2+3\,\Omega$

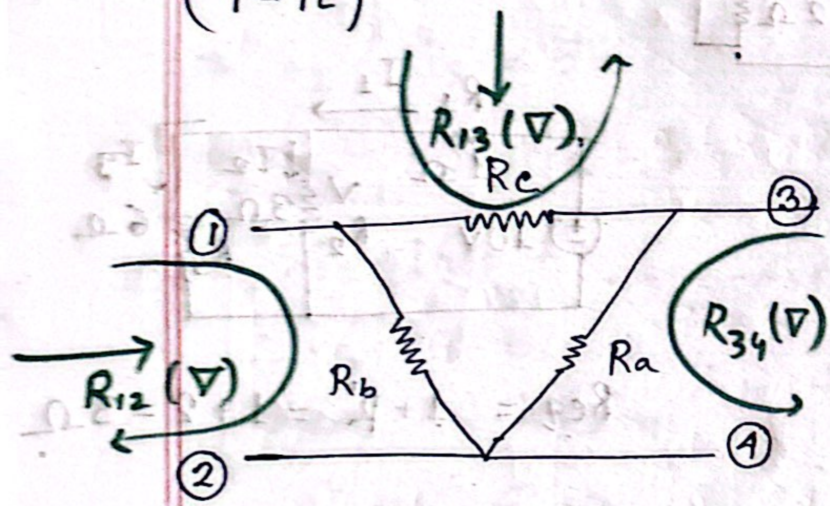


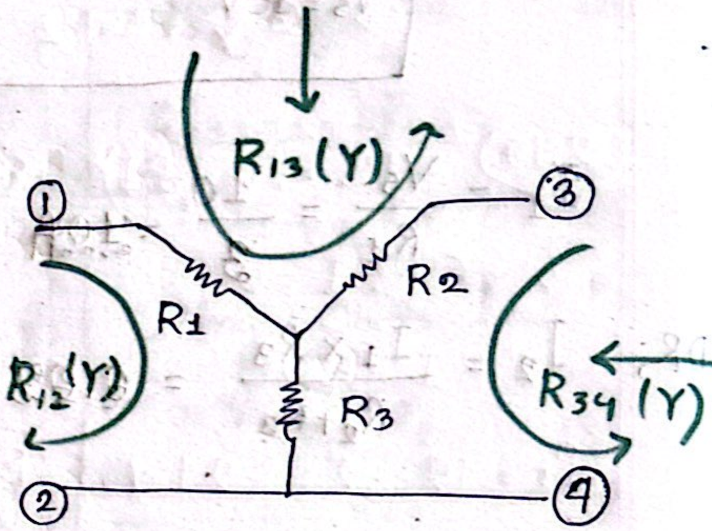

$G_1 = \frac{1}{2}\,S$ , $G_2 = \frac{1}{3}\,S$

$G_{eq} = \frac{2\times 3}{2+3} = 1.2\,S$

□ WYE-DELTA (Y-∇) Transformation

(T-π)




∇ connection

Y connection

$R_{12}(\nabla) = R_b \,||\, (R_c+R_a)$

$R_{13}(\nabla) = R_c \,||\, (R_a+R_b)$

$R_{34}(\nabla) = R_a \,||\, (R_b+R_c)$

$R_{12}(Y) = R_1+R_3$

$R_{13}(Y) = R_1+R_2$

$R_{34}(Y) = R_2+R_3$

$\therefore R_{12}(Y) = R_{12}(\nabla)$

$R_1 + R_3 = R_b \,||\, (R_c + R_a)$

$\Rightarrow R_1 + R_3 = \dfrac{R_b \times (R_c + R_a)}{R_b + R_c + R_a}$

$\therefore R_1 + R_3 = \dfrac{R_b R_c + R_b R_a}{R_b + R_c + R_a}$ ------ (I)

$\therefore R_{13}(Y) = R_{13}(\nabla)$

$\Rightarrow R_1 + R_2 = \dfrac{R_c \times (R_a + R_b)}{R_a + R_b + R_c}$

$\Rightarrow R_1 + R_2 = \dfrac{R_a R_c + R_c R_b}{R_a + R_b + R_c}$ ------ (II)

$\therefore R_{34}(Y) = R_{34}(\nabla)$

$\Rightarrow R_2 + R_3 = R_a \,||\, (R_b + R_c)$

$\Rightarrow R_2 + R_3 = \dfrac{R_a \times (R_b + R_c)}{R_a + R_b + R_c}$

$\therefore R_2 + R_3 = \dfrac{R_a R_b + R_a R_c}{R_a + R_b + R_c}$ ------ (III) eq (I) - eq (III),

$$R_1 - R_2 = \frac{R_bR_c - R_aR_c}{R_a+R_b+R_c} \text{ ------ (IV)}$$

eq (II) + eq (IV),

$$R_1 + R_2 + R_1 - R_2 = \frac{2R_bR_c + 2R_aR_c}{R_a+R_b+R_c}$$

$$\Rightarrow \quad 2R_1 = \frac{2(R_bR_c)}{R_a+R_b+R_c}$$

$$\therefore R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \text{ ------ (V)}$$

Substituting $R_1$ in eq (II),

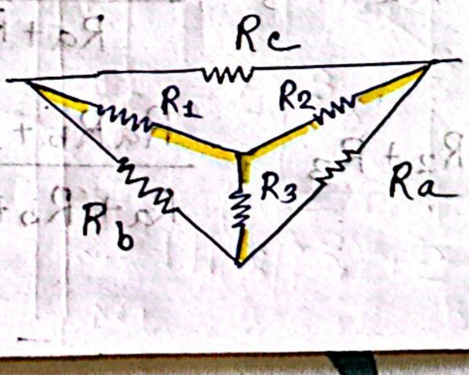
$$R_2 = \frac{R_aR_c + R_cR_b}{R_a+R_b+R_c} - \frac{R_bR_c}{R_a+R_b+R_c}$$

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

So, Similarly,

$\nabla$ to Y conversion

$$\begin{cases} R_1 = \dfrac{R_bR_c}{R_a+R_b+R_c} \\ R_2 = \dfrac{R_aR_c}{R_a+R_b+R_c} \\ R_3 = \dfrac{R_bR_c}{R_a+R_b+R_c} \end{cases}$$



$$R_1R_2+R_2R_3+R_3R_1 = \frac{R_bR_c(R_cR_a)}{(R_a+R_b+R_c)^2}+\frac{(R_cR_a)(R_aR_b)}{(R_a+R_b+R_c)^2}+\frac{(R_bR_c)(R_aR_b)}{(R_a+R_b+R_c)^2}$$

$$= \frac{R_aR_bR_c^2 + R_a^2R_bR_c + R_aR_b^2R_c}{(R_a+R_b+R_c)^2}$$

$$= \frac{R_aR_bR_c\,\cancel{(R_a+R_b+R_c)}}{(R_a+R_b+R_c)^{\cancel{2}}}$$

$$\therefore R_1R_2+R_2R_3+R_3R_1 = \frac{R_aR_bR_c}{R_a+R_b+R_c} \quad ---- \text{(A)}$$

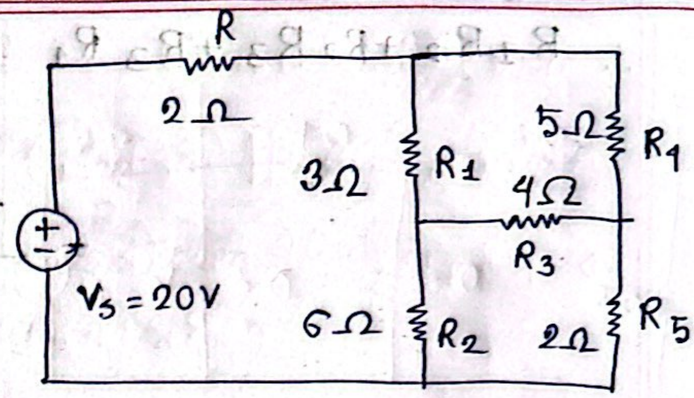
eqn (A) ÷ eqn (1),

$$\frac{R_1R_2+R_2R_3+R_3R_1}{R_3} = \frac{\dfrac{\cancel{R_a}\cancel{R_b}R_c}{\cancel{R_a+R_b+R_c}}}{\dfrac{\cancel{R_a}\cancel{R_b}}{\cancel{R_a+R_b+R_c}}} = R_c$$

So, similarly,

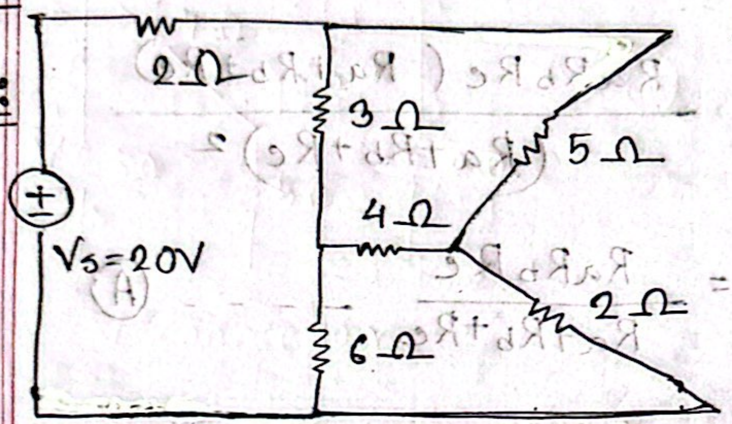
$$\left.\begin{aligned} R_c &= \frac{R_1R_2+R_2R_3+R_3R_1}{R_3} \\ R_b &= \frac{R_1R_2+R_2R_3+R_3R_1}{R_2} \\ R_a &= \frac{R_1R_2+R_2R_3+R_3R_1}{R_1} \end{aligned}\right\} \text{Y to } \nabla \text{ conversion}$$

Find I using WYE-DELTA Transformation.

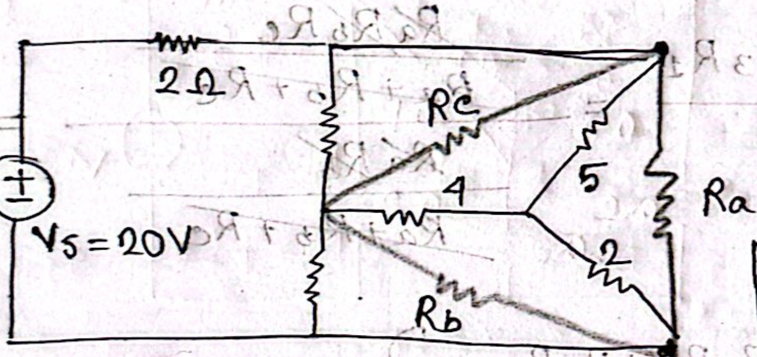



Y to ∇ :

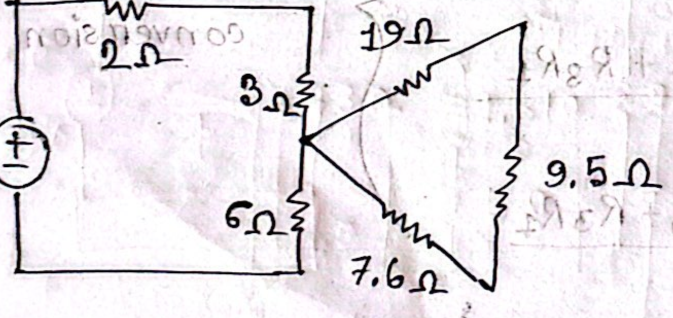
Step 1 :




Step 2 :




Step 3 :




$$R_a = \frac{(4\times5)+(5\times2)+(2\times4)}{4} = 9.5\,\Omega$$

$$R_b = \frac{(4\times5)+(5\times2)+(2\times4)}{5} = 7.6\,\Omega$$

$$R_c = \frac{(4\times5)+(5\times2)+(2\times4)}{2} = 19\,\Omega$$

$$R_{eq} = \left((19+9.5)\,||\,7.6\right)\,||\,(3+6)+2$$

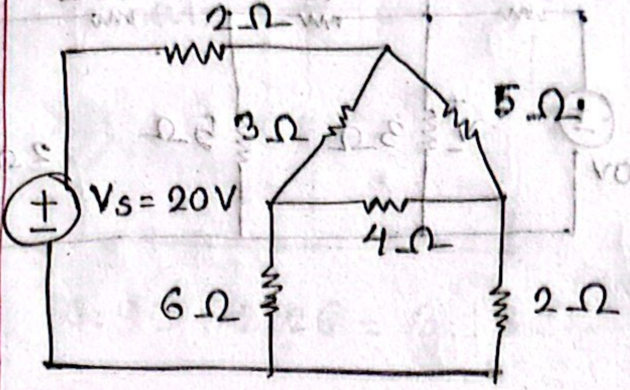
$$= (6\,||\,9)+2$$

$$R_{eq} = 3.6+2 = 5.6$$

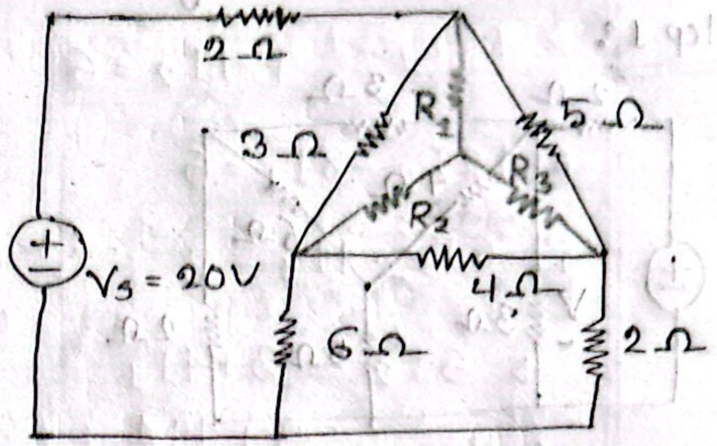
$$\therefore\ I = \frac{V_s}{R_{eq}} = \frac{20}{5.6} = 3.5\,A \text{ (Ans)}$$

Wecan also solve this by $\Delta$ to $Y$ conversion:

Step 1:




Step 2:

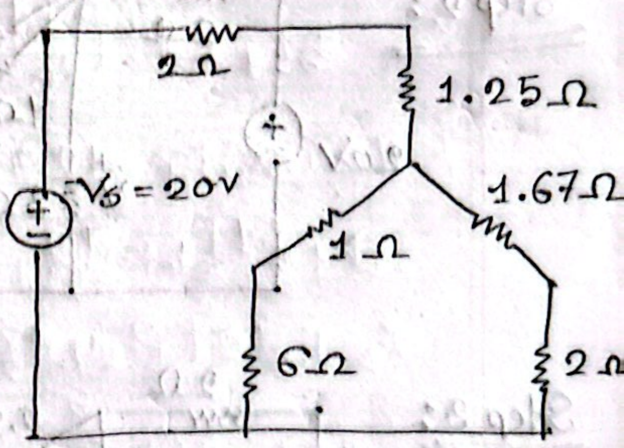



$$R_1 = \frac{5\times 3}{3+4+5} = 1.25\,\Omega$$

$$R_2 = \frac{3\times 4}{3+4+5} = 1\,\Omega$$

$$R_3 = \frac{5\times 4}{3+4+5} = 1.67\,\Omega$$

Step 3:




$$R_{eq} = \left((1+6)\,||\,(1.67+2)\right) + 1.25 + 2$$

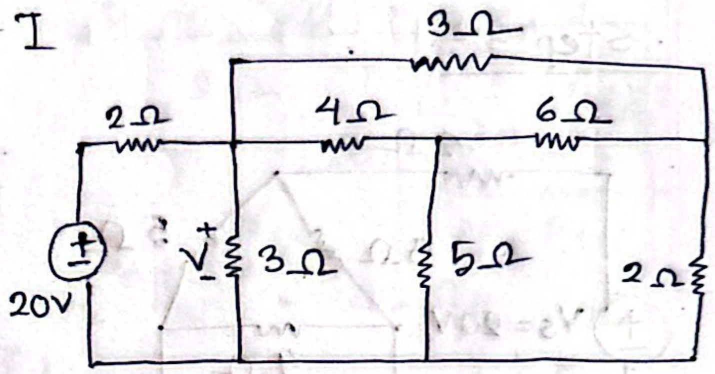
$$= 2.40 + 1.25 + 2$$

$$= 5.65\,\Omega$$

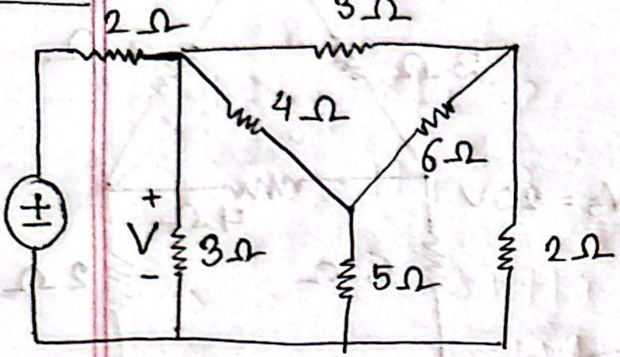
$$I = \frac{V_s}{R_{eq}} = \frac{20}{5.65} = 3.54\,A \text{ (Ans)}$$

09/07/2024

# Determine the current I and the voltage V.




Step 1:



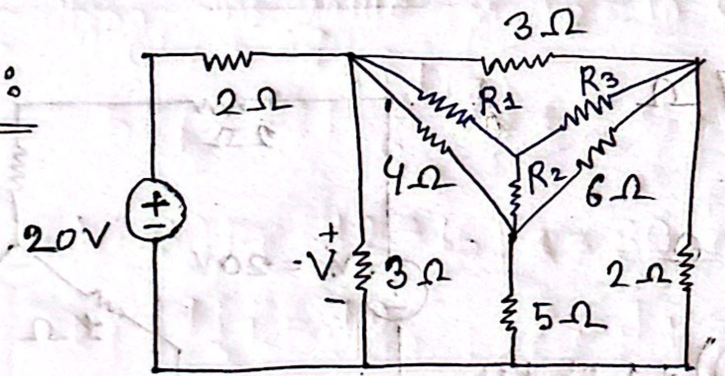

∇ connection

$$R_1 = \frac{4\times 3}{3+4+6} = 0.92\Omega$$

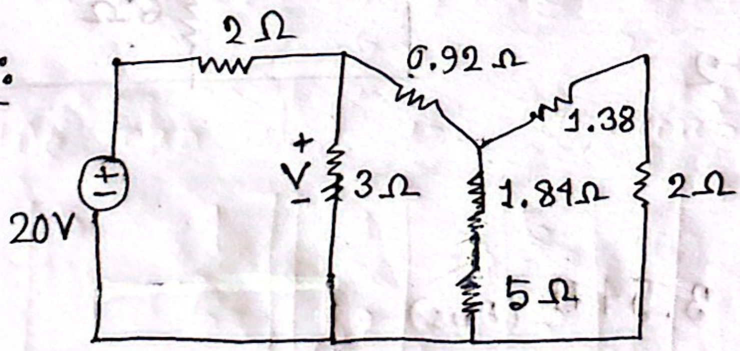
$$R_2 = \frac{6\times 4}{3+4+6} = 1.84\Omega$$

$$R_3 = \frac{3\times 6}{3+4+6} = 1.38\Omega$$

Step 2:



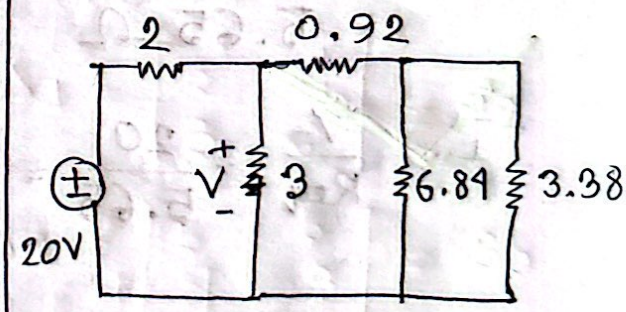

Step 3:




$1.84 + 5 = 6.84\Omega$

$1.38 + 2 = 3.38\Omega$

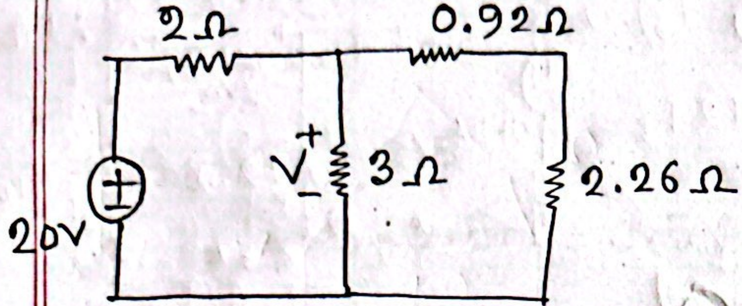
Step 4:




$6.84 \| 3.38 = 2.26\Omega$

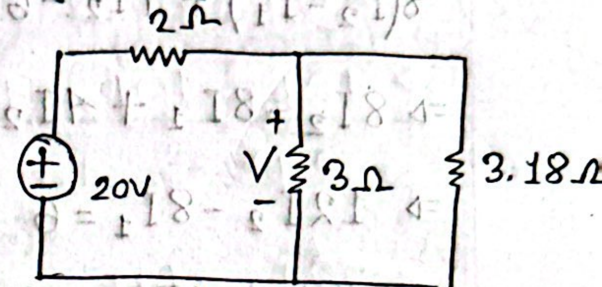
Scanned with CamScanner

**Step 5:**



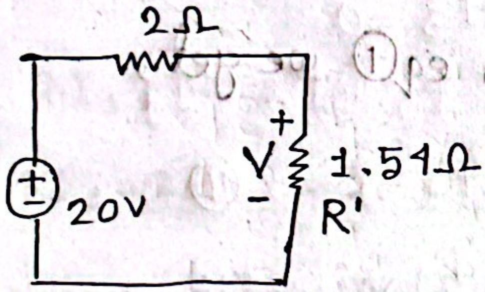

$0.92 + 2.26 = 3.18\,\Omega$

**Step 6:**




$3 \| 3.18 = 1.54\,\Omega$

**Step 7:**



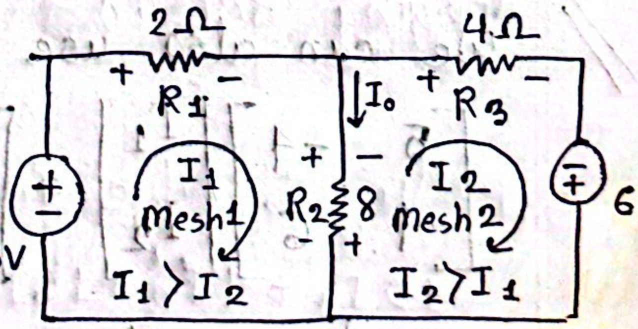

$\therefore R_{eq} = 2 + 1.54\,\Omega$
$= 3.54\,\Omega$

$\therefore I = \frac{V_s}{R_{eq}} = \frac{20}{3.54} = 5.65\,A$

$\therefore V = IR' = 5.65 \times 1.54 = 8.7V$

## Mesh Analysis

Find $I_1, I_2, I_0$.




$R_1 = 2\,\Omega$
$R_2 = 8\,\Omega$
$R_3 = 4\,\Omega$

KVL in mesh 1,

$-10 + 2I_1 + 8(I_1 - I_2) = 0$

$\Rightarrow 2I_1 + 8I_1 - 8I_2 = 10$

$\Rightarrow 10I_1 - 8I_2 = 10$

$\therefore 5I_1 - 4I_2 = 5$ ---- (1)

KVL in mesh 2,

$$8(I_2 - I_1) + 4I_2 - 6 = 0$$

$$\Rightarrow 8I_2 - 8I_1 + 4I_2 = 6$$

$$\Rightarrow 12I_2 - 8I_1 = 6$$

$$\therefore 6I_2 - 4I_1 = 3 \quad \text{----} (11)$$

$$\Rightarrow 6I_2 = 3 + 4I_1$$

$$\therefore I_2 = \frac{3 + 4I_1}{6}$$

putting the value of $I_2$ in eq (1) we get,

$$5I_1 - 4\left(\frac{3+4I_1}{6}\right) = 5$$

$$\Rightarrow 30I_1 - 12 - 16I_1 = 30$$

$$\Rightarrow 14I_1 = 42 \qquad \therefore I_1 = 3A \text{ (Ans)}$$

$$\therefore I_2 = \frac{3 + (4 \times 3)}{6} = \frac{15}{6} = 2.5A \text{ (Ans)}$$

// We can also use Cramer's Rule to find $I_1, I_2$

$$\begin{bmatrix} 5 & -4 \\ -4 & 6 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$$

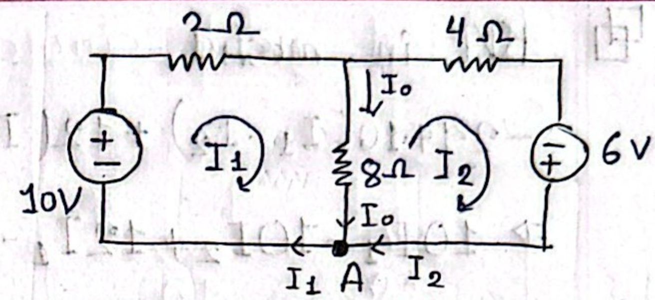
$$\Delta = \begin{bmatrix} 5 & -4 \\ -4 & 6 \end{bmatrix} = 14$$

$$\Delta_1 = \begin{bmatrix} 5 & -4 \\ 3 & 6 \end{bmatrix} = 42$$

$$\Delta_2 = \begin{bmatrix} 5 & 5 \\ -4 & 3 \end{bmatrix} = 35$$

$$I_1 = \frac{\Delta_1}{\Delta} = 3A \; ; \; I_2 = \frac{\Delta_2}{\Delta} = 2.5$$

Applying KCL in node A,

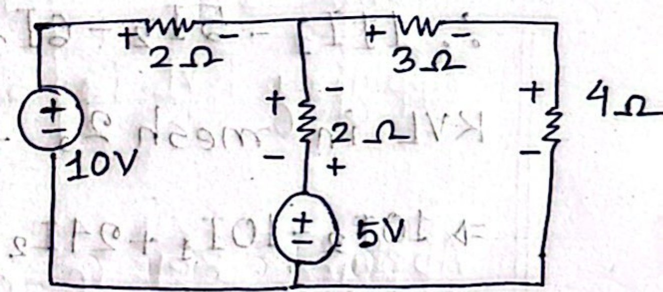



$I_1 = I_o + I_2$

$\Rightarrow 3 = I_o + 2.5$

$\therefore I_o = 3 - 2.5 = 0.5\,A$. (Ans)

Find the mesh currents.




Applying KVL in mesh 1,

$-10 + 2I_1 + 2(I_1 - I_2) + 5 = 0$

$\Rightarrow 2I_1 + 2I_1 - 2I_2 = 10 - 5$

$\Rightarrow 4I_1 - 2I_2 = 5$ - - - - - (I)

Applying KVL in mesh 2, $-5 + 2(I_2 - I_1) + 3I_2 + 4I_2 = 0$

$\Rightarrow 2I_2 - 2I_1 + 3I_2 + 4I_2 = 5$

$\Rightarrow -2I_1 + 9I_2 = 5$ - - - - - (II)

$$\begin{bmatrix} 4 & -2 \\ -2 & 9 \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 5 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 4 & -2 \\ -2 & 9 \end{bmatrix} = 36 - (4) = 32$$

$$\Delta_1 = \begin{bmatrix} 5 & -2 \\ 5 & 9 \end{bmatrix} = 45 - (-10) = 55$$

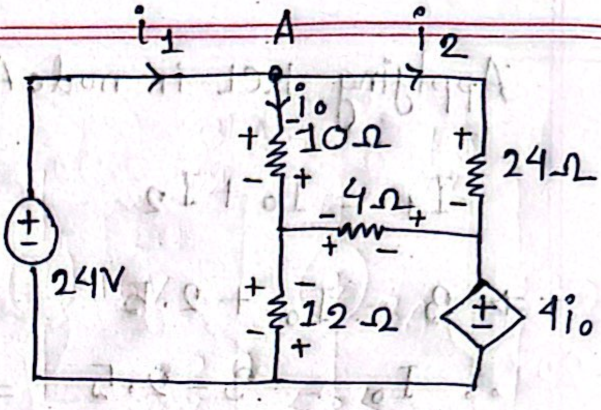
$$\Delta_2 = \begin{bmatrix} 4 & 5 \\ -2 & 5 \end{bmatrix} = 20 - (-10) = 30$$

$I_1 = \frac{\Delta_1}{\Delta} = \frac{55}{32} = 1.7\,A$ (Ans)

$I_2 = \frac{\Delta_2}{\Delta} = 0.93\,A$ (Ans)

KVL in mesh 1,

$-24+10(I_1-I_2)+12(I_1-I_3)=0$




$\Rightarrow 10I_1-10I_2+12I_1-12I_3 = 24$

$\Rightarrow 22I_1-10I_2-12I_3=24$

$\therefore 11I_1-5I_2-6I_3=12$ ---- (I)

KVL in mesh 2, $+10(I_2-I_1)+24I_2+4(I_2-I_3)=0$

$\Rightarrow 10I_2-10I_1+24I_2+4I_2-4I_3=0$

$\Rightarrow -10I_1+38I_2-4I_3=0$

$\therefore -5I_1+19I_2-2I_3=0$ ---- (II)

KVL in mesh 3, $12(I_3-I_1)+4(I_3-I_2)+4i_o=0$

$\Rightarrow 12I_3-12I_1+4I_3-4I_2+4i_o=0$

$\Rightarrow -12I_1-4I_2+16I_3+4i_o=0$ ---- (III)

Applying KCL in node A, $I_1=I_2+i_o$

$\therefore i_o=I_1-I_2$

putting $i_o$ value in eq (III),

$-12I_1-4I_2+16I_3+4(I_1-I_2)=0$

$\Rightarrow -12I_1-4I_2+16I_3+4I_1-4I_2=0$

$\Rightarrow -8I_1-8I_2+16I_3=0$ $\therefore -I_1-I_2+2I_3=0$

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$$\begin{bmatrix} 11 & -5 & -6 \\ -5 & 19 & -2 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 12 \\ 0 \\ 0 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 11 & -5 & -6 \\ -5 & 19 & -2 \\ -1 & -1 & 2 \end{vmatrix} = 11(38-2) - (-5)(-10-2) - 6(5+19)$$
$$= 192$$

$$\Delta_1 = \begin{vmatrix} 12 & -5 & -6 \\ 0 & 19 & -2 \\ 0 & -1 & 2 \end{vmatrix} = 12(38-2) - 0 + 0$$
$$= 432$$

$$\Delta_2 = \begin{vmatrix} 11 & 12 & -6 \\ -5 & 0 & -2 \\ -1 & 0 & 2 \end{vmatrix} = 11(0-0) - 12(-10+2) - 6(0-0)$$
$$= (-12 \times -8) = 96$$

$$\Delta_3 = \begin{vmatrix} 11 & -5 & 12 \\ -5 & 19 & 0 \\ -1 & 1 & 0 \end{vmatrix} = 11(0-0) + 5(0-0) + 12(-5+19)$$
$$= 168$$

$$I_1 = \frac{\Delta_1}{\Delta} = 2.25\ A$$

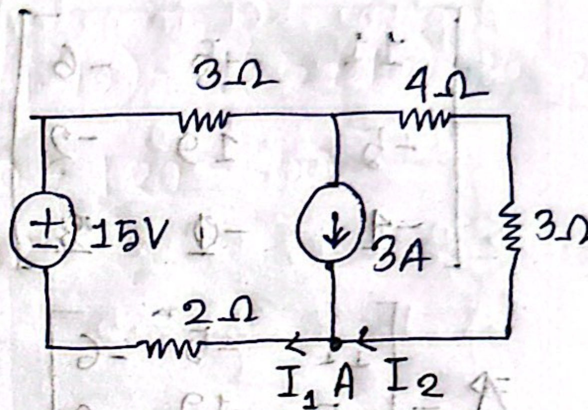
$$I_2 = \frac{\Delta_2}{\Delta} = \frac{96}{192} = 0.5\ A$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{168}{192} = 0.875\ A$$

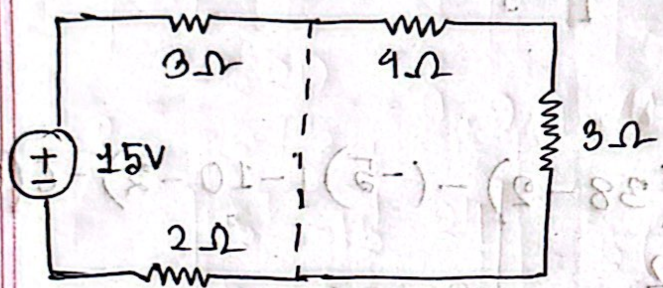
$$i_o = I_1 - I_2$$
$$= 2.25 - 0.5$$
$$= 2.20\ A$$

যদি দুটো mesh এর মাঝে current source থাকে তাহলে Supermesh = (mesh1 + mesh2) ধরে নিতে হবে)

⊞ Find mesh currents:-




Soln:




Applying KVL in supermesh, $-15+3I_1+4I_2+3I_2+2I_1=0$

$\Rightarrow 5I_1+7I_2=15$ ---- (i)

Applying KCL in node A, $I_S+I_2=I_1$

$\Rightarrow I_1-I_2=3$

$\therefore I_1=I_2+3$ ---- (ii)

putting eq(ii) in eq(i),

$5(I_2+3)+7I_2=15$

$\Rightarrow 5I_2+15+7I_2=15$

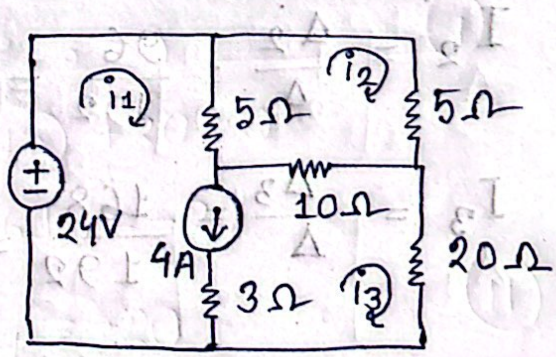
$\Rightarrow 12I_2=0$

$\therefore I_2=0\ A$ (Ans)

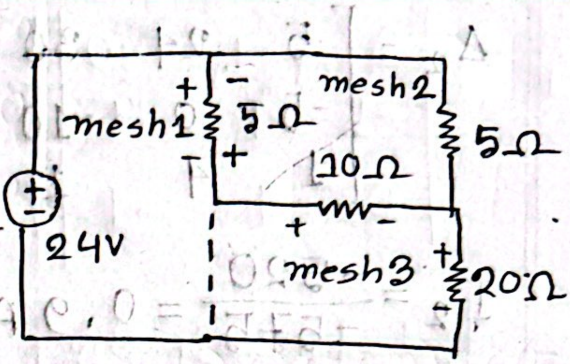
$I_1=0+3$

$\therefore I_1=3A$ (Ans)

⊞ Find mesh currents.



KVL in Supermesh (mesh 1 + mesh 3);




$-24 + 5(I_1 - I_2) + 10(I_3 - I_2) + 20I_3 = 0$

$\Rightarrow 5I_1 - 5I_2 + 10I_3 - 10I_2 + 20I_3 = 24$

$\Rightarrow 5I_1 - 15I_2 + 30I_3 = 24$ ------ (i)

KVL in mesh 2, $5(I_2 - I_1) + 5I_2 + 10(I_2 - I_3) = 0$

$\Rightarrow 5I_2 - 5I_1 + 5I_2 + 10I_2 - 10I_3 = 0$

$\Rightarrow 20I_2 - 5I_1 - 10I_3 = 0$ ----- (ii)

Apply KCL in node A, $I_1 = 4 + I_3$ ------ (iii)

$$\begin{bmatrix} 5 & -15 & 30 \\ -5 & 20 & -10 \\ 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 24 \\ 0 \\ 4 \end{bmatrix}$$

$\Delta = 5(20-0) - (-15)(-5+10) + 30(0-20)$

$\Delta = 100 - 75 - 600 = -575$

$\Delta_1 = \begin{bmatrix} 24 & -15 & 30 \\ 0 & 20 & -10 \\ 4 & 0 & 1 \end{bmatrix} = -2520$

$= 24(20-0) + 15(0-40) + 30(0-80)$

$\Delta_1 = 480 + (-600) + (-2400) = -2520$

$I_1 = \frac{-2520}{-575}$

$= 4.38\ A$ (Ans)

$$\Delta_2 = \begin{bmatrix} 5 & 24 & 30 \\ -5 & 0 & -10 \\ 1 & 4 & 1 \end{bmatrix} = 5(0+40) - 24(-5+10) + 30(-20)$$

$$= 200 - 120 - 600$$

$$= -520$$

$$I_2 = \frac{-520}{-575} = 0.9\,A \text{ (Ans)}$$

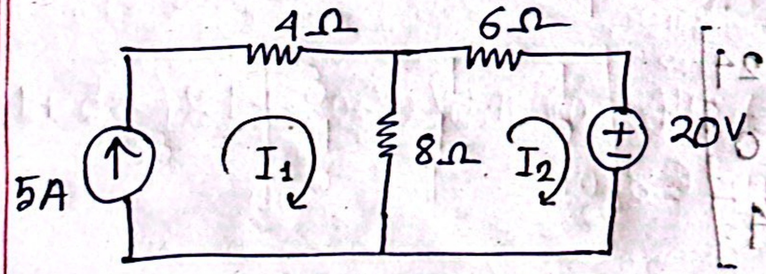
$$\Delta_3 = \begin{bmatrix} 5 & -15 & 24 \\ -5 & 20 & 0 \\ 1 & 0 & 4 \end{bmatrix} = 5(80-0) + 15(-20+0) + 24(0-20)$$

$$= 400 - 300 - 480$$

$$= -380$$

$$I_3 = \frac{-380}{-575} = 0.66\,A \text{ (Ans)}$$

□ Find mesh currents




KVL in mesh 1, $4I_1 + 8(I_1 - I_2) = 0$

$$\Rightarrow 4I_1 + 8I_1 - 8I_2 = 0$$

$$\Rightarrow 12I_1 - 8I_2 = 0 \quad \text{——— (I)}$$

KVL In mesh 2, $8(I_2 - I_1) + 6(I_2) + 20 = 0$

$$\Rightarrow 8I_2 - 8I_1 + 6I_2 = -20$$

$$\Rightarrow 14I_2 - 8I_1 = -20 \quad \text{——— (II)}$$

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~~Applying KCL in node A, $I_1$~~ For mesh 1,

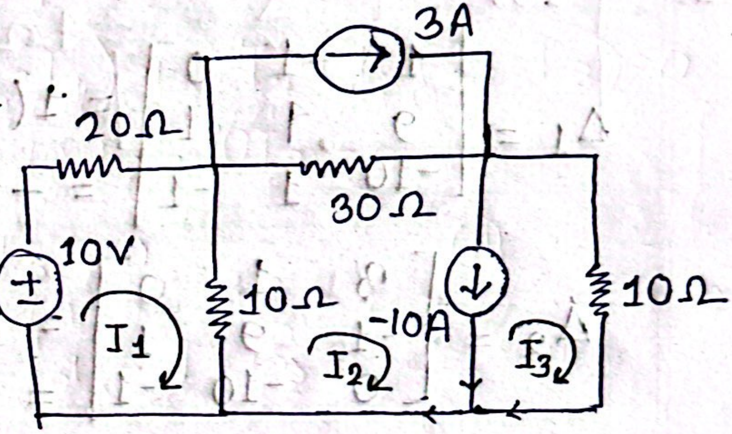
We can say $I_1 = 5A$ (Ans)

putting this value in eq (ii),

$$14 I_2 - (8 \times 5) = -20$$

$$\Rightarrow I_2 = \frac{-20+40}{14} = 1.42\,A \text{ (Ans)}$$

Lab




KVL in mesh 1,

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

$$\Rightarrow 20I_1 + 10I_1 - 10I_2 = 10$$

$$\Rightarrow 30I_1 - 10I_2 = 10$$

$$\therefore 3I_1 - I_2 = 1 \quad \text{---- (i)}$$

KVL in (mesh 2 + mesh 3) = Supermesh,

$$10(I_2 - I_1) + 30(I_2 - 3) + 10(I_3)\cancel{R2} = 0$$

$$\Rightarrow 10I_2 - 10I_1 + 30I_2 - 90 + 10I_3 \cancel{-10I_2} = 0$$

$$\Rightarrow -10I_1 + 40I_2 + 10I_3 = 90$$

$$\Rightarrow -I_1 + 4I_2 + I_3 = 9 \quad \text{---- (ii)}$$

KVL in node (A), $I_2 = -10 + I_3$

$$I_2 - I_3 = -10 \quad \text{---- (iii)}$$

$$\begin{bmatrix} 3 & -1 & 0 \\ -1 & 4 & 1 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 9 \\ -10 \end{bmatrix}$$

$$\Delta = \begin{bmatrix} 3 & -1 & 0 \\ -1 & 4 & 1 \\ 0 & 1 & -1 \end{bmatrix} = 3(-4-1) - (-1)(1-0) + 0$$
$$= -14$$

$$\Delta_1 = \begin{bmatrix} 1 & -1 & 0 \\ 9 & 4 & 1 \\ -10 & 1 & -1 \end{bmatrix} = 1(-4-1) - (-1)(-9+10) + 0$$
$$= -4$$

$$\Delta_2 = \begin{bmatrix} 3 & 1 & 0 \\ -1 & 9 & 1 \\ 0 & -10 & -1 \end{bmatrix} = 3(-9+10) - 1(1-0) + 0$$
$$= 2$$

$$\Delta_3 = \begin{bmatrix} 3 & -1 & 1 \\ -1 & 4 & 9 \\ 0 & 1 & -10 \end{bmatrix} = 3(-40-9) - (-1)(10-0) + 1(-1-0)$$
$$= -138$$

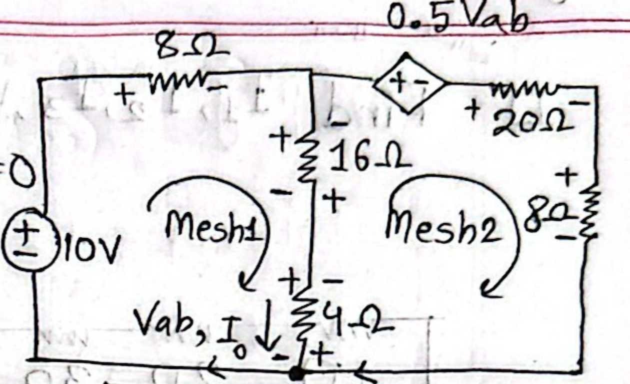
$$I_1 = \frac{\Delta_1}{\Delta} = \frac{-4}{-14} = 0.285\ A$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{2}{-14} = 0.142\ A$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{-138}{-14} = 9.85\ A$$

## Lab2

KVL in mesh 1,




$-10+8I_1+16(I_1-I_2)+4(I_1-I_2)=0$

$\Rightarrow 8I_1+20I_1-20I_2=10$

$\Rightarrow 28I_1-20I_2=10$

$\Rightarrow 14I_1-10I_2=5$ —— (1)

KCL, $I_0+I_2=I_1$

$\therefore I_0=I_1-I_2$

KVL in mesh 2, $4(I_2-I_1)+16(I_2-I_1)+0.5V_{ab}$

$+20I_2+8I_2=0$

$\Rightarrow 4I_2-4I_1+16I_2-16I_1+0.5(4I_1-4I_2)+28I_2=0$

$\Rightarrow 20I_2-4I_1+2I_1-2I_2+28I_2=0$

$\Rightarrow -18I_1+46I_2=0$

$\Rightarrow -9I_1+23I_2=0$ $\therefore 9I_1-23I_2=0$

$$\begin{bmatrix}14 & -10\\ 9 & -23\end{bmatrix}\begin{bmatrix}I_1\\ I_2\end{bmatrix}=\begin{bmatrix}5\\ 0\end{bmatrix}$$

$\Delta(-322+90)=-232$

$\Delta_1=\begin{bmatrix}5 & -10\\ 0 & -23\end{bmatrix}=-115$

$\Delta_2=\begin{bmatrix}14 & 5\\ 9 & 0\end{bmatrix}=(0-45)=-45$

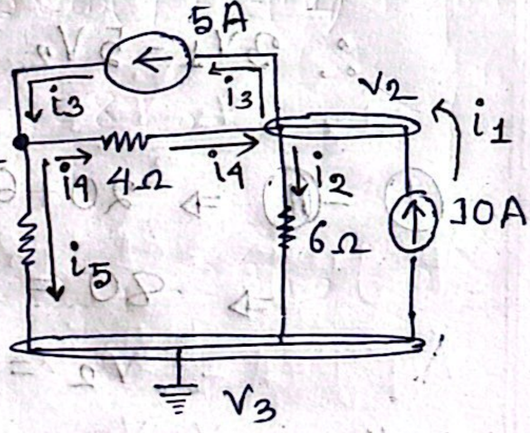
$I_1=\dfrac{-115}{-232}=0.49A$ $I_2=\dfrac{-45}{-232}=0.19A$

## □ Nodal Analysis

Steps :
1. Node identification
2. Reference/ground node ($\frac{\perp}{=}$)
3. Flow of current

Current, $i = \dfrac{V_{HIGH} - V_{LOW}}{R}$ (Current(i) যেখান থেকে pass হওয়া start হবে সেখানে $V_{HIGH}$)

$V_{HIGH} \xrightarrow{i \text{ flow}} V_{LOW}$




□ Applying Ohm's law,

$i_1 = 10A$

$i_2 = \dfrac{V_2 - 0}{6} = \dfrac{V_2}{6}$

$i_3 = 5A$

$i_4 = \dfrac{V_1 - V_2}{4}$

$i_5 = \dfrac{V_1 - 0}{2} = \dfrac{V_1}{2}$

Applying KCL at node $V_1$, $i_3 = i_4 + i_5$

$\Rightarrow 5 = \dfrac{V_1 - V_2}{4} + \dfrac{V_1}{2}$

$\Rightarrow 5 \times 4 = V_1 - V_2 + 2V_1$ $\quad \therefore 20 = 3V_1 - V_2$ ---- (1)

Applying KCL at node $V_2$,

$$i_1 + i_4 = i_2 + i_3$$

$$\Rightarrow \frac{V_1 - V_2}{4} + 10 = 5 + \frac{V_2}{6}$$

$$\Rightarrow \frac{V_1 - V_2}{4} - \frac{V_2}{6} = -5$$

$$\Rightarrow \frac{3V_1 - 3V_2 - 2V_2}{12} = -5$$

$$\therefore 3V_1 - 5V_2 = -60 \text{ ---- (ii)}$$

(i) − (ii) $\Rightarrow 20 + 60 = \cancel{3V_1} - V_2 - \cancel{3V_1} + 5V_2$

$$\Rightarrow 80 = 4V_2$$

$$\therefore V_2 = 20V$$

putting $V_2$ in eq (i), $3V_1 - 20 = 20$

$$\Rightarrow 3V_1 = 40$$

$$\therefore V_1 = \frac{40}{3} = 1.33V$$

$$i_2 = \frac{V_2}{6} = 3.33V$$

$$i_4 = \frac{V_1 - V_2}{4} = -4.66V$$

$$i_5 = \frac{V_1}{2} = 0.66V_1 =$$

Determine node voltage:

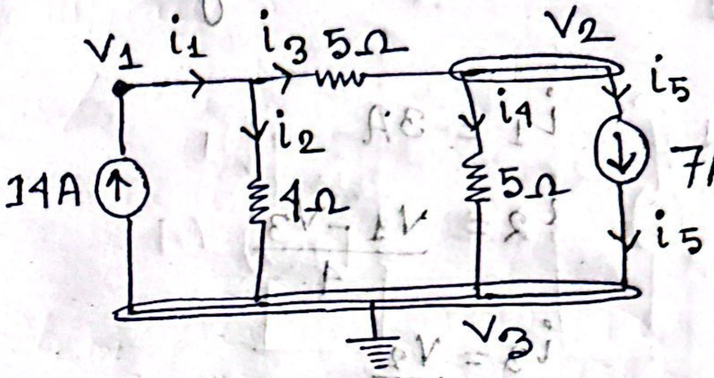
$i_1 = 14A$

$i_2 = \frac{V_1 - 0}{4} = \frac{V_1}{4}$

$i_3 = \frac{V_1 - V_2}{5}$

$i_4 = \frac{V_2}{5}$

$i_5 = 7A$




Applying KCL at $V_1$,

$i_1 = i_2 + i_3$

$\Rightarrow 14 = \frac{V_1}{4} + \frac{V_1 - V_2}{5}$

$\Rightarrow 20 \times 14 = 5V_1 + 4V_1 - 4V_2$

$\Rightarrow 280 = 9V_1 - 4V_2$ ——— (i)

Applying KCL at node $V_2$,

$i_3 = i_4 + i_5$

$\Rightarrow \frac{V_1 - V_2}{5} = \frac{V_2}{5} + 7$

$\Rightarrow \frac{V_1 - V_2 - V_2}{5} = 7$

$\Rightarrow V_1 - 2V_2 = 35$ ——— (ii)

(i) $- (2 \times$ (ii)$)$,

$280 - 70 = 9V_1 - \cancel{4V_2} - 2V_1 + \cancel{4V_2}$

$\Rightarrow 210 = 7V_1$

$\Rightarrow V_1 = \frac{210}{7} = 30V$

putting the value in eq (ii),

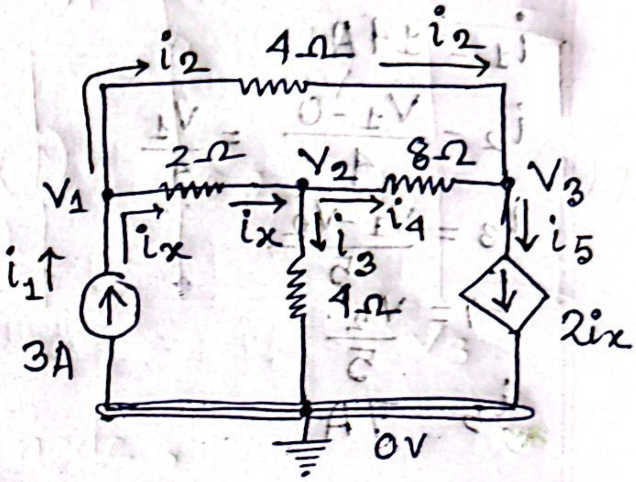
$30 - 2V_2 = 35$

$\Rightarrow -2V_2 = 5$

$\therefore V_2 = \frac{5}{-2} = -2.5V$

Node

Determine Node Voltages and $i_x$.




$i_1 = 3A$

$i_2 = \frac{V_1 - V_3}{4}$

$i_3 = \frac{V_2}{4}$

$i_4 = \frac{V_2 - V_3}{8}$

$i_5 = 2i_x = 2 \times \frac{V_1 - V_2}{2} = V_1 - V_2$

$i_x = \frac{V_1 - V_2}{2}$

Applying KCL in node 1,

$i_1 = i_2 + i_x$

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

$\Rightarrow 12 = 2V_1 - 2V_3 + 2V_1 - 2V_2$

$\therefore 3V_1 - 2V_1 - V_3 = 12$ — (i)

Applying KCL in node 2, $i_x = i_3 + i_4$

$\Rightarrow \frac{V_1 - V_2}{2} = \frac{V_2}{4} + \frac{V_2 - V_3}{8}$

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

$$\Rightarrow 8V_1 - 8V_2 = 4V_2 + 2V_2 - 2V_3$$

$$\therefore 4V_1 - 7V_2 + V_3 = 0 \quad \text{—— (ii)}$$

Applying KCL at node 3,

$$i_2 + i_4 = i_5$$

$$\Rightarrow \frac{V_1 - V_3}{4} + \frac{V_2 - V_3}{8} = V_1 - V_2$$

$$\Rightarrow 2V_1 - 2V_3 + V_2 - V_3 = 8V_1 - 8V_2$$

$$\therefore 2V_1 - 3V_2 + V_3 = 0 \quad \text{—— (iii)}$$

$$\Delta = \begin{bmatrix} 3 & -2 & -1 \\ 4 & -7 & 1 \\ 2 & -3 & 1 \end{bmatrix} = -10$$

$$\Delta_1 = \begin{bmatrix} 12 & -2 & -1 \\ 0 & -7 & 1 \\ 0 & -3 & 1 \end{bmatrix} = -48$$

$$\Delta_2 = \begin{bmatrix} 3 & 12 & -1 \\ 4 & 0 & 1 \\ 2 & 0 & 1 \end{bmatrix} = -24$$

$$\Delta_3 = \begin{bmatrix} 3 & -2 & 12 \\ 4 & -7 & 0 \\ 2 & -3 & 0 \end{bmatrix} = 24$$

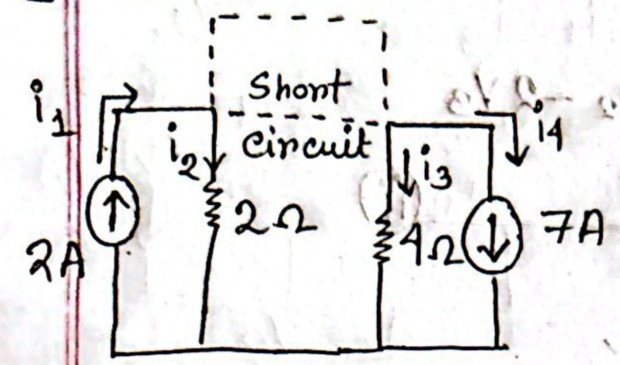
$$V_1 = \frac{-48}{-10} = 4.8 \text{ V}$$

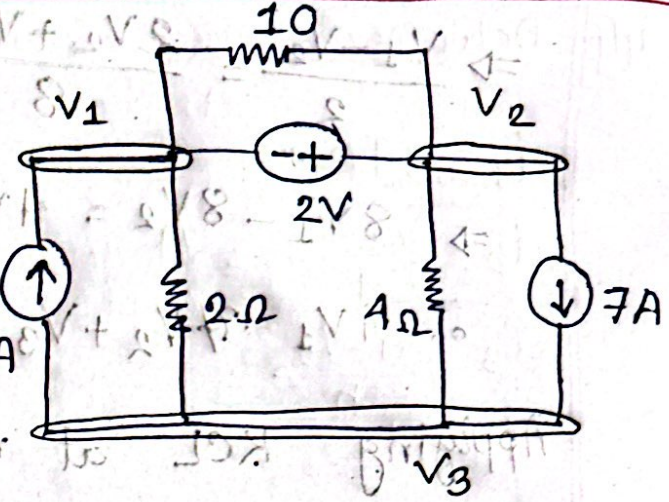
$$V_2 = \frac{-24}{-10} = 2.4 \text{ V}$$

$$V_3 = \frac{24}{-10} = -2.4 \text{ V}$$

$$i_x = \frac{V_1 - V_2}{2} = 1.2 \text{ A}$$

Solution:




Applying KCL in Super node,

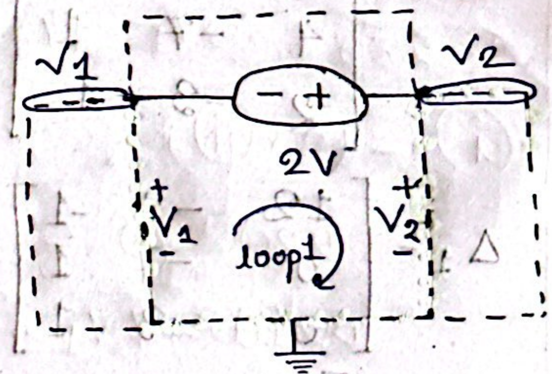
$$i_1 = i_2 + i_3 + i_4$$

$$\Rightarrow 2 = i_2 + i_3 + 7$$

$$\Rightarrow \frac{V_1}{2} + \frac{V_2}{4} = -5$$

$$\therefore 2V_1 + V_2 = -20 \quad \text{—— (I)}$$

Applying KVL in loop 1,




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

$$\Rightarrow V_2 - V_1 = 2 \quad \text{—— (II)}$$

eq (I) − eq (II), $2V_1 + V_2 - V_2 + V_1 = -20 - 2$

$$\Rightarrow 3V_1 = -22 \qquad \therefore V_1 = \frac{-22}{3} = -7.33V$$

putting in eq (II),

$$\therefore V_2 = 2 + V_1 = 2 - 7.33 = -5.33 V$$