Basic Electrical Engineering

Charge and current:

The relationship between current i, charge q and time t is

$$i = \frac{dq}{dt} \quad \text{--- (1)}$$

Integrating both side

$$Q = \int_{t_0}^{t} i\,dt.$$

Voltage:

$$V = \frac{dw}{dq} \quad \text{--- (2)}$$

Power: $p = \frac{w}{t}$

$$= \frac{dw}{dt} \quad \text{--- (3)}$$

(1), (2), (3) $\Rightarrow$

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = VI$$

$$\boxed{p = VI}$$

Example: 1.4

$i = 2A \qquad dw = 2.3\,kJ = 2.3 \times 10^3$

$t = 10s.$

The total charge,

$\Delta q = I \Delta t$

$= 2 \times 10 = 20C.$

The voltage drop,

$$V = \frac{dw}{\Delta q} = \frac{2.3 \times 10^3}{20} = 115\,V.$$

Practice problem:

$q = 2c \qquad q = -6c.$

$V = \frac{dw}{dq}$

$= \frac{-30}{2}$

$= -15V$

$V = \frac{dw}{dq}$

$= \frac{-30}{-6}$

$= 5V.$

Example : 1.5

$i = 5\cos 60\pi t$

(a) $v = 3i$ (b) $v = 3\frac{di}{dt}$

(a) The valtage is $v = 3i$

$= 3 \times 5\cos 60\pi t$

$= 15\cos 60\pi t$

$p = vi$

$= 75\cos^2 60\pi t$

At, $t = 3ms$,

$p = 75\cos^2(60\pi \times 3 \times 10^{-3})$

$= 53.48\ w.$

$3\times(-60\pi)\, 5\sin 60\pi t$

(b) $v = 3\frac{di}{dt}$

$= 3(-60\pi) 5\sin 60\pi t = -900\pi \sin 60\pi t\ V.$

$p = vi = -4500\pi \sin 60\pi t \cos 60\pi t\ W$

At, $t = 3ms$

$p = -4500\pi \sin 0.18\pi \cos 0.18\pi\ W$

$= -14137.167 \sin 32.4^0 \cos 32.4^0$

$= -6.396\ kW.$

Practice problem: 1.6

$V = 240\ v$

$i = 15\ A$

$dw = 60\ kJ$

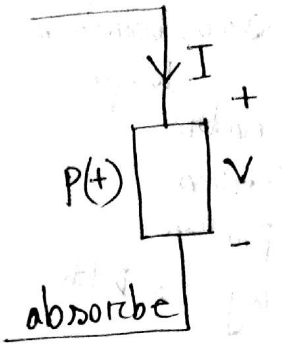
$t = ?$

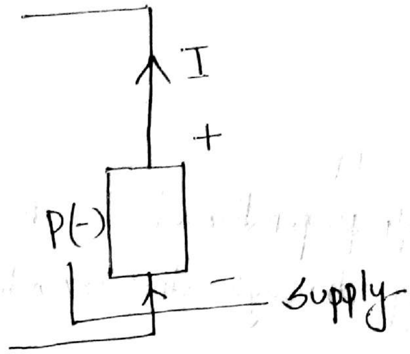
$p = vi = 240 \times 15 = 3600$

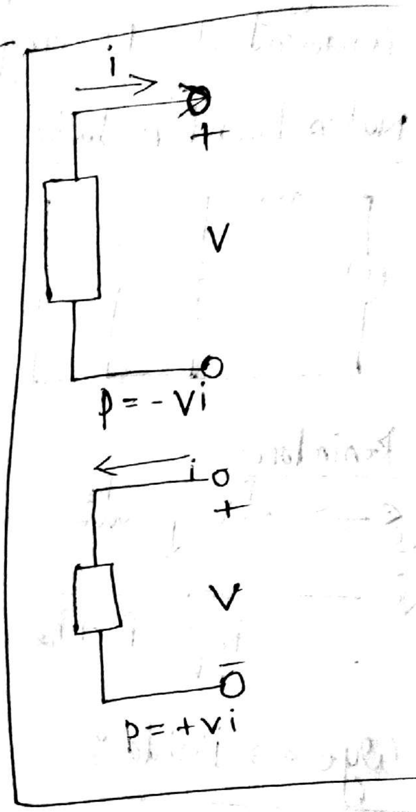
$p = \frac{dw}{dt}$

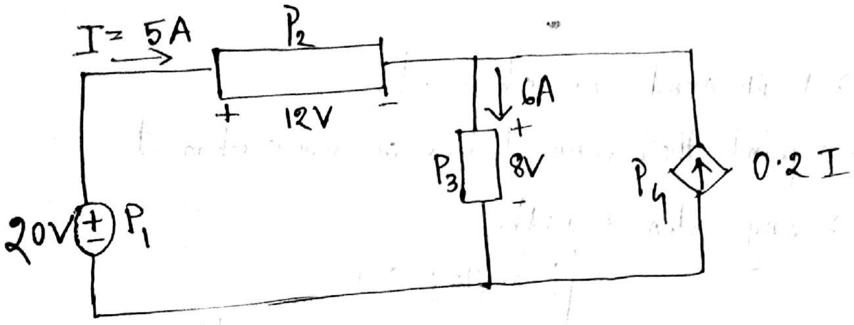
$dt = \frac{dw}{p} = \frac{6000}{3600}$

$= 16.667\ s.$









we, know,

$p = VI$

$P_1 = -VI$

$= -(20 \times 5)$

$= -100\,W$

$\boxed{\text{supplied power}}$

$P_2 = 12 \times 5$
$= 60W$

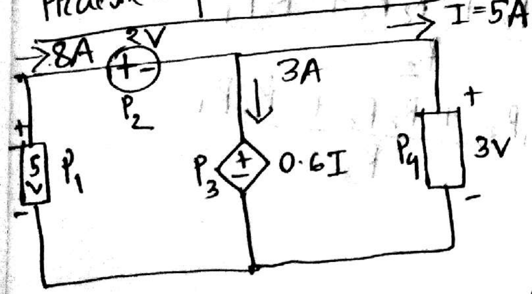
$P_3 = 8 \times 6$
$= 48W$

$P_4 = 8 \times (-0.2 \times 5)$
$= -8W$

$\therefore P_1 + P_2 + P_3 + P_4 = -100 + 60 + 48 - 8$

$\Sigma P = 0$

Practice problem: 1.7



$P_1 = -(5 \times 8)$
$= -40\,W$

$P_2 = 2 \times 8$
$= 16W$

$P_3 = 3 \times (0.6 \times 5)$
$= 9$

$P_4 = 3 \times 5$
$= 15W$

$\therefore P_1 + P_2 + P_3 + P_4 = -40 + 16 + 9 + 15$

$\therefore \Sigma P = 0$

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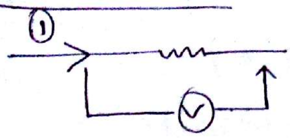
Ohm's law:

(1)



$V \propto I \rightarrow V = IR$

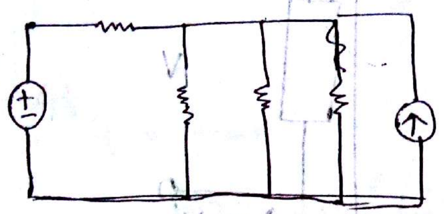
Voltage V, is directly proportional to the current I, flowing through the resistor.

(2.2) → ohm's law

(2.3) → Nodes, branches loops

→ Resistors
→ series
→ parallels
→ wye ↔ Delta.

Nodes, branches, loops:



branch → represent one element.

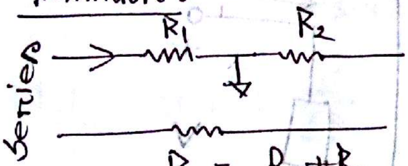
node → a point that connect two or more element

loops → any closed path.

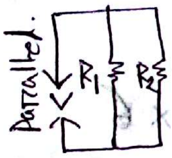
Example: 2.1

$$R = \frac{V}{I} = \frac{120}{2} = 60\,\Omega.$$

Resistors:

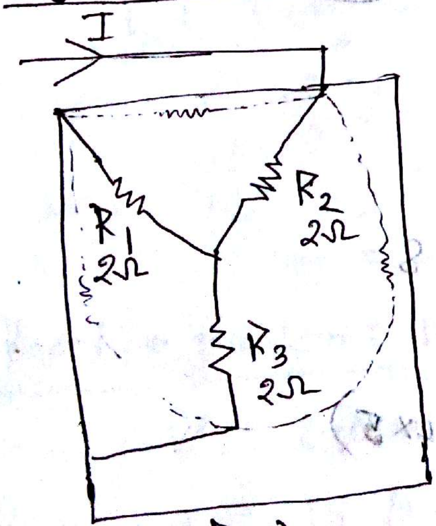


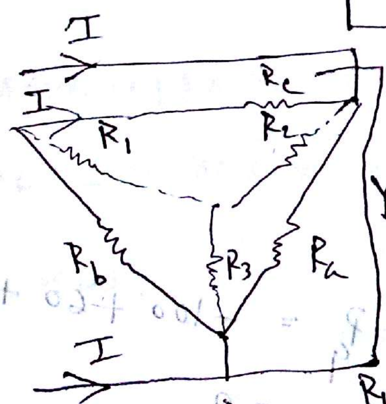
$R_{eq} = R_1 + R_2$



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

Wye ↔ Delta:





Y to Δ

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

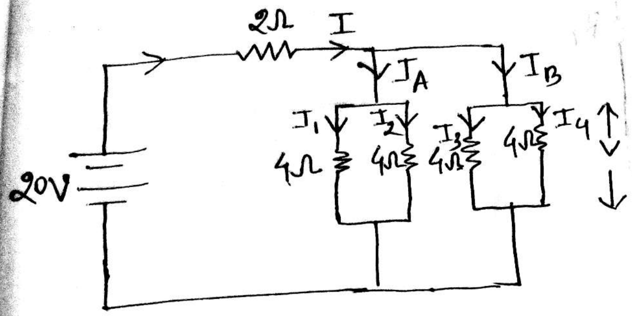
$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

$$R_1 = \frac{R_bR_c}{R_a + R_b + R_c}$$

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

$$R_3 = \frac{R_aR_b}{R_a + R_b + R_c}$$



$$\frac{1}{R} = \frac{1}{4} + \frac{1}{4}$$

$$\frac{1}{R} = \frac{1}{2} \Rightarrow R = 2$$

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{4}$$

$$\frac{1}{R} = \frac{1}{2} \Rightarrow R = 2$$

$$\frac{1}{R} = \frac{1}{2} + \frac{1}{2}$$

$$= 1$$

$$R = 2 + 1 = 3\Omega.$$

$$V = IR$$

$$I = \frac{V}{R} = \frac{20}{3} = 6.66$$

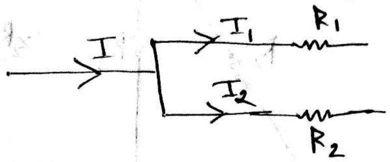
$$I_A = \left(\frac{2}{2+2}\right) 6.66$$

$$= 3.33$$

$$I_B = \left(\frac{2}{2+2}\right) \times 6.66$$

$$= 3.33$$

Current Dividere Rule :



(I) → I_1 and I_2

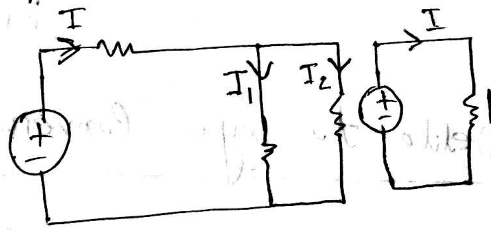
$$I_1 = \frac{R_2}{R_1 + R_2} \times I$$

$V = IR \; (V_1 \cdots\cdots)$

$P = VI$

$\hookrightarrow E = Pt.$

$$I_2 = \frac{R_1}{R_1 + R_2} \times I$$



$$I_1 = \left(\frac{2}{2+2}\right) \times 3.3$$

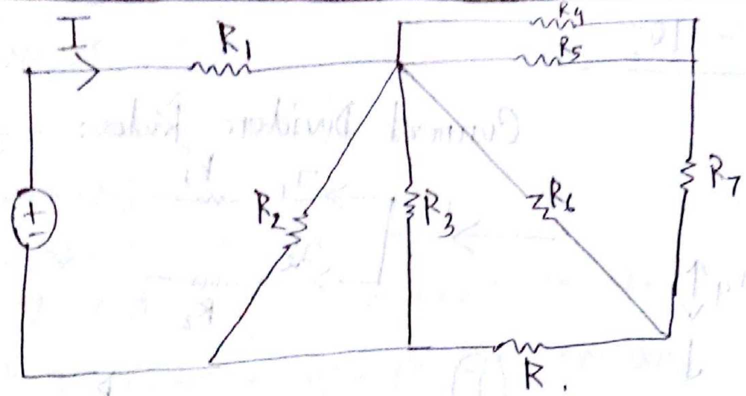
$$= 1.665$$

$$I_2 = \left(\frac{2}{2+2}\right) \times 3.33$$

$$= 1.665$$

CT ⇒ প্রথম থেকে শুরু করে wye Δ পর্যন্ত। (2.5 - 17)

Q ⊛



$$\boxed{\frac{1}{R_8} = \frac{1}{R_4} + \frac{1}{R_5}} \rightarrow R$$

$$R_9 = R_8 + R_7$$

$$1/R_{10} = 1/R_9 + \frac{1}{R_6}$$

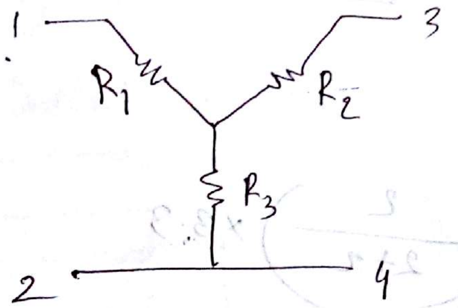
$$1/R_{11} = \frac{1}{R} + \frac{1}{R_{10}}$$

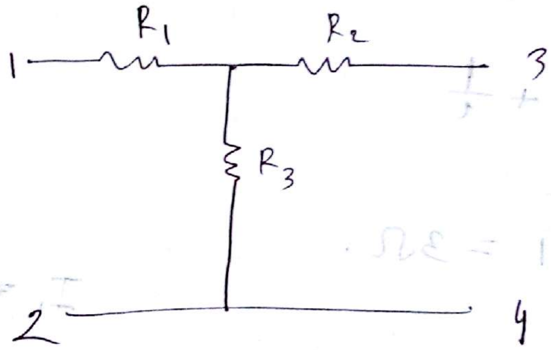
$$1/R_{12} = \frac{1}{R_{11}} + \frac{1}{R_3} + \frac{1}{R_2}$$

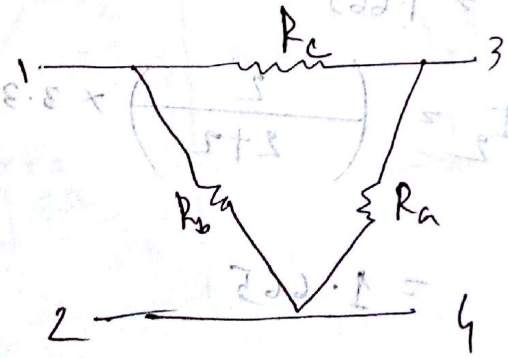
$$R_{13} = R_{12} + R_1$$

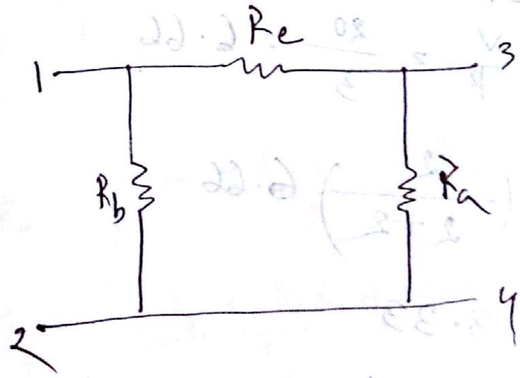
Series R_7

Delta to wye Conversion:









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

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

$$R_{12} = R_1 + R_3 = \frac{R_b(R_a+R_c)}{R_a+R_b+R_c} \quad \text{— (1)}$$

Similarly:

$$R_{13} = R_1 + R_2 = \frac{R_c(R_a+R_b)}{R_a+R_b+R_c} \quad \text{— (2)}$$

$$R_{34} = R_2 + R_3 = \frac{R_a(R_b+R_c)}{R_a+R_b+R_c} \quad \text{— (3)}$$

(1) − (3) ⟹

$$R_1 - R_2 = \frac{R_b(R_a+R_c)}{R_a+R_b+R_c} - \frac{R_a(R_b+R_c)}{R_a+R_b+R_c}$$

$$= \frac{\cancel{R_aR_b} + R_bR_c - \cancel{R_aR_b} - R_aR_c}{R_a+R_b+R_c}$$

$$= \frac{R_c(R_b-R_a)}{R_a+R_b+R_c} \quad \text{— (4)}$$

(2) + (4) ⟹

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

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

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

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

C

(1)-(2) ⇒

(2)-(4) ⇒

$$R_1 = \frac{R_bR_c}{R_1+R_2+R_3} \quad \text{— (5)}$$

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

$$\text{or } 2R_2 = \frac{R_aR_c + \cancel{R_bR_c} - \cancel{R_bR_c} + R_aR_c}{R_a+R_b+R_c}$$

$$\text{or } 2R_2 = \frac{2R_aR_c}{R_a+R_b+R_c}$$

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

(3) - (5)

Series

$$R_1+R_3 - R_1 = \frac{R_aR_b+R_bR_c}{R_a+R_b+R_c} - \frac{R_bR_c}{R_a+R_b+R_c}$$

$$= \frac{R_aR_b + \cancel{R_bR_c} - \cancel{R_bR_c}}{R_a+R_b+R_c}$$

$$R_3 = \frac{R_aR_b}{R_a+R_b+R_c}$$

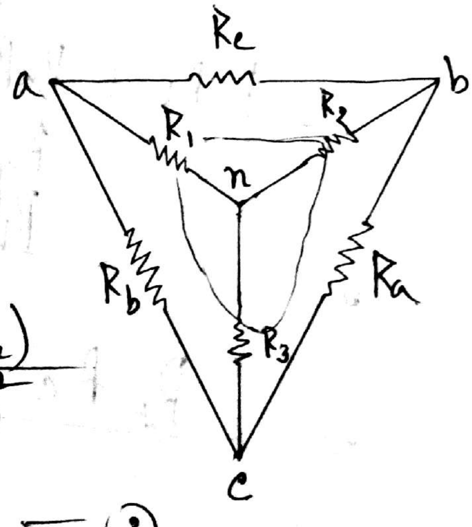
Wye to Delta:

$$R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \quad \text{— (1)}$$

$$R_3 = \frac{R_aR_b}{R_a+R_b+R_c} \quad \text{— (2)}$$

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

$$= \frac{R_aR_bR_c}{R_a+R_b+R_c}. \quad \text{— (3)}$$



Dividing eq^n ③ by each of eq^n ① to ② leads to the following eq^n.

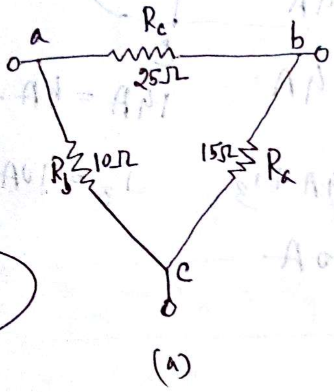
$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}$$

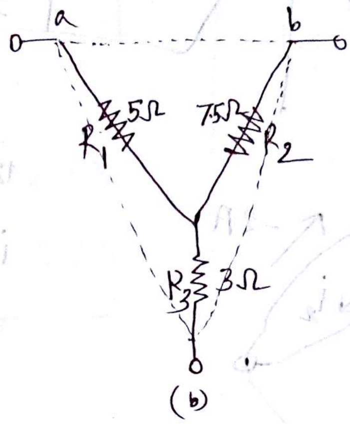
$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}$$

Example 2.14

D - Y



(a)



(b)

$$R_1 = \frac{10 \times 25}{15 + 10 + 25} = \frac{250}{50} = 5\Omega$$

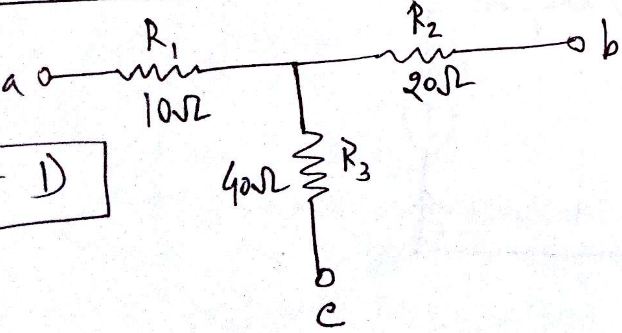
$$R_2 = \frac{25 \times 15}{15 + 10 + 25} = \frac{375}{50} = 7.5\ \Omega$$

$$R_3 = \frac{10 \times 15}{15 + 10 + 25} = \frac{150}{50} = 3\ \Omega.$$

200 + 800 + 400

Practice problem: 2.14

Y - D



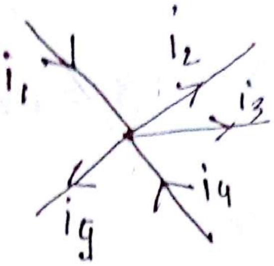
$$R_a = \frac{10\times20 + 20\times40 + 40\times10}{10} = 140\Omega$$

$$R_b = \frac{10\times20 + 20\times40 + 40\times10}{20} = 70\Omega$$

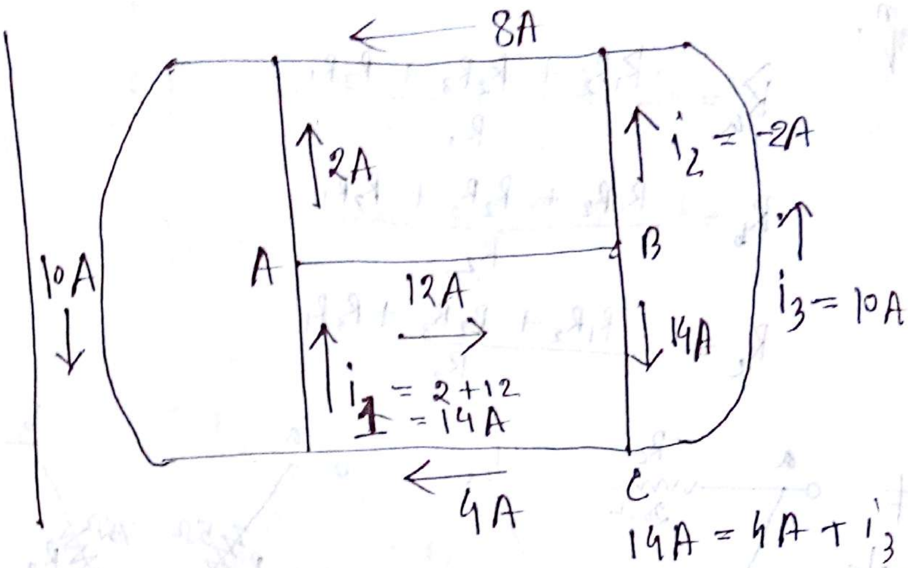
$$R_c = \frac{10\times20 + 20\times40 + 40\times10}{40} = 35\Omega$$

KVL and KCL:

KCL:



$$i_1 + i_4 = i_2 + i_3 + i_5$$



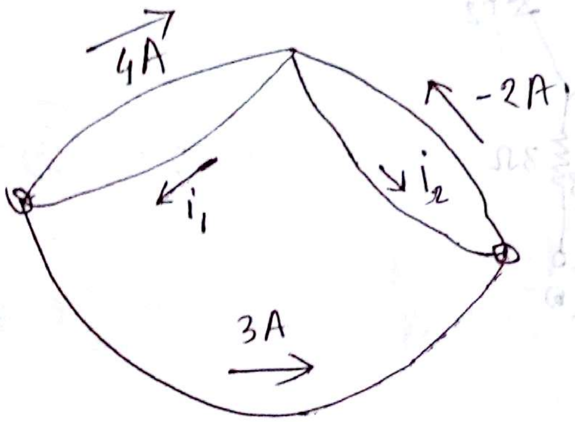
$$14A = 4A + i_3$$

$$i_3 = 10A$$

$$12A = 4A + i_3$$

$$i_3 = 10A.$$

#1

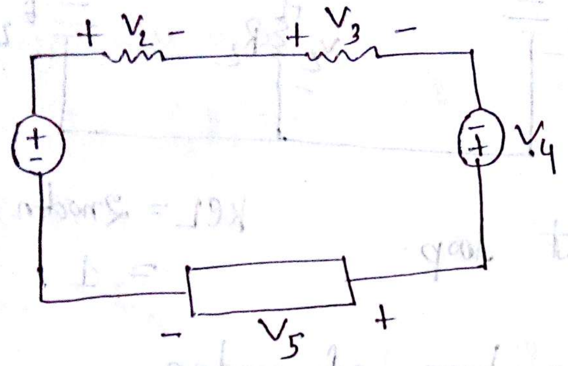


$$i_1 = 4 + 3$$
$$= 7A$$

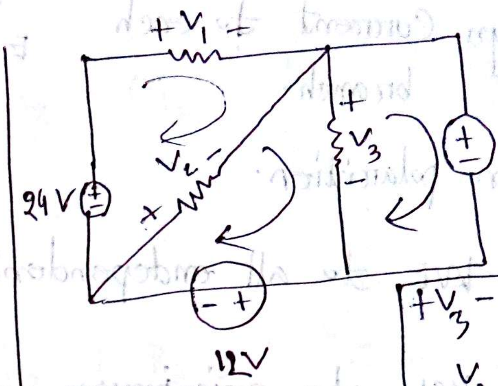
$$i_2 + 3 = -2$$

$$i_2 = -5A.$$

KVL: Total voltage rise = total voltage drop
↳ around a closed loop path.



$V_1, V_2, V_3 = ?$



$+V_3 - 10V = 0$

$V_3 = 10V$

KVL $\Rightarrow$ $V_1 + V_4 = V_2 + V_3 + V_5$

$$\boxed{+V_1 - V_2 - V_3 + V_4 - V_5 = 0}$$

$-V_2 - V_3 - 12V = 0$

$-V_2 - 10 - 12 = 0$

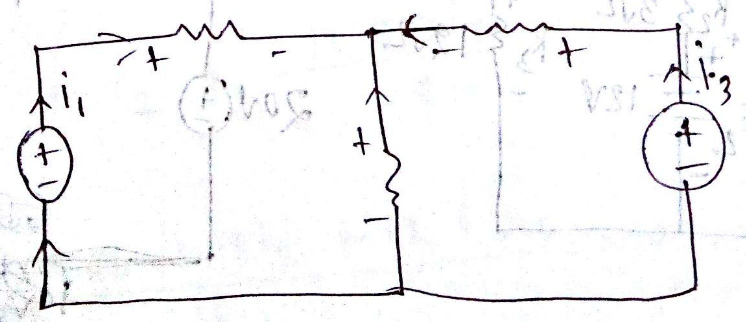
$V_2 = -22V.$

$+24V - V_1 + V_2 = 0$

$24 - V_1 - 22 = 0$

$V_1 = -2V.$

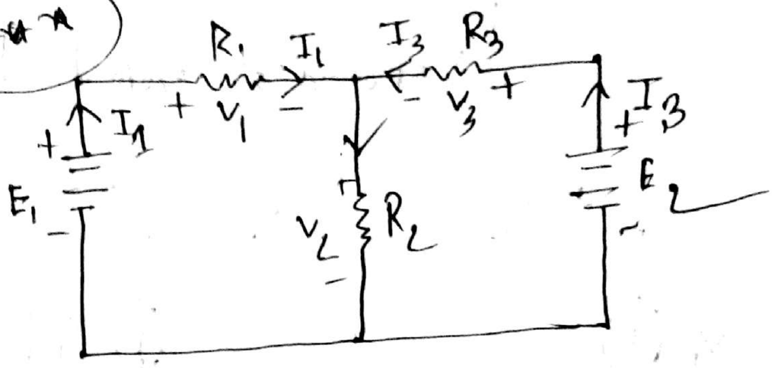
Branch Current Analysis:



Branch current Analysis:

$KCL \Rightarrow I_1 + I_3 = I_2$

Step:

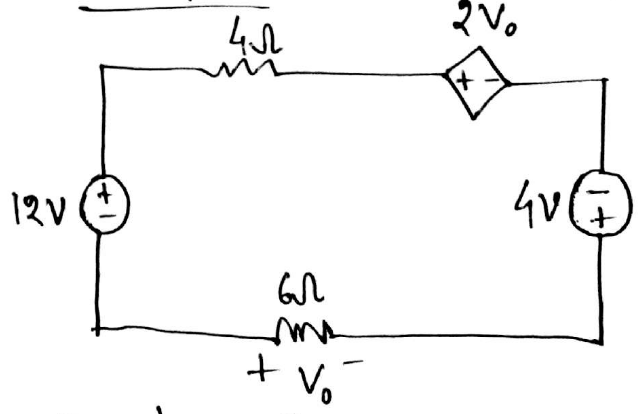


1. Assign Current to each branch.
2. Assign polarities.
3. Apply KVL to all endependent loop.

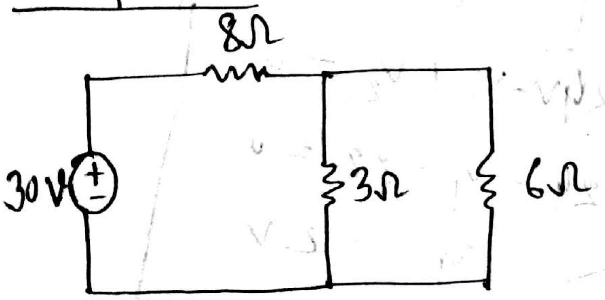
$KCL = 2\text{nodes} - 1$
$= 1$

4. Apply KCL to minimum numbers of nodes.
5. Solve all equation

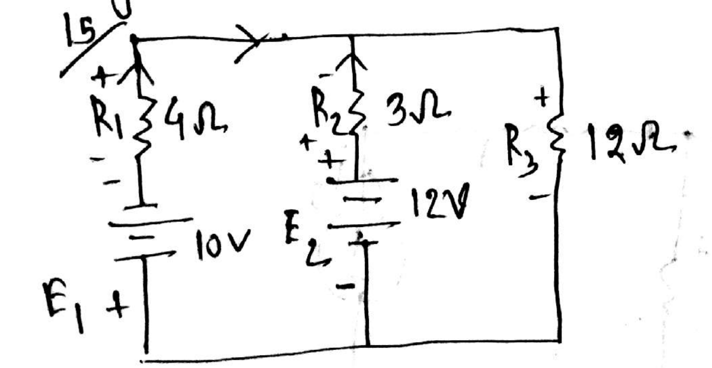
Example : 2·6



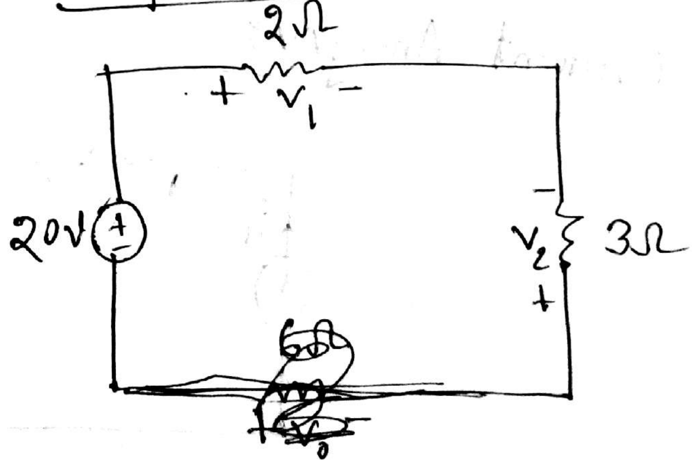
Example : 2·8



Boylested



Example : 2.5



(A) (A) (A)

KCL $\Rightarrow I_1 + I_3 = I_2 \qquad I_1 - I_2 + I_3 = 0$

KVL $\Rightarrow$ (1)

$+E_1 - V_1 - V_1 = 0$

$E_1 - i_1 R_1 - i_2 R_2 = 0 \qquad -R_1 i_1 - R_2 i_2 + 0 i_3 = -E_1$

KVL $\Rightarrow$ (2)

$V_2 + V_3 - E_2 = 0$

$i_2 R_2 + i_3 R_3 - E_2 = 0 \qquad 0 i_1 + R_2 i_2 + R_3 i_3 = E_2$

Boylested:

$-i_1 + i_2 + i_3 = 0$

$-10 + 4i_1 - 3i_2 - 12 = 0$

$\Rightarrow -22 + 4i_1 - 3i_2 = 0$

$\Rightarrow 4i_1 = 3i_2 + 22$

$\Rightarrow i_1 = \frac{3i_2 + 22}{4}$

$12 - 3i_2 - 12i_3 = 0$

$\Rightarrow -12i_3 = -12 - 3i_2$

$\Rightarrow -12i_3 = -(12 + 3i_2)$

$\Rightarrow i_3 = \frac{12 + 3i_2}{12}$

$$-\frac{3i_2 + 22}{4} + i_2 + \frac{12 + 3i_2}{12} = 0$$

$$\Rightarrow \frac{-9i_2 + 66 + 12i_2 + 12 + 3i_2}{12} = 0$$

$$\Rightarrow \frac{6i_2 + 78}{} = 0$$

$i_2 = -\frac{78}{6}$

$i_2 = -13A$

$i_1 = \frac{3i_2 + 22}{4}$

$\Rightarrow i_1 = \frac{-39 + 22}{4}$

$i_1 = -4.25A$

$i_3 = \frac{12 + 3\times(-13)}{12}$

$= \frac{-27}{12}$

$= -2.25\ A.$

$I_2 = I_1 + I_3$ — (1)

KVL $\Rightarrow$

$-E_1 + I_1R_1 + I_2R_2 - E_2 = 0$

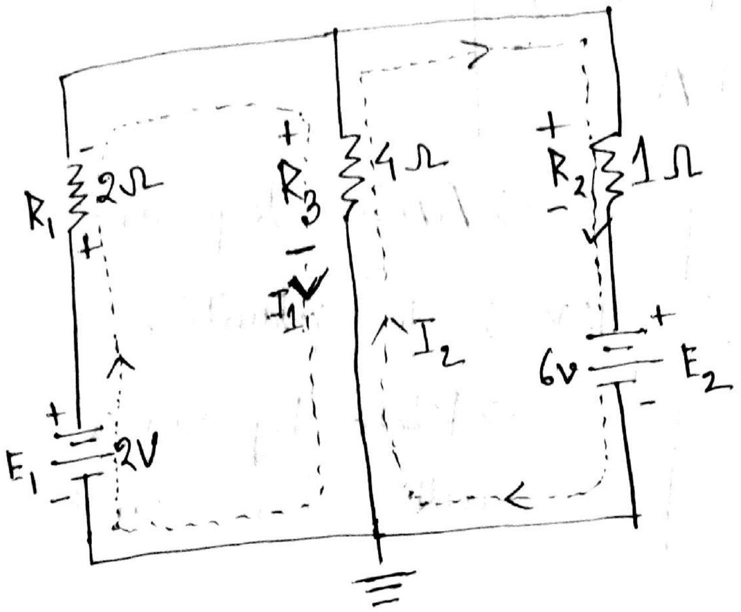
$\Rightarrow -10 + 4I_1 + 3I_2 - 12 = 0$

$\Rightarrow 4I_1 + 3I_2 = 22$ — (2)

$+E_2 - I_2R_2 - I_3R_3 = 0$

$\Rightarrow 12 - 3I_2 - 12I_3 = 0$

Mesh current Analysis:



$R_3 \rightarrow I = I_1 - I_2$

or, $I_2 - I_1$

Steps:

1. Assign loop current to all independent loops in the clockwise direction.
2. Indicates polarities according to loop current
3. Apply KVL to each loop in the clockwise direction.
4. Solve equations.

KVL

loop 1:

$+2V - 2 \cdot I_1 - 4(I_1 - I_2) = 0$

$\Rightarrow 2V - 2I_1 - 4I_1 + 4I_2 = 0 \Rightarrow 6I_1 - 4I_2 = 2$

Loop 2:

$-4(I_2 - I_1) - 1 \cdot I_2 - 6 = 0$

$\Rightarrow -4I_2 + 4I_1 - I_2 - 6 = 0$

$\Rightarrow 4I_1 - 5I_2 = 6$

$I_1 = -1A$; $I_2 = -2A$

$6I_1 - 4I_2 = 2$

$4I_1 - 5I_2 = 6$

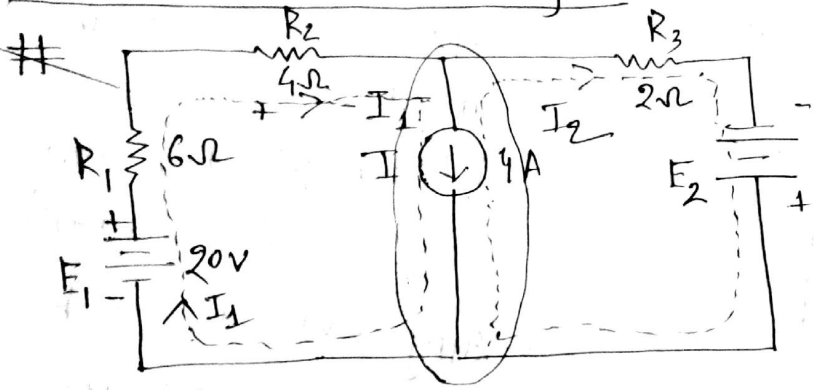
$10I_1$

Current for $R_3 \Rightarrow I_3 = I_1 - I_2$
$= -1 - (-2)$
$= 1A$.

$I_3 = I_2 - I_1$

Super Mesh current Analysing:

#

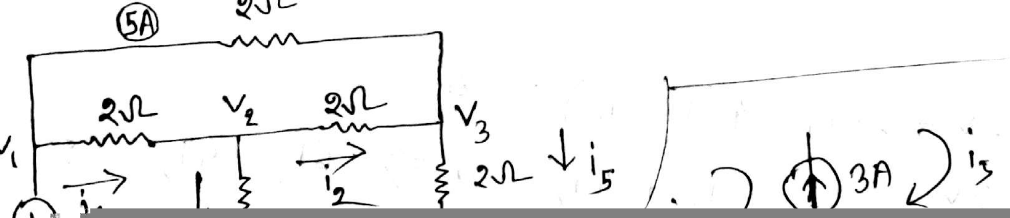


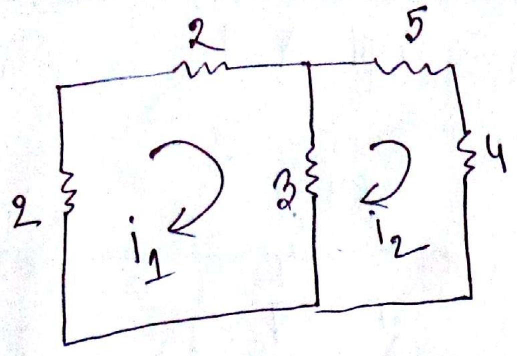
→ Assign loop current
→ " polarities
→ Relate loop current with a source current.

$I_1 = 4 + I_2$

$+20V - 6I_1 - 4I_1 - 2I_2 + 12 = 0$

Mid question: 2016 → I_4

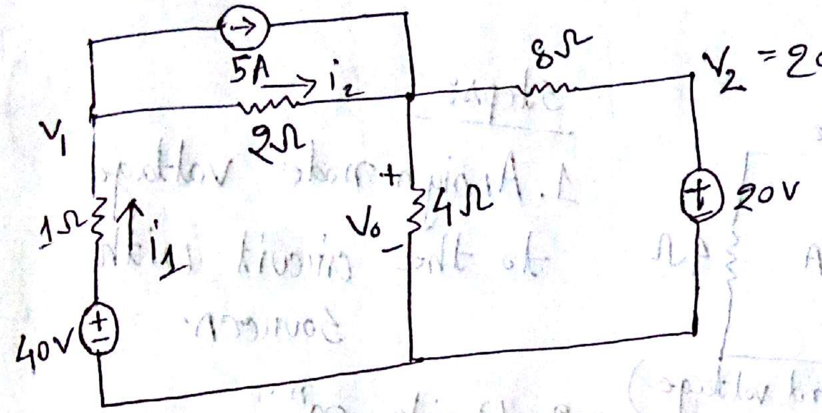




$2i_1 + 2i_1 + 3i_1 - 3i_2 = 0$

$3i_2 + 5i_2 + 4i_2 - 3i_1 = 0$

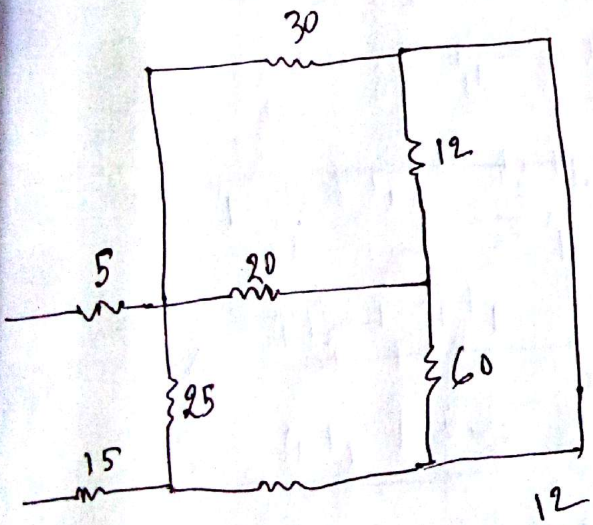
#

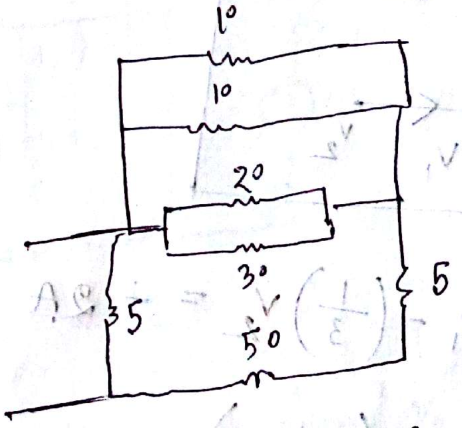


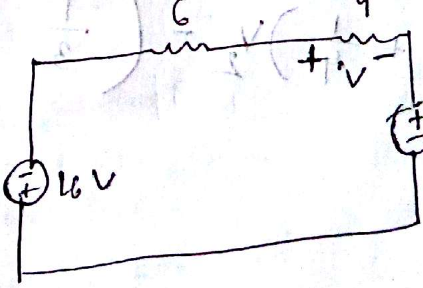
$V_2 = 20$ Find volume of V_o.

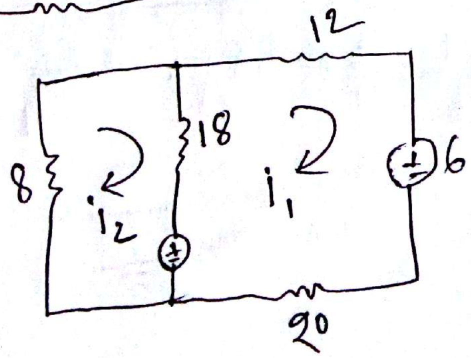
$i_1 = 5 + i_2$ — (1) $i_1 = \frac{40 - v_1}{1}$

$5 + i_2 = i_3 + i_4$ — (11)









$8i_2 + 18i_2 + 5 - 18i_1 = 0$

$18i_1 + 12i_1 + 6 - 18i_2 + 20i_1 = 0$

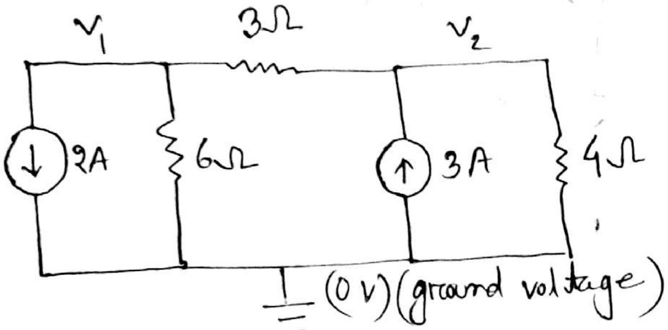
Mesh + supermesh - 1

Node + Supernode - 1

Thevenin, Superposition } - 1

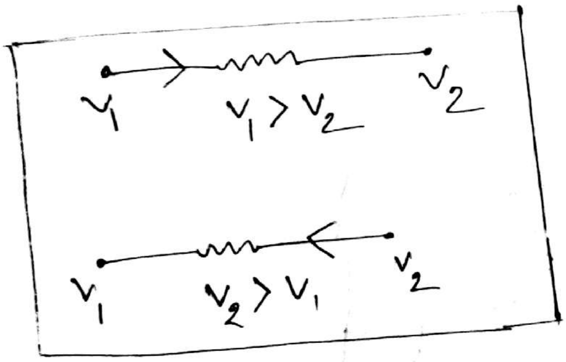
others - 1

Nodal Analysis:



Steps:

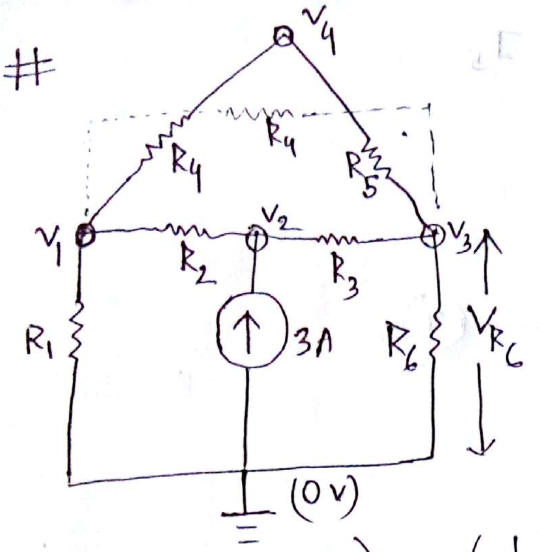
1. Assign node voltage to the circuit with sources.
2. Write eqn.
3. Solve.



V_1: $\left(\frac{1}{3} + \frac{1}{6}\right)V_1 - \left(\frac{1}{3}\right)V_2 = -2A$

V_2: $\left(\frac{1}{3} + \frac{1}{4}\right)V_2 - \left(\frac{1}{3}\right)V_1 = +3A$.

#



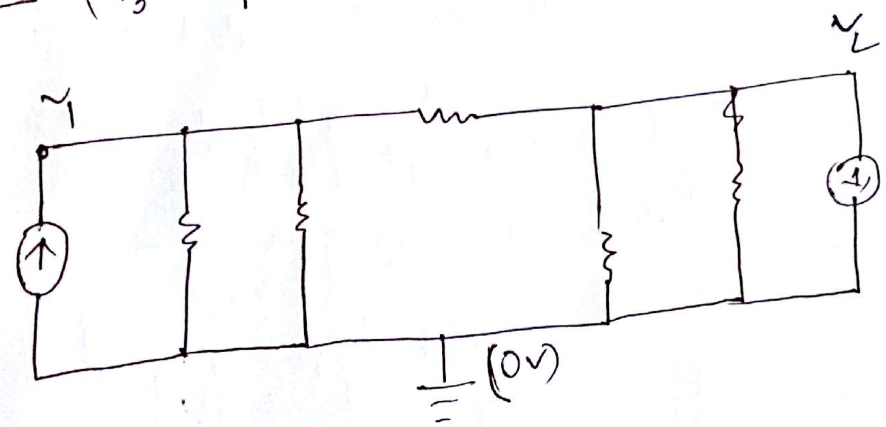
$$\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_6}\right)V_3-\left(\frac{1}{R_3}\right)V_2-\left(\frac{1}{R_4}\right)V_1=0$$

$\underline{V_1}$: $\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_4}\right)V_1-\left(\frac{1}{R_2}\right)V_2-\left(\frac{1}{R_4}\right)V_3=0$

$\underline{V_2}$: $\left(\frac{1}{R_2}+\frac{1}{R_3}\right)V_2-\left(\frac{1}{R_1}\right)V_1-\left(\frac{1}{R_3}\right)V_3=0+3A$

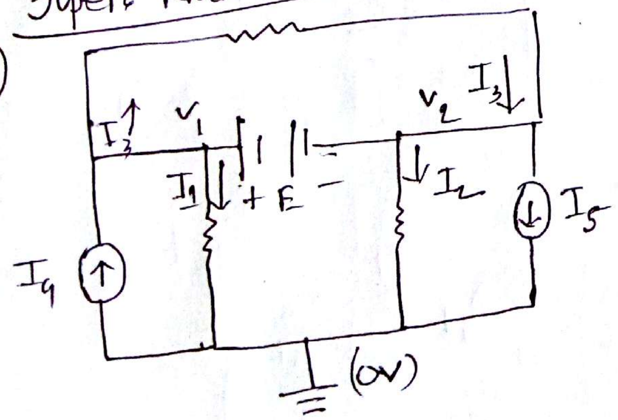
$\underline{V_3}$: $\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_6}\right)V_3-\left(\frac{1}{R_3}\right)V_2-\left(\frac{1}{R_4}\right)V_1=0$

3



Super Node:

4



→ V_1 and V_2.

→ assign current.

→ relation betn voltage source of nodal analysis.

$\boxed{E = V_1 - V_2}$ $\boxed{V_1 - V_2 = E}$ —— 1

$$KCL \Rightarrow I_4 + I_3 = I_3 + I_1 + I_2 + I_5$$

$$\Rightarrow I_4 = I_1 + I_2 + I_5$$

$$I_1 + I_2 = 2$$

$$\boxed{\frac{V_1}{R_1} + \frac{V_2}{R_2} = 2} \quad \text{—— } (9)$$