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DC circuit

★ (A) Types of circuit elements

(1) Linear and non-linear circuit elements

Linear circuit element → if across the parti-
-cular element the excitation is directly proportional to response

ex → Resistance — $V \propto I$; Inductance — $V = I \times L$; Capacitance — $V = I \times C$

These element follows homogenity and additivity for linearity.

Homogenity → if $x \to y = f(x)$

$\alpha x \to \alpha y$

the change is same

additivity → $x_1 \to y_1$

$x_2 \to y_2$

$(x_1 + x_2) \to (y_1 + y_2)$

Non-linear element → excitation is not directly proportional to response ex diodes transistor. Do not follow homogenity and additivity both

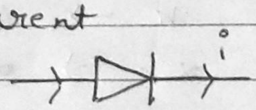
② Active and passive element

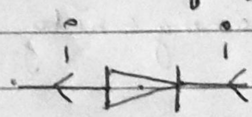
Active element → delever net power or energy to other element present in circuit ex → sources voltage and current.

Passive element → consumes power and energy when connected in a cairecuit.
ex → Resistance Inductance Capacitance.

③ Unilateral & bilateral

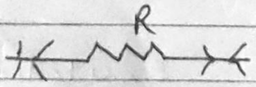
Unilateral element → Accross which V-I relation depends on direction of flow of current





R = 0 R = ∞

Bilateral element → independent of direction of current V-I relations



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

R L C are bi lateral.

Types of sources

- Current source
  - Independent
    - Ideal
    - Practical
  - dependent
    - voltage
    - current
- Voltage source
  - Independent
    - ideal
    - Practical
  - Dependent
    - voltage
    - current

☆

5V  Voltage dependent Voltage source.

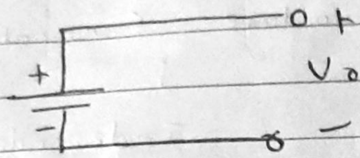
3I  current dependent volatage

2A  current dependent current source.

4V  Voltage dependent ~~vol~~ current source.

Independent voltage Source

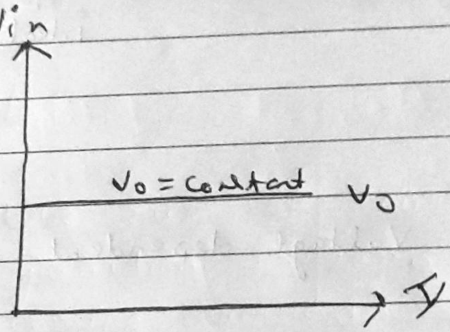
(1) **Ideal** → is capable of delivering constant output voltage irrespective of current taken from it. $R_{int} = 0$



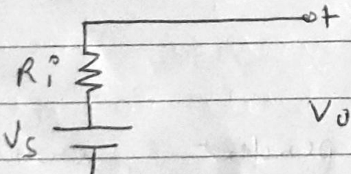
$R_i = 0$

ideal source voltage

Graph



(2) **Practical** → terminal voltage decrease with current taken.

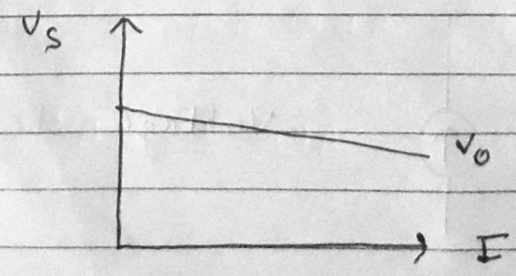


R_i in series

KVL

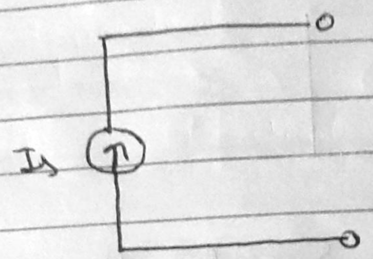
$$\downarrow V_0 = V_s - \overset{\uparrow}{I} R_i \uparrow$$

Graph



Independent Current sources

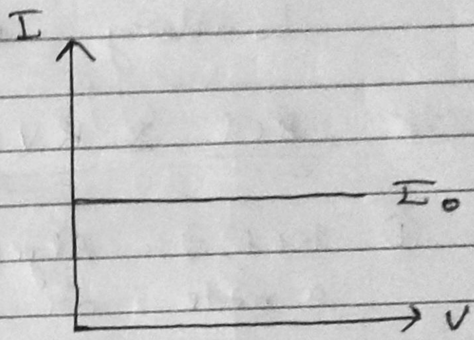
① Ideal → delivers constant current irrespective of its voltage across terminal



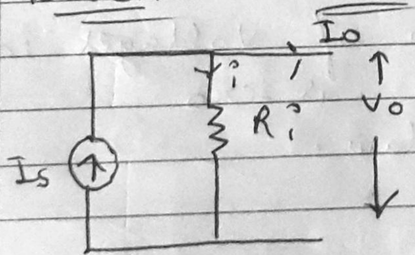
$R_i = \infty$ replaced by open ckt

$I_o = I_s$

Graph



② Practical current source → I_o decrese with Increasing Voltage.



i → internal current

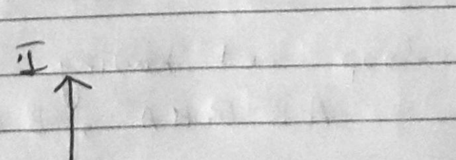
KCL

$I_s = i + I_o$

$I_o = I_s - i$

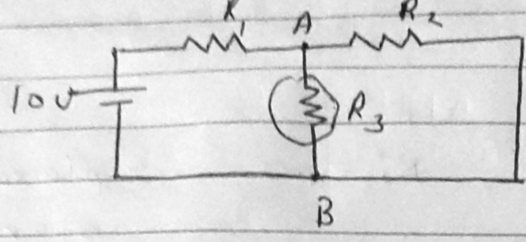
$I_o = I_s - \frac{V_o}{R_i}$

Graph



☆ (A) (4) → lumped and distributed circuit

(i) lumped → are those where the physical boundaries are specified.



(ii) distributed → cannot specify the physical boundary ex → transmission line.

☆ KCl & KVL

① KCl → Algebric sum of current across a node or junction is zero
Sum of incoming current = Sum of outgoing current
(Node or junction)

② KVL → Algebric sum of voltages in a closed loop or mesh is zero.
energy conservation law.
(Mesh or Closed loop)

Mesh → smallest loop not having any closed loop in it. ABGHA, BCFGB etc

Closed loop → ABCFGHA → two or more mesh.

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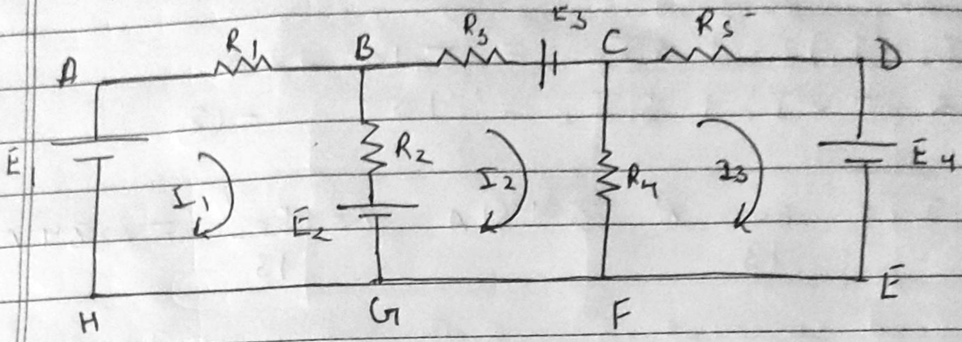
Examples Numericals (Mesh Analysis)



Mesh ABGHA :-

$I_1 R_1 + (I_1 - I_2) R_2 = - E_2 + E_1$

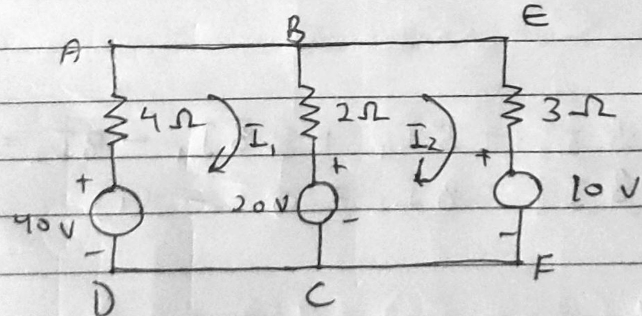
Mesh BCFGB :-

$I_2 R_3 + (I_2 - I_1) R_2 + (I_2 - I_3) R_4 = - E_3 + E_2$

Mesh CDEFC

$I_3 R_5 + (I_3 - I_2) R_4 = - E_4$

☆



find current in 2 Ω

Mesh A B C D A

$4 I_1 + (I_1 - I_2) 2 \Omega = -20 + 40$

$4 I_1 + 2 I_1 - 2 I_2 = 20$

$6 I_1 - 2 I_2 = 20 \quad — (1)$

Mesh BEFCB

$(I_2 - I_1)2 + 3I_2 = -10 + 20$

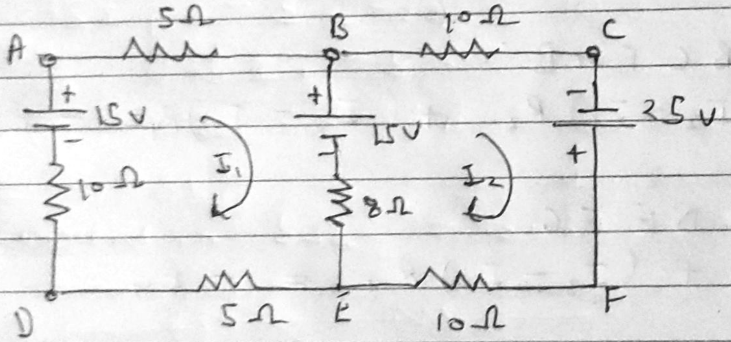
$-2I_1 + 5I_2 = 10$ — (2)

$I_1 = \frac{60}{13}$ A $= 4.61$ A $\quad Y = \frac{50}{13} = 3.84$ A

Current in $2\Omega = I_1 - I_2$

$= 0.769$ A B to C

(2)



Mesh ABEDA

$10I_1 + 5I_1 + 5I_1 + 8I_1 - 8I_2 = +15 - 1$

$28I_1 - 8I_2 = 0$ — (1)

Mesh BCFEB

$8I_2 - 8I_1 + 10I_2 + 10I_2 = 15V + 25V$

$-8I_1 + 28I_2 = 40$ — (2)

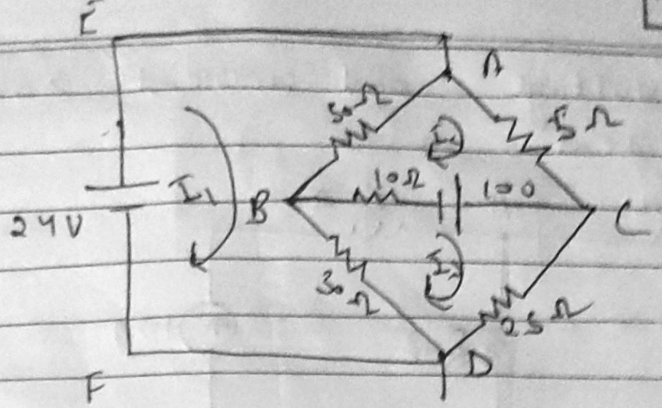
$I_1 = 4/9 \qquad I_2 = \cancel{50/13}\ 14/9$

$= 0.445$ A $\qquad = 1.55$ A

I in $8\Omega = I_2 - I_1 = 1.55 - 0.445$

$= 0.967$ A BE

3



I in 10Ω

Mesh EABDEE

$(I_1 - I_2)50 + (I_1 - I_3)30 = 24$

$50I_1 - 50I_2 + 30I_1 - 30I_3 = 24$

$80I_1 - \cancel{80I_2 = 24}\ 50I_2 - 30I_3 = 24$ — ①

Mesh ACBA

$50(I_2 - I_1) + 5I_2 + 10I_2 = -10V$ $(I_2 - I_3)$

$-50I_1 + 65I_2 - 10I_3 = -10$ — ②

Mesh BCDB

$10(I_3 - I_2) + 30(I_3 - I_1) + 25I_3 = +10$

$10I_3 - 10I_2 + 30I_3 - 30I_1 + 25I_3 = 10$

$-30I_1 - 10I_2 + 65I_3 = 10$ — ③

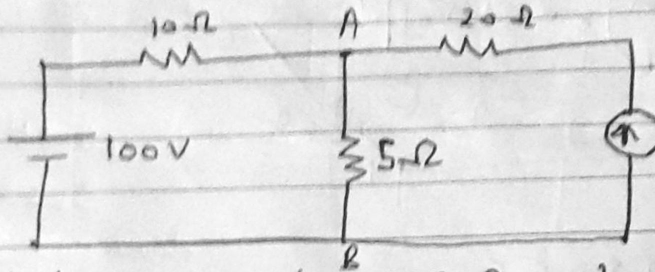
$I_1 = 1.11$ $I_2 = 0.82$ $I_3 = 0.794$

in 10Ω = $I_2 - I_3$ = $0.825 - 0.794$

$= 0.031$ A

★ Both voltage and current source are present.

①



find current in 5 Ω by mesh analysis

$10 I_1 + 5(I_1 - I_2) = 100$

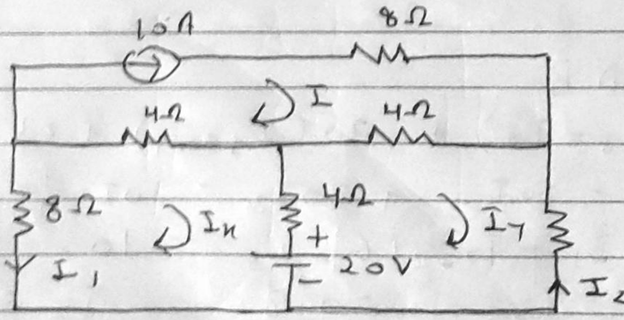
$15 I_1 - 5(-10) = 100$

$15 I_1 = 50$

$I_1 = 3.33\ A$

Current in 5 Ω = 13.33 A to B

②



$I = 10\ A$

$8 I_x + 4(I_x - I) + 4(I_x - I_y) = -20$

$16 I_x - 4 I_y - 40 = -20$

$16 I_x - 4 I_y = 20$

$4(I_y - I) + 8 I_y + 4(I_y - I_x) = 20$

$-4 I_x \quad 16 I_y = 60$

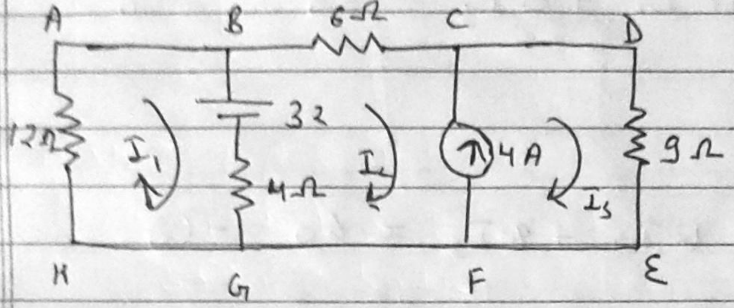
$I_x = 2.333\ A \qquad I_y = 4.33\ A$

Current $I_1 = -2.333$

$I_2 = -4.333$

★ Super mesh analysis for common current source

1.



Current in 6Ω by mesh analysis.

By KVL in ABGHA

$0 I_3 + 16 I_1 - 4 I_2 = -32$

In Supermesh BCDEFGB

$6 I_2 + 9 I_3 + 4 (I_2 - I_1) = 32$

$-4 I_1 + 6 I_2 + 9 I_3 = 32$

By KCL at Node C

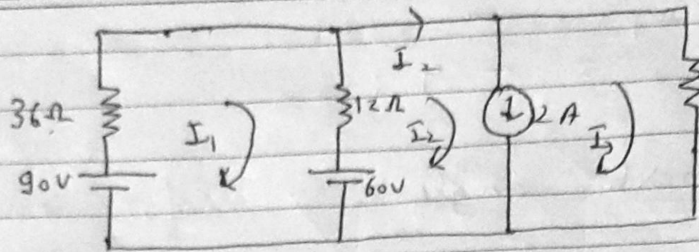
$I_2 + 4 = I_3$ — (3)

$0 I_1 + I_2 + I_3 = -4$

$I_1 = -2.166A$ $I_2 = -0.666A$ $I_3 = 3.33A$

I in 6Ω = 0.666 C − B

2



I in 8Ω

$$48 I_1 - 12 I_2 + 0 I_3 = 30 \quad -(1)$$

Supermesh

$$12 I_2 - 12 I_1 + 8 I_3 = 60 \quad -(2)$$

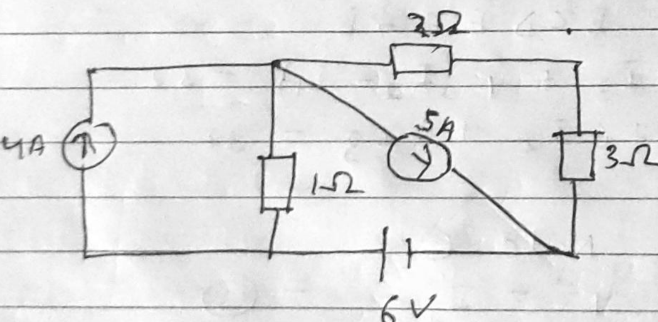
By KCL:

$$I_2 - 2 = I_3$$

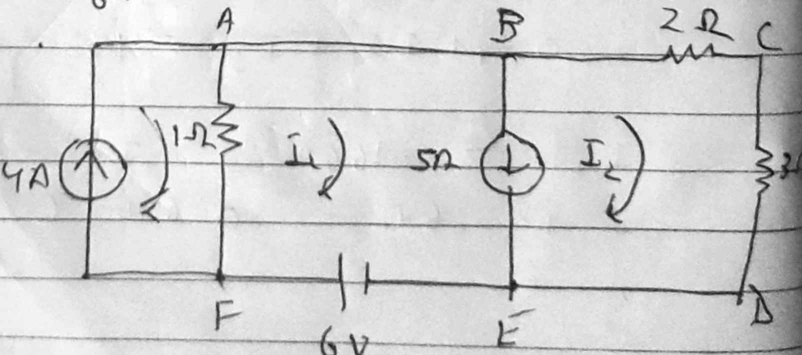
$$0 I_1 + I_2 - I_3 = 2 \quad -(3)$$

$I_1 = 1.85A$ $\quad$ $I_2 = 4.91A$ $\quad$ $I_3 = 2.911A$

3



Simplified



$$1(I_1 - 4) + 2 I_2 + 3 I_2 = 6$$

$$I_1 + 5 I_2 = 10 \quad -(1)$$

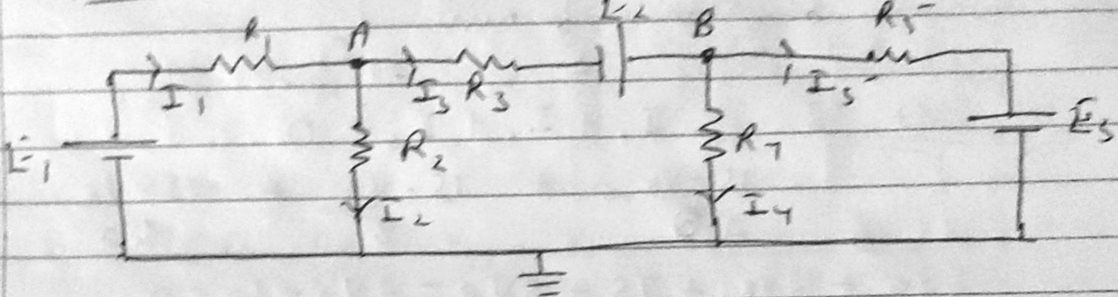
By KCL at B

$$I_1 = 5 + I_2 \quad -(2)$$

$$I_1 = 5.833 \quad I_2 = 0.833$$

$$V = I_2 R = 0.833 \times 3 = \underline{\underline{2.499\,V}}$$

Nodal analysis



Nodes + 3 are more elements are connected.

Applying KCL at A

$$I_1 = I_2 + I_3$$

$$0 + \frac{E_1 - V_A}{R_1} = \frac{V_A}{R_2} + \frac{V_A - V_B + E_2}{R_3}$$

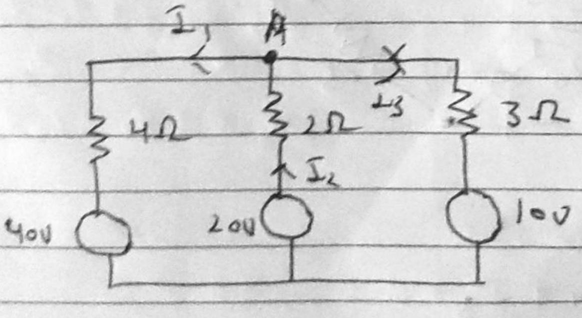
At B

$$I_3 = I_4 + I_5$$

for B

$$\frac{V_A + E_2 - V_B}{R_3} = \frac{V_B}{R_4} + \frac{V_B - E_5}{R_5}$$

☆



By KCL

$$I_2 = I_1 + I_3$$

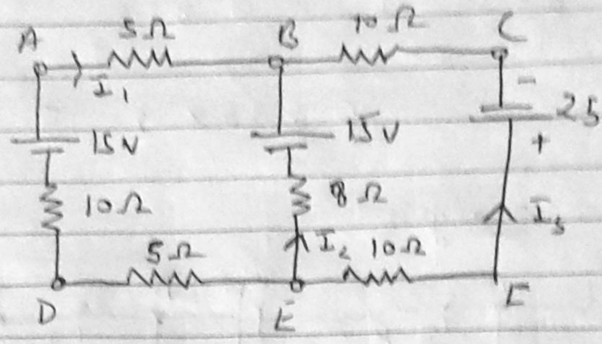
$$\frac{20 - V_A}{2} = \frac{V_A - 40}{4} + \frac{V_A - 10}{3}$$

$$120 - 6V_A = 3V_A - 120 + 4V_A - 40$$

$$13\,V_A = 280 \qquad V_A = 21.538\,\text{Volt}$$

$I_2 = \frac{20 - 21.538}{2} = -0.769\ A$ (opposite direction)

☆



At B $\quad I_1 + I_2 + I_3 = 0$

$$\frac{15 - V_B}{20} + \frac{15 - V_B}{8} + \frac{-25 - V_B}{20}$$

$$30 - 2V_B + 75 - 5V_B - 2V_B - 50 = 0$$

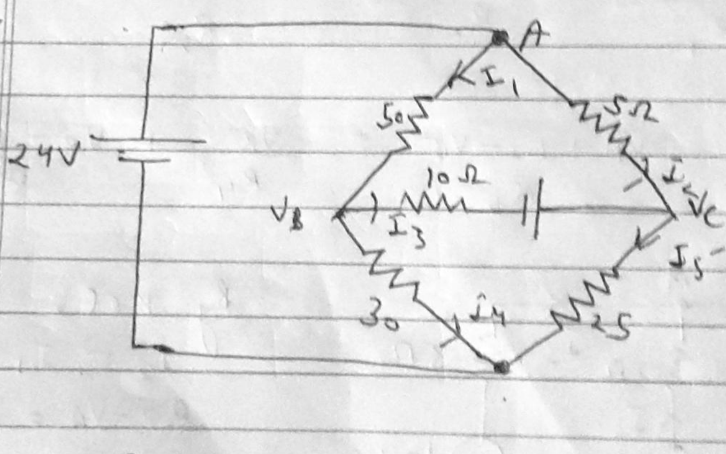
$$9V_B = 55$$

$$V_B = 6.111\ \text{Volt}$$

I in 8 Ω

$$I_2 = \frac{15 - 6.111}{8} = 1.111\ A \quad E \text{ to } B$$

☆



$V_A = 24\ V$

at B

$$I_1 = I_4 + I_3$$

$$\frac{24 - V_B}{5} = \frac{V_B}{30} + \frac{V_B + 10 - V_C}{10}$$

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$$72 - 3V_B = 5V_B + 15V_B + 150 - 15V_C$$
$$23V_B - 15V_C = -78 \quad - (1)$$

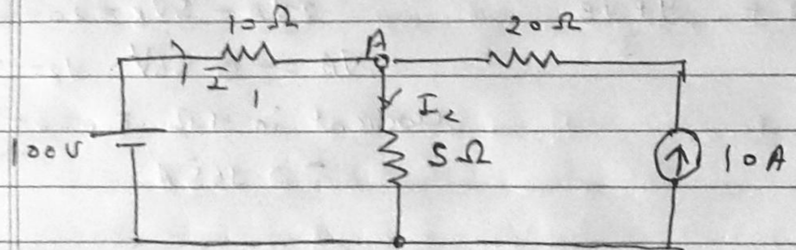
At C
$$I_3 + I_2 = I_1$$
$$\frac{V_B + 10 - V_C}{10} + \frac{24 - V_C}{5} = \frac{V_C}{25}$$

$$5V_B + 50 - 5V_C + 240 - 10V_C = 2V_C$$
$$5V_B - 17V_C = -290 \quad - (2)$$

$V_B = 9.569\,V \qquad V_C = 19.873\,V$

I in 10 Ω is $\quad I_3 = \frac{V_B + 10 - V_C}{10} = -0.030A$

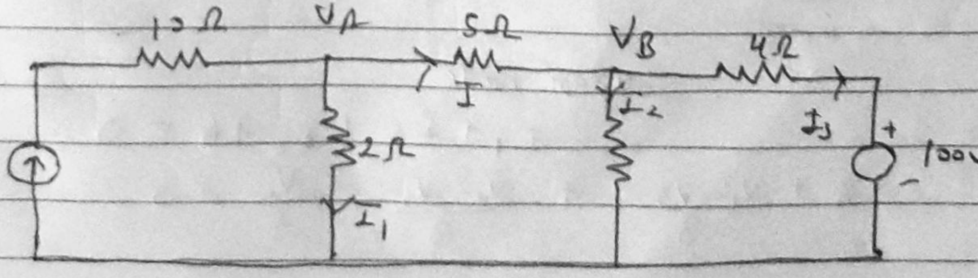
C - to B



At A $\quad I_1 + 10 = I_2$
$$\frac{100 - V_A}{10} + 10 = \frac{V_A}{5}$$

$100 - V_A + 100 = 2V_A$
$3V_A = 200$
$V_A = 66.66V$

I in 5Ω
$I_2 = \frac{V_A}{5} = 13.33$



At A $\quad 2 = I_1 + I$

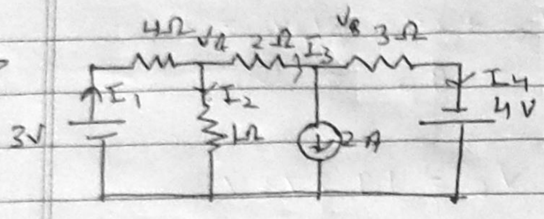
$$2 = \frac{V_A}{V_2} + \frac{V_A - V_B}{5} \quad - (1)$$

At B

$$I = I_2 + I_3$$

$$\frac{V_A - V_B}{5} = \frac{V_A}{2} + \frac{V_B - 100}{4} \quad - (2)$$

☆



At node A

$$I_1 = I_2 + I_3$$

$$\frac{3 - V_A}{4} = \frac{V_A}{1} + \frac{V_A - V_B}{2}$$

At B

$$I_3 = 2 + I_4$$

$$\frac{V_A - V_B}{2} = 2 + \frac{4 + V_B}{3}$$

$$7V_A - 2V_B = 3 \quad - (1)$$

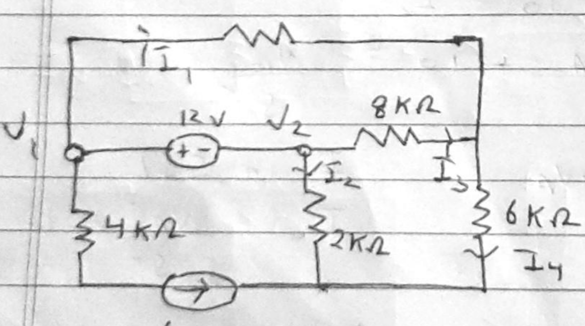
$$3V_A - 5V_B = 20 \quad - (2)$$

$V_A = -0.86V \quad V_B = -4.517V$

current in 4Ω $\quad I_1 = \frac{3 - (-0.86)}{4}$

$$= 0.965\,A$$

☆ Super node



Node 3

$$I_1 + I_3 = I_4$$

$$\frac{V_1 - V_3}{8} + \frac{V_2 - V_3}{8} = \frac{V_3}{6}$$

$$3V_1 + 3V_2 - 10V_3 = 0 \quad (1)$$

Super node

$$I_1 + I_3 + I_2 + 6 = 0$$

$$6 + \frac{V_1 - V_3}{8} + \frac{V_2 - V_3}{8} + \frac{V_2}{2} = 0$$

$48 + V_1 - V_3 + V_2 - V_3 + 4V_2 = 0$

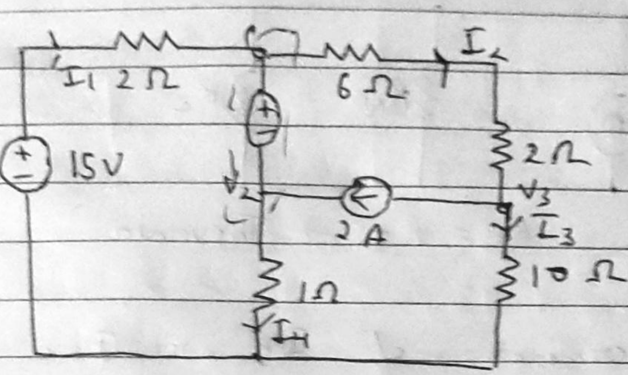
$V_1 + 5V_2 - 2V_3 = -48$ — (2)

KVL in super node $\quad V_1 = V_2 + 12$

$V_1 = 1 \qquad V_2 = -11 \qquad V_3 = -3$

I in $2\,\Omega$ KΩ $= \frac{V_2}{2} = -11/2 = -5.5\,mA$

☆



At Supernode

$I_1 + 2 = I_2 + I_4$

$\frac{15 - V_1}{2} + 2 = \frac{V_1 - V_3}{8} + \frac{V_2}{1}$

$5V_1 + 8V_2 - V_3 = 76$ — (1)

At (3)

$I_2 = I_3 + 2$

$\frac{V_1 - V_3}{8} = 2 + \frac{V_3}{10}$

$5V_1 + 0V_2 - 9V_3 = 80$ (2)

$V_1 - V_2 + 0V_3 = 30$ — (3)

$V_1 = 24.678\,V$

$V_2 = -5.321\,V$

$V_3 = 4.821\,V$

I in $1\,\Omega = 5.321\,A \uparrow$

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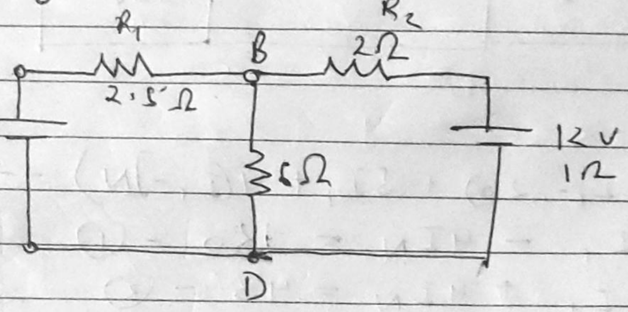
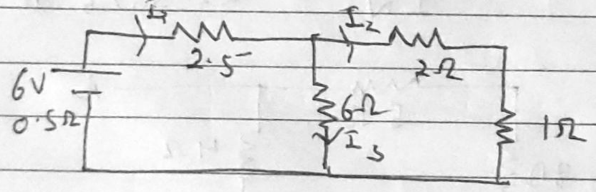
Superposition Theorem

In any linear ~~lateral~~ linear active bilateral network consisting of two or more sources the current flowing in any branch is algebric sum of current that would flow in the same ~~direction~~ branch when each current source is considered seperately with all other sources replaced by internal resistance.



Step I considering 6 V



At B

$I_1' = I_2' + I_3'$

$\frac{6-V_B}{3} = \frac{V_B}{3} + \frac{V_B}{6}$

$12 - 2V_B = 2V_B + V_B$

$V_B = 2.4$ Volts

$I_1' = 1.2\ A$ A to B

$I_2' = 0.8\ A$ B to C

$I_3' = 0.4$ B to D

$I = \frac{\text{Total incoming current}}{R \text{ in Parallel Sum}} \times R$ of branch

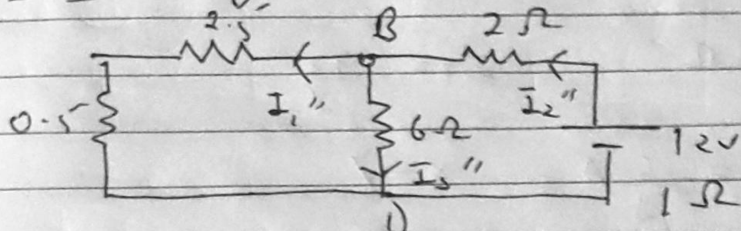
$R_T = 2.5 + \frac{3 \times 6}{9} + 0.5 = 5\Omega$

$$I_1' = \frac{6}{5} = 1.2\,A$$

$$I_2' = \frac{I_1'}{6+3} \times 6 = \frac{1.2}{9} \times 6 = 0.8$$

$$I_3' = \frac{1.2}{6+3} \times 3 = 0.4\,\Omega$$

Considering 12V



At B

$$I_2'' = I_1'' + I_3''$$

$$\frac{12 - V_B}{3} = \frac{V_B}{3} + \frac{V_B}{6}$$

$$V_B = \frac{24}{5} = 4.8\ \text{Volt}$$

$I_1'' = 1.6A$ B to A

$I_2'' = 2.4A$ C to B

$I_3'' = 0.8A$ B to D

Step 3 Net current $I_1 = I_1' + I_1''$

$= -1.2 + 1.6 = 0.4$

B to A

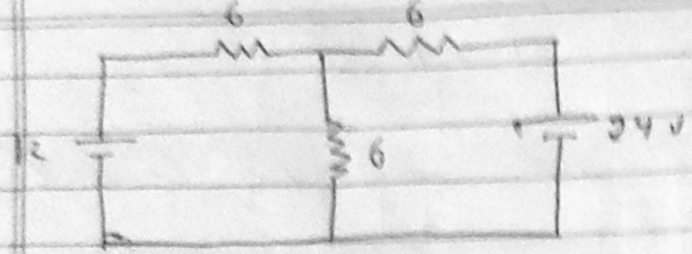
Net $I_2 = I_2' + I_2''$

$= -0.8 + 2.4 = 1.6$ C to B

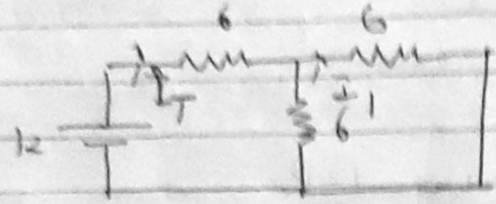
Net $I_3 = I_3' + I_3'' = 0.4 + 0.8$

$= 1.2A$ B to D

3)

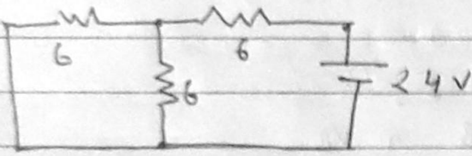


for 12V



$R_T = 9\Omega$ $\quad I_T = \frac{12}{9}$

$I_1 = \frac{6}{9}$ A $\quad$ X - Y

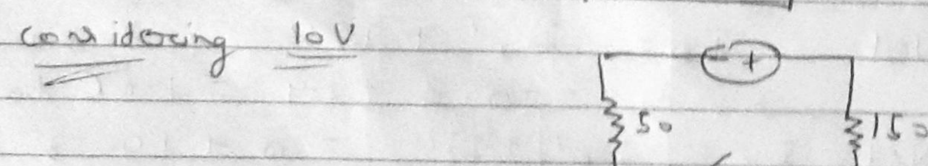


$R_T = 9\Omega$ $\quad I_2 = I_T = \frac{24}{9}$ $\quad$ Y - X

Total $= I_1 + I_2 = \frac{6}{9} - \frac{24}{9}$

$= -2A$

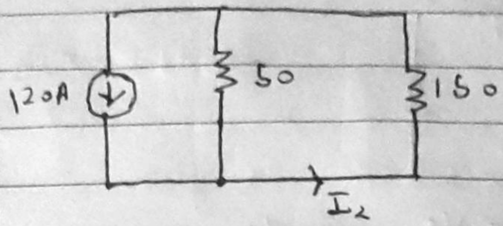
☆



considering 10V

$I_1 = \frac{10}{200}$ A

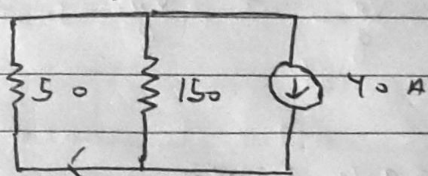
Considering 120A Source



$$I_2 = \frac{120}{200} \times 50$$

$$= I_2 = -30A$$

Considering 40A

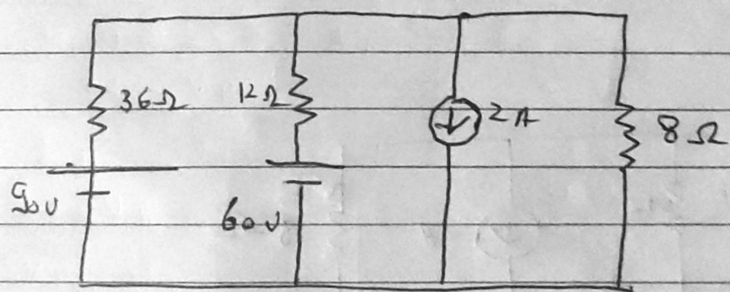


$$I_3 = \frac{\cancel{40}^{\,\cancel{20}^{\,2}}}{\cancel{200}_{\,10}} \times 150$$

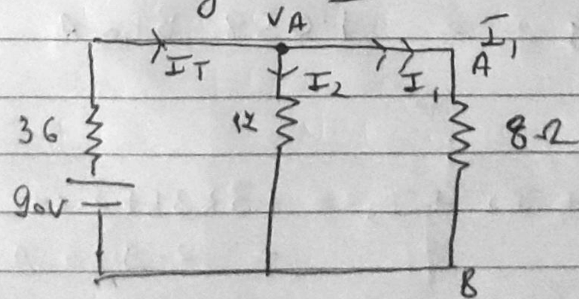
$$= 30A$$

Net current = $I_1 + I_2 + I_3 = \frac{10}{200}$ A

3



Considering 90V



At Node $I_T = I_2 + I_1$

$$\frac{90 - V_A}{36} = \frac{V_A}{12} + \frac{V_A}{8}$$

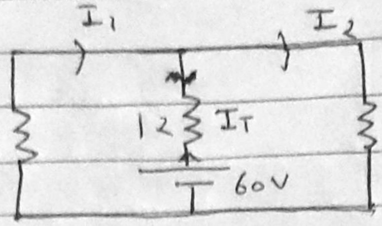
$$180 - 2V_A = 6V_A + 9V_A$$

$$17V_A = 180$$

$$V_A = 10.588$$

$$I_1 = 1.3235 \text{ A to B}$$

60V



$I_1 + I_T = I_2$

$$\frac{0 - V_A}{36} + \frac{60 - V_A}{12} = \frac{V_A}{8}$$

$$\frac{60 - V_A}{\cancel{36}\ 12} = \frac{V_A}{8} + \frac{V_A}{8}$$

$$360 - 6V_A = 9V_A + 2V_A$$

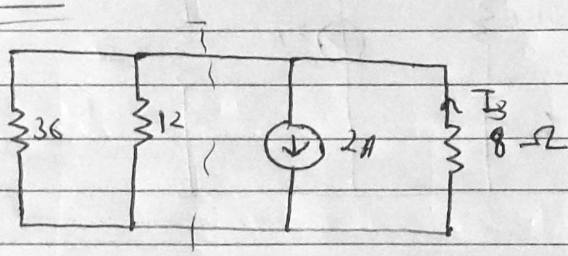
$$17 V_A = 360$$

$$V_A = 21.\cancel{2}176\ V$$

$$I_2 = 2.647\ A \qquad A - B$$

for 2 A

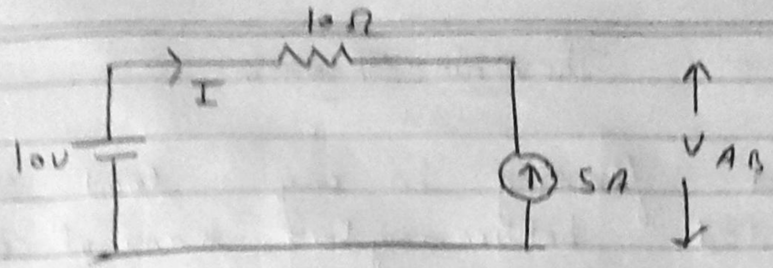
9Ω



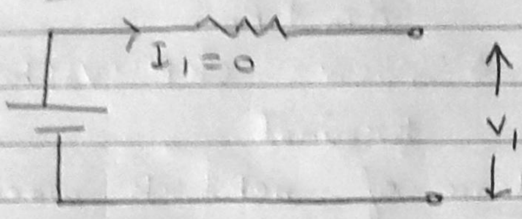
$$I_3 = \frac{2}{(9+8)} \times 9 = 1.058 \quad B\ to\ A$$

Total $= I_1 + I_2 + I_3 = 1.3235 + 2.647 - 1.058$
$= 2.910\ A$

4

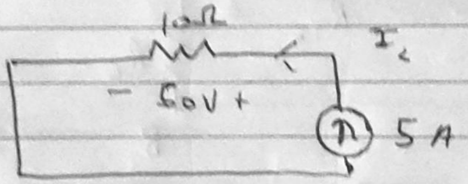


for 10V



$V_1 = 10V$

for 5 A



$I_2 = -5A$

Net $I = I_1 + I_2 = -5A$

Net $V \Rightarrow V_{AB} = V_1 + V_2 = 10 + 50$

$= 60V$

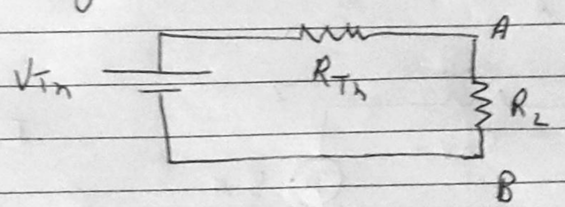
Thevenin Theorem

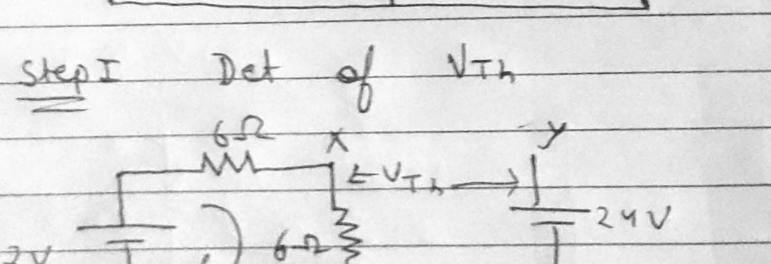
Current flowing in any load resistance R_L connected between any two terminal of a linear active bilateral network is given by

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

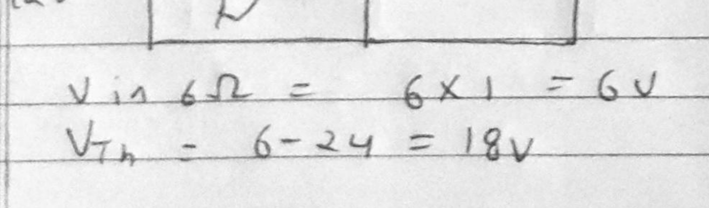
where $V_{Th} \rightarrow$ open ckt voltage across load terminal

$R_{Th} \rightarrow$ Resistance of network when looked back into the network with all sources are replaced by their internal resistance





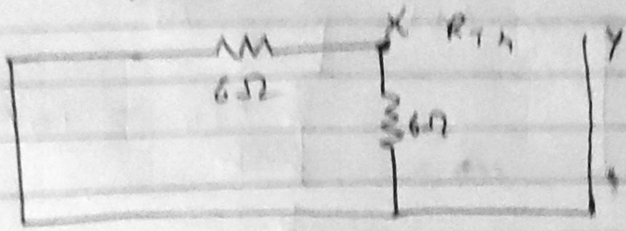
Step I Det of V_{Th} (load open)



V in 6Ω = 6 × 1 = 6V

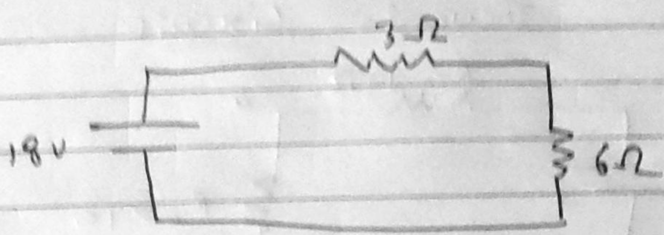
V_{Th} = 6 − 24 = 18V

II Det of R_{Th} Short batteries



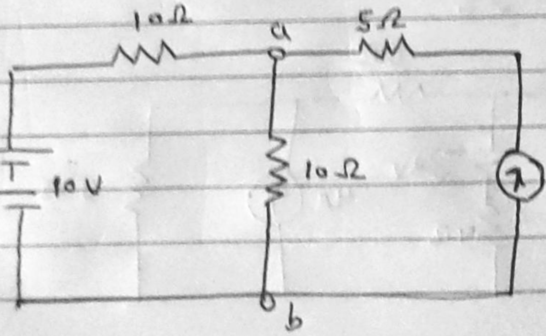
$R_{Th} = 6 \| 6 = 3\,\Omega$

III

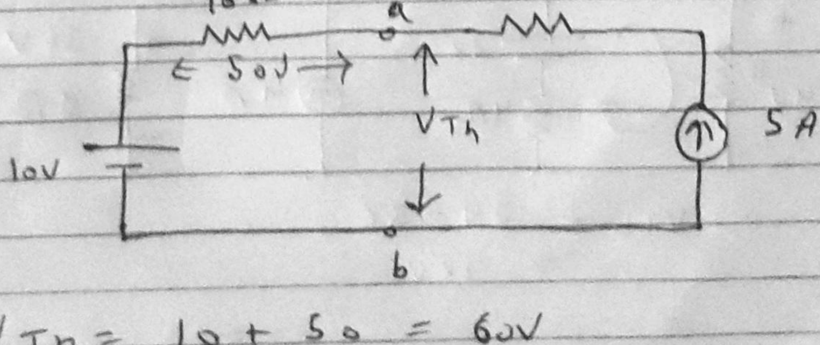


$I_L = \frac{V_{Th}}{R_{Th}+R_L} = \underline{\underline{2A}}$

2

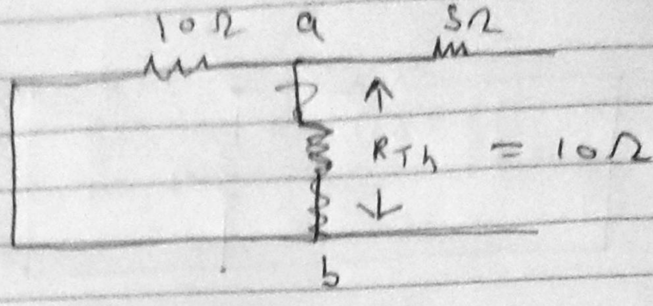


(i) Det $\underline{\underline{V_{Th}}}$

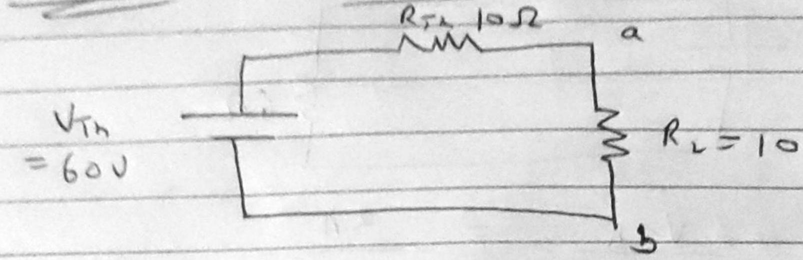


$V_{Th} = 10 + 50 = 60V$

II R_{Th}

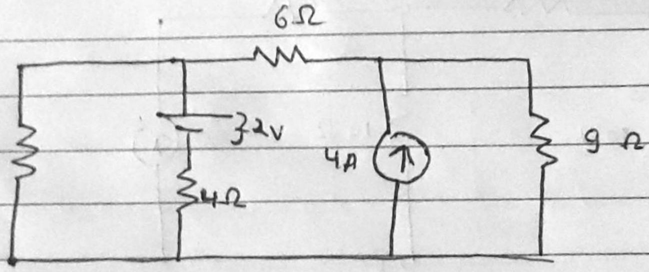


III Draw Thevenin Circuit



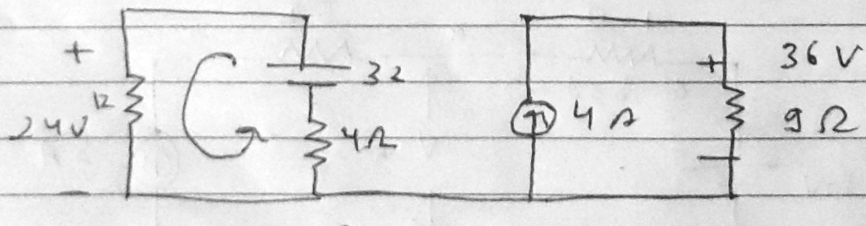
$$I_L = \frac{60}{20} = \underline{\underline{3\ A}}$$

3



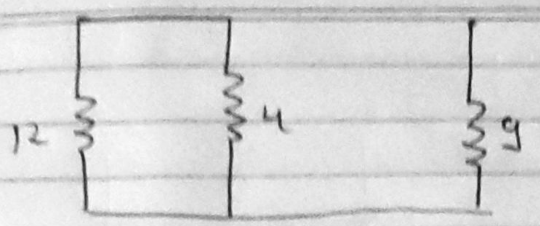
in 6Ω

I Find V_{Th}



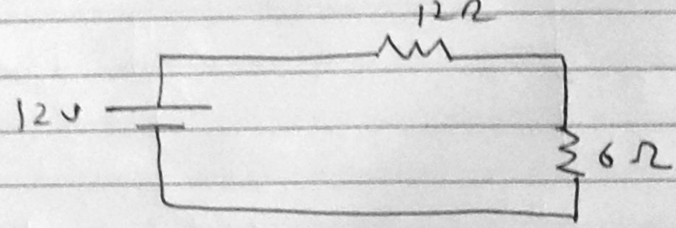
V_{Th} = 24 − 36
= 12V

II



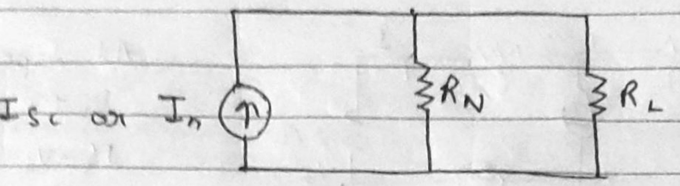
$$R_{Th} = \frac{12 \times 4}{12 + 4} \times 9 = 12\,\Omega$$

III Draw Thevenin



$$I_L = \frac{12}{18} = 0.666\,\Omega \quad B \text{ to } A$$

★ Narton's Theorem



$I_L = \frac{I_n R_n}{(R_n + R_L)}$

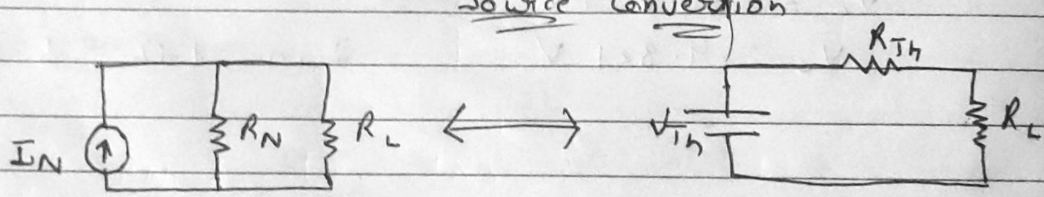
$R_N = R_{Th} \rightarrow$ Thevenin

Step I → determination of I_n or I_{sc} Short ckt

Step 2 → determination of R_n

Step 3 → draw Nortor ckt.

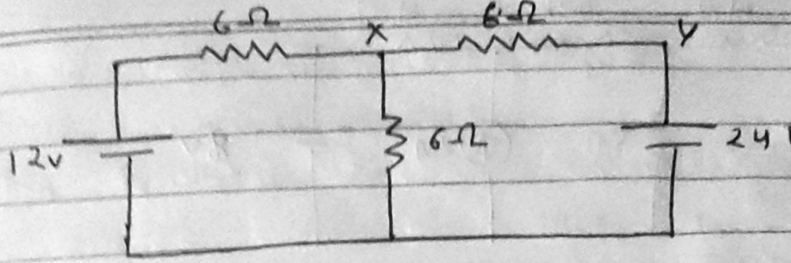
Source convertion



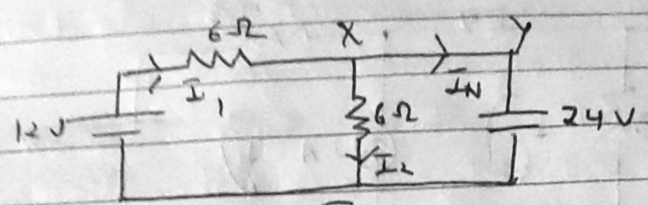
$I_n = \frac{V_{Th}}{R_{Th}}$ $\quad R_n = R_{Th}$ $\quad V_{Th} = I_n R_N$

$R_N = R_{Th}$

*



→



$V_x = 24V$

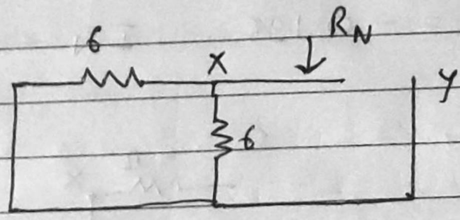
$I_1 = I_2 + I_N$

$\frac{12 - V_x}{6} = \frac{V_x}{6} + I_N$

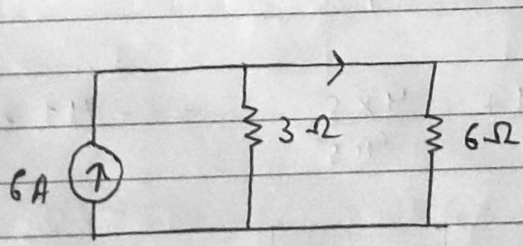
$-2 = 4 + I_n$

$I_n = -6\ A$

Det of RN

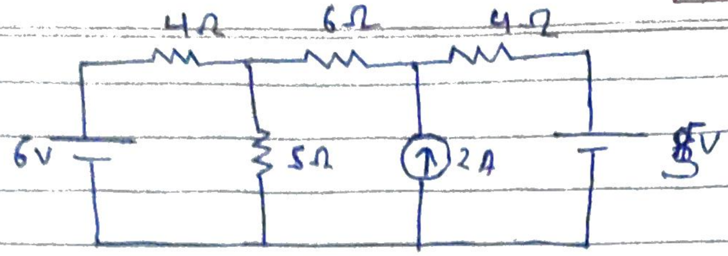


$R_N = 6 \parallel 6 = 3\,\Omega$

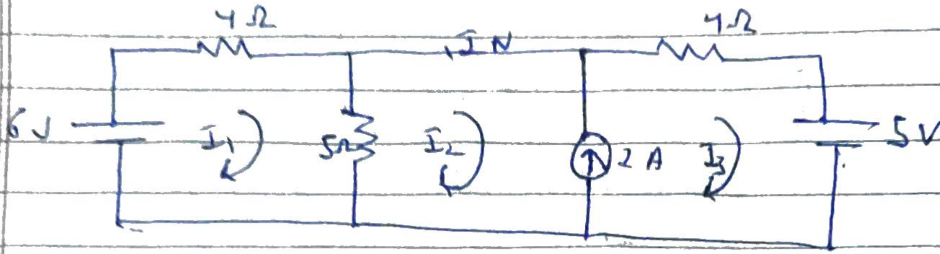


$I_L = 2A$

2



→

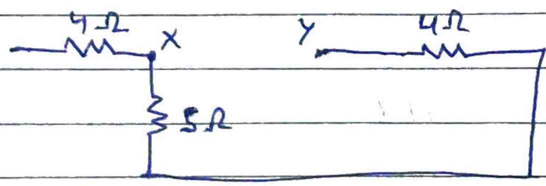


$$9I_1 - 5I_N + 0I_3 = 6 \quad -(1)$$
$$-5I_1 + 5I_N + 4I_3 = -5 \quad -(2)$$
$$0I_1 + I_N - I_3 = -2 \quad -(3)$$

$I_1 = -0.196$ $\quad I_N = -1.55$ $\quad I_3 = 0.4464$

Y to X

(ii) RN



$$R_N = 4 + \frac{4\times 5}{4+5} = 4 + \frac{20}{9} = 6.222\Omega$$