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Network Terminology & Basic Concepts

→ Electrical network → interconnection of electrical elements.

→ Electrical circuit → electrical network with at least one source & a sink having a closed path for current flow.

→ Active element → supplies | delivers ~~electrical~~ energy in an electric circuit. Ex: Voltage and current sources.

→ Passive element → Stores/absorbs energy in an electric circuit. Ex: Resistor, Capacitor.

→ Electric current → Rate of flow of charge across the cross section of a conductor.

$I = Q/t$ or $i = dq/dt$.

Unit: Ampere (A).

→ Potential difference → Energy req. to move unit +ve charge from one terminal to another

$V = W/Q$

Unit: volt (V)

→ Electric Power → Rate of absorption | delivery of electrical energy.

$P = W/t = VI$.

Unit: watt (W)

→ Ohm's law → At constant temp., potential difference across terminals of conductor is directly proportional to current flowing through it. $V \propto I \Rightarrow V = IR$

Resistance unit: Ohm (Ω)

→ Resistance → opposition to flow of current.

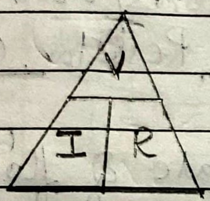
$$R = \frac{\rho l}{A}$$

unit of ρ → Ωm (Ohm meter)

→ Conductance (G) → Reciprocal of Resistance

$$G = \frac{1}{R}$$

Unit of G → Ω^{-1} (mho) or siemens(S)



$V = IR$
$I = V/R$
$R = V/I$

→ Active sign convention → Current leaves the terminal in active element.

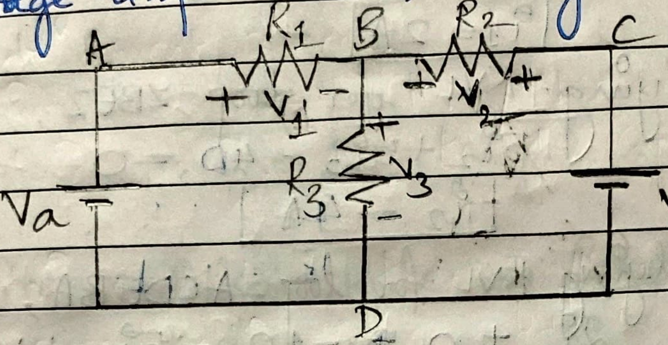
→ Passive sign convention → current enters the terminal in passive element.

→ Ideal voltage source → Its terminal voltage is independent of current flowing through it & depends on the circuit to which it's connected.

→ Ideal current source → Current is independent of voltage across it. The voltage across it depends on the circuit to which it's connected.

→ Kirchoff's Current law → At every node in an electric network, algebraic sum of currents is zero **or** sum of incoming currents is equal to sum of outgoing currents. It signifies conservation of charge.
Incoming current → +ve, Outgoing current → −ve.

→ Kirchoff's Voltage law → Around every closed path / loop in an electric network, the algebraic sum of voltages is zero.
Voltage drop → −ve, Voltage rise → +ve.

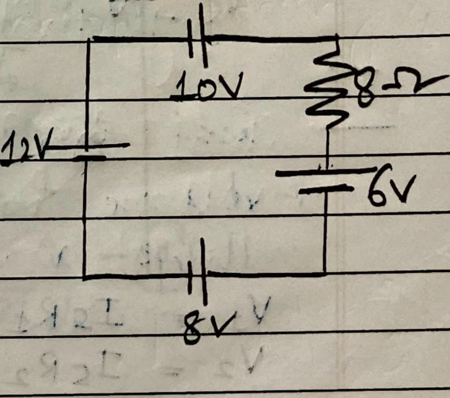


Signifies conservation of energy.

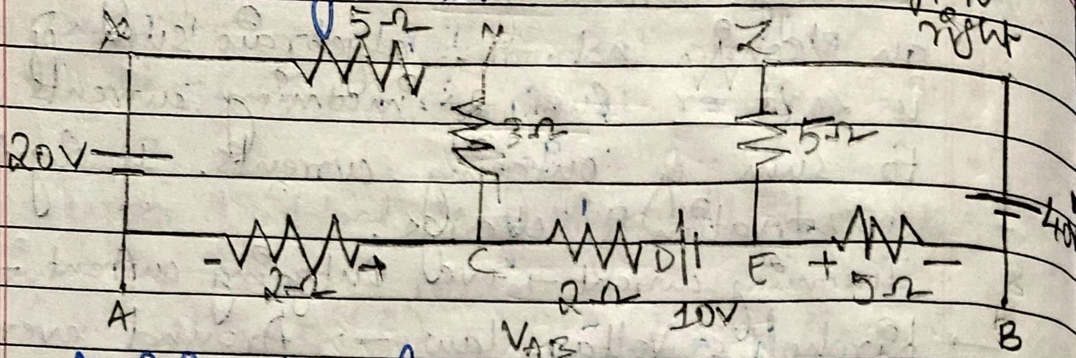
Apply KVL for loop ABDA,
$$V_a + V_1 - V_3 = 0$$
Apply KVL for loop BCDB,
$$V_2 + V_3 - V_b = 0$$
Apply KVL for loop ABCDA,
$$V_2 - V_1 + V_a - V_b = 0$$

Q. Find current through 8 Ω resistor.

Applying KVL,
$$10 - 8i - 6 - 8 + 12 = 0$$
$$8 = 8i$$
$$\boxed{i = 1A}$$



Q- find voltage V_{AB}. Current — left to right



Applying KVL for loop AXYCA

$$20 - 5i_1 - 3i_1 - 2i_1 = 0$$
$$\boxed{i_1 = 2A}$$

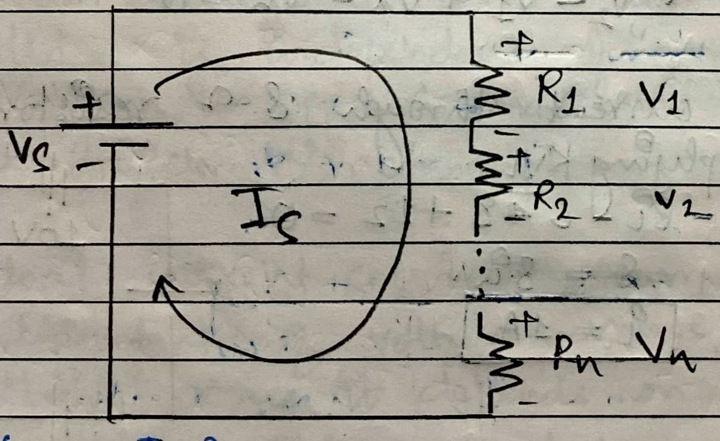
Applying KVL for loop ZBEZ,

$$5i_2 + 5i_2 - 40 = 0$$
$$\boxed{i_2 = 4A}$$

Applying KVL for loop ACDEBA;

$$2i_1 + 0 - 10 - 5i_2 + V_{AB} = 0$$
$$4 + 0 - 10 - 20 + V_{AB} = 0$$
$$\boxed{V_{AB} = 26V}$$

→ Voltage division rule → series circuits



$V_1 = I_S R_1$
$V_2 = I_S R_2$
$V_n = I_S R_n$

Applying KVL,

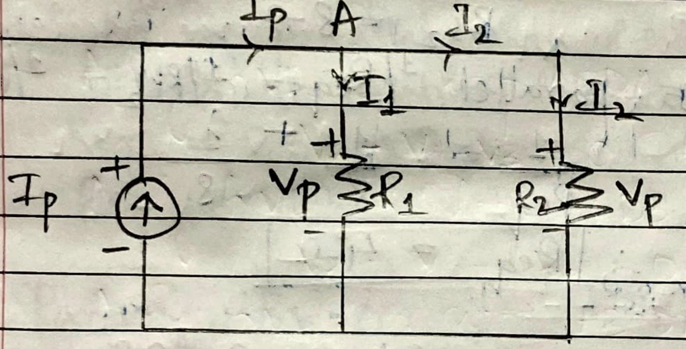
$$V_s = V_1 + V_2 + \dots + V_n$$
$$V_s = I_sR_1 + I_sR_2 + \dots + I_sR_n$$
$$V_s = I_s(R_1 + R_2 + \dots + R_n)$$
$$V_s = I_s R_{eq}$$
$$I_s = V_s / R_{eq}$$

$$V_1 = I_s R_1$$
$$V_1 = \left(\frac{V_s}{R_{eq}}\right) R_1$$

$|||^{ly}$ $$V_2 = \left(\frac{V_s}{R_{eq}}\right) R_2$$

$$V_n = \left(\frac{V_s}{R_{eq}}\right) R_n$$

→ Current Division Rule → Parallel circuits



$$I_1 = \frac{V_p}{R_1}$$
$$I_2 = \frac{V_p}{R_2}$$
$$I_n = \frac{V_p}{R_n}$$

Applying KCL at A,

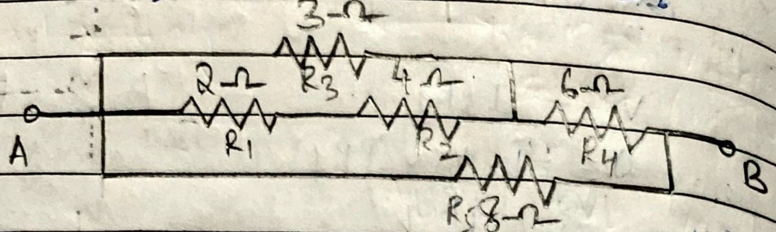
$$I_p = I_1 + I_2$$
$$I_p = \frac{V_p}{R_1} + \frac{V_p}{R_2}$$
$$V_p = I_p\left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$
$$V_p = I_p\left(\frac{R_1R_2}{R_1+R_2}\right) \quad -(1)$$

$$I_1 = \frac{V_p}{R_1}$$
$$I_1 = \frac{I_p}{\cancel{R_1}}\left(\frac{\cancel{R_1}R_2}{R_1+R_2}\right) \quad (\text{from } (1))$$

$$I_1 = I_p\left(\frac{R_2}{R_1+R_2}\right)$$

III^{ly} $$I_2 = I_p\left(\frac{R_1}{R_1+R_2}\right)$$

Q- find Req between A and B.



R_1, R_2 series. $R_{s_1} = R_1 + R_2 = 6\Omega$.

R_{s_1}, R_3 parallel. $1/R_{p_1} = 1/R_{s_1} + 1/R_3$

$$\frac{1}{R_{p_1}} = \frac{1}{6} + \frac{1}{3}$$

$$R_{p_1} = 2\Omega$$

R_{p_1}, R_4 series, $R_{s_2} = R_{p_1} + R_4$

$$R_{s_2} = 8\Omega$$

R_{s_2}, R_5 parallel, $1/R_{eq} = 1/R_{s_2} + 1/R_5$

$$\frac{1}{R_{eq}} = \frac{1}{8} + \frac{1}{8}$$

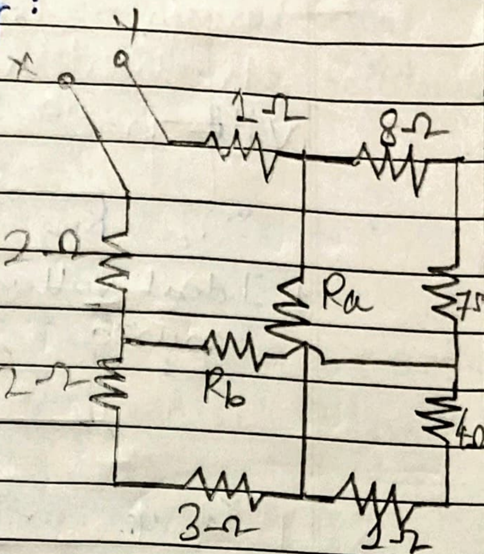
$$\therefore \boxed{R_{eq} = 4\Omega}$$

→ Open circuit → has infinite resistance
$R = \infty$, $I = 0$.

Voltage across open circuit can be any finite value.

→ Short circuit → has zero resistance
voltage is zero. current can be any finite value.

Q. Find Req b/w X & Y if:
(i) $R_a = \infty$, $R_b = \infty$
(ii) $R_a = 0$, $R_b = \infty$
(iii) $R_a = \infty$, $R_b = 0$
(iv) $R_a = 0$, $R_b = 0$



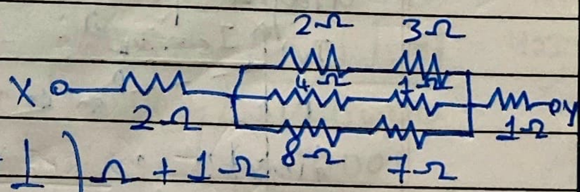
(i) $R_a = \infty$, $R_b = \infty$
Open circuit

$R_{eq} = 1\Omega + 8\Omega + 7\Omega + 4\Omega + 3\Omega + 1\Omega + 2\Omega + 2\Omega$
$R_{eq} = 28\Omega$.

(ii) $R_a = 0$, $R_b = \infty$
short circuit, open circuit
Ra in parallel with 8Ω, 7Ω, 4Ω, 1Ω so this combination has zero resistance.
$R_{eq} = 2\Omega + 2\Omega + 3\Omega + 1\Omega$
$R_{eq} = 8\Omega$

(iii) $R_a = \infty$, $R_b = 0$
Rb in parallel with 2Ω, 3Ω, 1Ω, 4Ω so, this combination has zero resistance.
$R_{eq} = 2\Omega + 1\Omega + 8\Omega + 7\Omega$
$R_{eq} = 18\Omega$

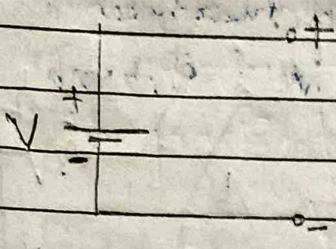
(iv) $R_a = 0$, $R_b = 0$

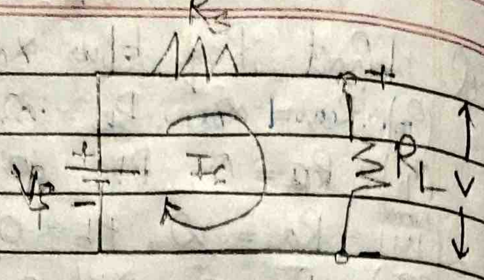


$R_{eq} = 2\Omega + \left(\frac{1}{5} + \frac{1}{5} + \frac{1}{15}\right)\Omega + 1\Omega$

$R_{eq} = 2\Omega + \frac{15}{7}\Omega + 1\Omega$

$R_{eq} = \frac{36}{7}\Omega$



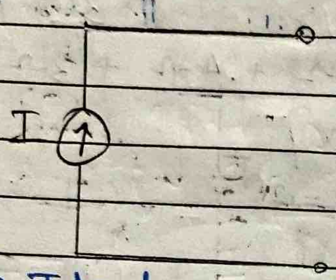


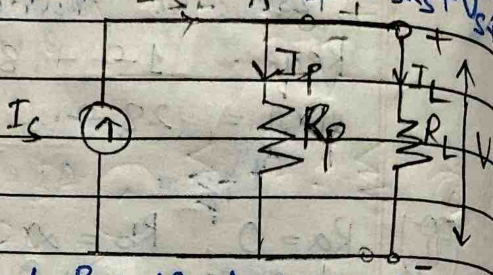
1. Ideal voltage source

2. Practical voltage source (Resistance in series)

Applying KVL, $V_S - I_S R_S - V = 0$

$V = -I_S R_S + V_S$





3. Ideal current source

4. Practical current source (Resistance in parallel).

Applying KCL at A,

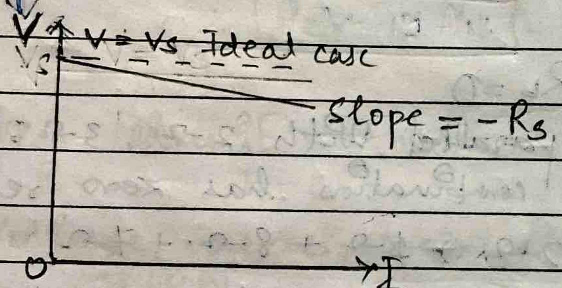
$I_S - I_P - I_L = 0$

$I_S = I_P + I_L$

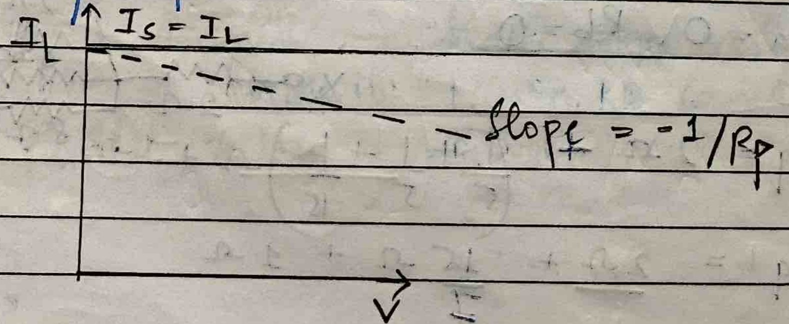
$I_L = I_S - I_P$

$I_L = I_S - \frac{V}{R_P}$

→ Graph for 2.



→ Graph for 4.



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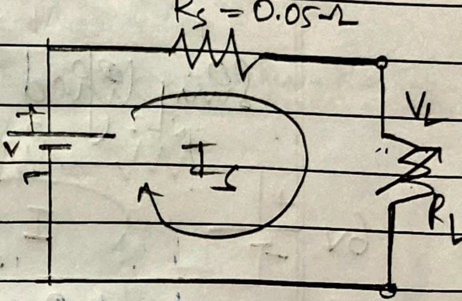
→ Practical current source → Modelled as ideal current source in ||el with internal resistance

Q- A battery of EMF 12V & internal resistance 0.05Ω supplies power to load resistance RL. Determine the % change in load voltage as load resistance varies from 10Ω to 100Ω.



Case 1: When $R_L = 10\Omega$

Voltage division rule,

$$V_{L_1} = \left(\frac{V_s}{R_{eq}}\right) R_L$$

$$V_{L_1} = \frac{12}{10.05} \times 10$$

$$\boxed{V_{L_1} = 11.94\,V}$$

1005) 12000 (11.94
-1005
1950
-1005
9450
-9045
4050
4020
30

Case 2: When $R_L = 100\Omega$

$$V_{L_2} = \left(\frac{V_s}{R_{eq}}\right) R_L$$

$$V_{L_2} = \frac{12 \times 100}{100.05}$$

$$V_{L2} = 11.99V$$

10005 × 9 = 90045

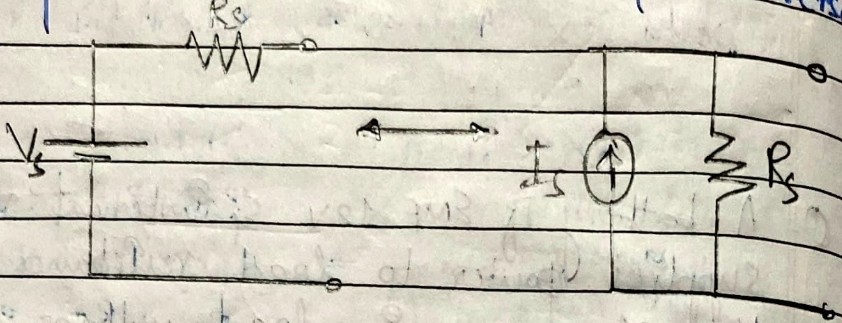
10005) 120000 (11.99
-10005
19950
-10005
99450
-90045
94050
-90045

$$\% V_L = \frac{11.99 - 11.94}{11.94} \times 100$$

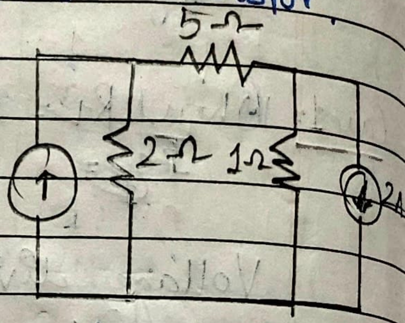
$$\boxed{\% V_L = 0.42\%}$$

→ Source transformation:

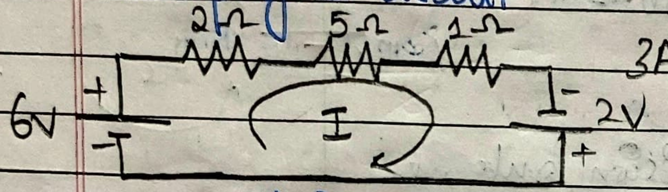
Practical voltage source can be transformed to practical current source & vice versa



Q- Find the current through 5Ω resistor.



Simplified circuit



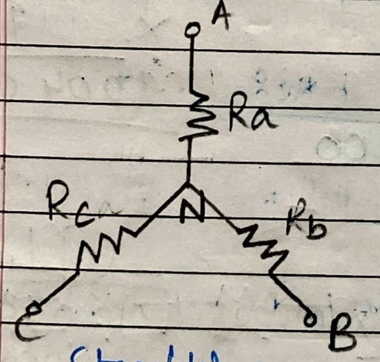
Applying KVL,

$$6 - 2I - 5I - I + 2V = 0$$

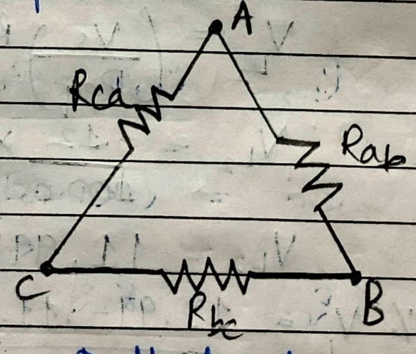
$$8 - 8I = 0$$

$$\boxed{I = 1A}$$

→ Star-Delta Transformations:



Star/Wye Connection



Delta/Mesh Connection

→ Delta to star transformation

Star → A and B, Ra and Rb are in series
Delta → A and B, Rab || Rbc + Rca (Rbc, Rca series)

$$R_a + R_b = \frac{R_{ab}(R_{bc}+R_{ca})}{R_{ab}+R_{bc}+R_{ca}} \quad -(1)$$

lly $$R_b + R_c = \frac{R_{bc}(R_{ca}+R_{ab})}{R_{bc}+R_{ca}+R_{ab}} \quad -(2)$$

lly $$R_c + R_a = \frac{R_{ca}(R_{ab}+R_{bc})}{R_{ca}+R_{ab}+R_{bc}} \quad -(3)$$

$$(1) - (2) + (3) \Rightarrow 2R_a = \frac{\cancel{R_{ab}R_{bc}} + R_{ab}R_{ca} - \cancel{R_{bc}R_{ca}} - \cancel{R_{bc}R_{ab}} + R_{ca}R_{ab} + \cancel{R_{ca}R_{bc}}}{R_{ab}+R_{bc}+R_{ca}}$$

$$\cancel{2}R_a = \frac{\cancel{2}R_{ab}R_{ca}}{R_{ab}+R_{bc}+R_{ca}}$$

$$R_a = \frac{R_{ab}R_{ca}}{R_{ab}+R_{bc}+R_{ca}} \quad -(4)$$

lly $$R_b = \frac{R_{ab}R_{bc}}{R_{ab}+R_{bc}+R_{ca}} \quad -(5)$$

$\Delta \Rightarrow \lambda$

lly $$R_c = \frac{R_{ca}R_{bc}}{R_{ab}+R_{bc}+R_{ca}} \quad -(6)$$

→ Star to Delta transformation

$$R_{ab} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c} \quad -(7)$$

$$R_{bc} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a} \quad -(8)$$

$$R_{ca} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b} \quad -(9)$$

$\lambda \Rightarrow \Delta$

Q- Transform the given delta to equivalent star.

$$R_a = \frac{R_{ab} R_{ca}}{R_{ab} + R_{ca} + R_{bc}}$$

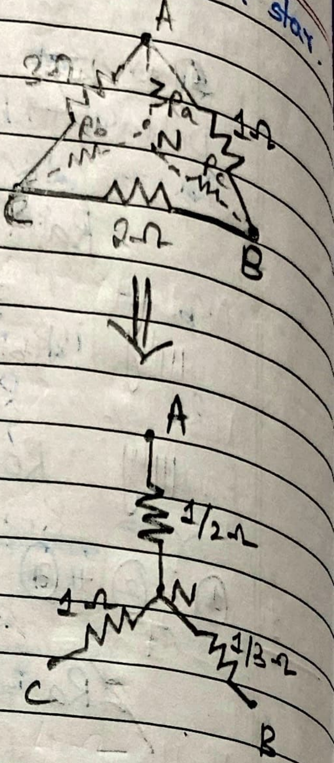
$$R_a = \frac{\cancel{3}}{\cancel{6}} \; \frac{1}{2} \Omega$$

$$R_b = \frac{R_{bc} R_{ab}}{R_{ab} + R_{ca} + R_{bc}}$$

$$R_b = \frac{\cancel{2}}{\cancel{6}} \; \frac{1}{3} \Omega$$

$$R_c = \frac{R_{ca} R_{bc}}{R_{ab} + R_{ca} + R_{bc}}$$

$$R_c = \frac{\cancel{6}}{\cancel{6}} \; 1 \Omega$$



Q- Transform given star to equivalent delta.

$$R_{ab} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_{ab} = \frac{2 + 6 + 3}{3}$$

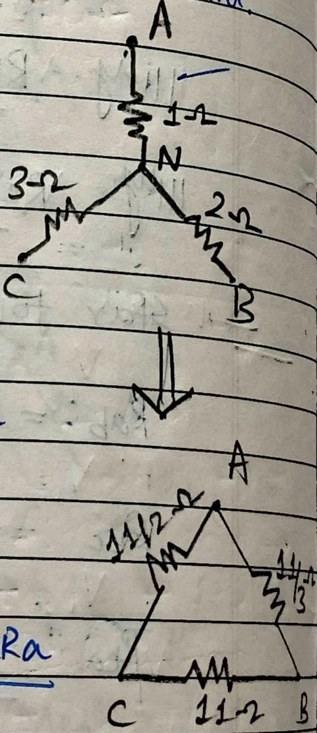
$$R_{ab} = \frac{11}{3} \Omega$$

$$R_{bc} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$

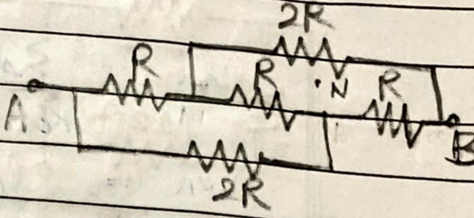
$$R_{bc} = \frac{11}{1} \Omega$$

$$R_{ca} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$$R_{ca} = \frac{11}{2} \Omega$$



Q- Find equivalent resistance b/w A & B.

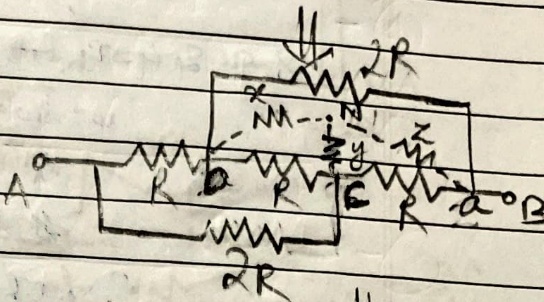


$$R_a = \frac{R_{ab} . R_{ca}}{R_{ab} + R_{bc} + R_{ca}}$$

$$R_a = \frac{2R^{\cancel{2}}}{2 \cdot 4\cancel{R}} = \frac{R}{2} \Omega = x$$

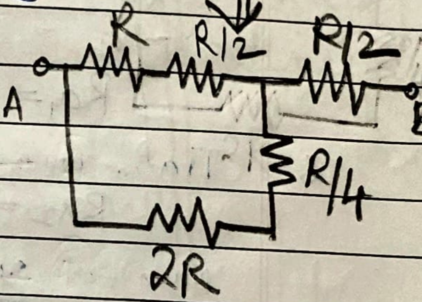
$$R_b = \frac{R_{bc} . R_{ab}}{R_{ab} + R_{bc} + R_{ca}}$$

$$R_b = \frac{R^{\cancel{2}}}{4\cancel{R}} = \frac{R}{4} \Omega = y$$



$$R_c = \frac{R_{ca} . R_{bc}}{R_{ab} + R_{bc} + R_{ca}}$$

$$R_c = \frac{2R^{\cancel{2}}}{2 \cdot 4\cancel{R}} = \frac{R}{2} \Omega = z$$



R and $R/2$ → series

$$R' = R + R/2$$

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

$R/4$ & $2R$ → series

$$R'' = R/4 + 2R$$

$$R'' = \frac{9R}{4} \Omega$$

R' & R'' → parallel

$$\frac{1}{r} = \frac{1}{R'} + \frac{1}{R''}$$

$$\frac{1}{r} = \frac{\frac{3R}{2} \cdot \frac{9R}{4}}{\frac{3R}{2} + \frac{9R}{4}}$$

$$\frac{1}{r} = \frac{\frac{27R^{\cancel{2}}}{8}}{\frac{15\cancel{R}}{\cancel{4}}}$$

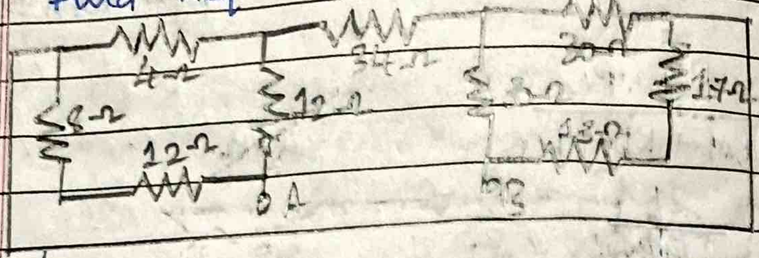
$$r = 0.9R \Omega$$

r & $R/2$ → series

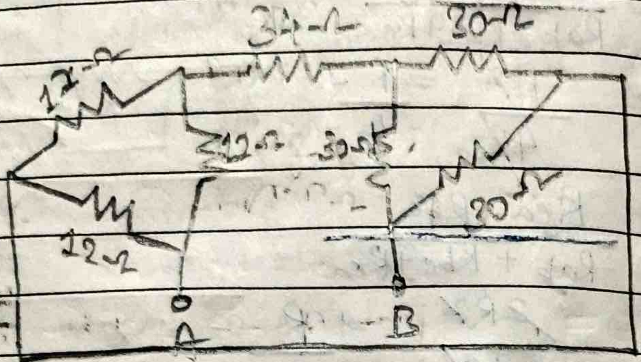
$$R_{eq} = 0.9R + 0.5R$$

$$R_{eq} = 1.4R \Omega$$

Q- find Req b/w A & B.

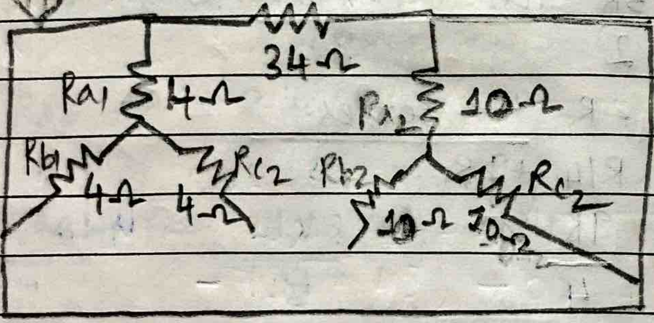


8Ω & 4Ω → series , 17Ω & 13Ω → series

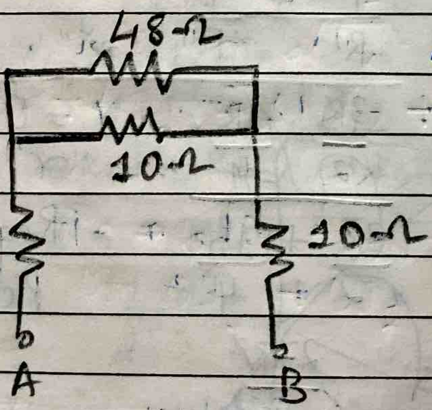


$$R_{a_1} = R_{b_1} = R_{c_1} = \frac{12}{3} = 4\Omega$$

$$R_{a_2} = R_{b_2} = R_{c_2} = \frac{30}{3} = 10\Omega$$



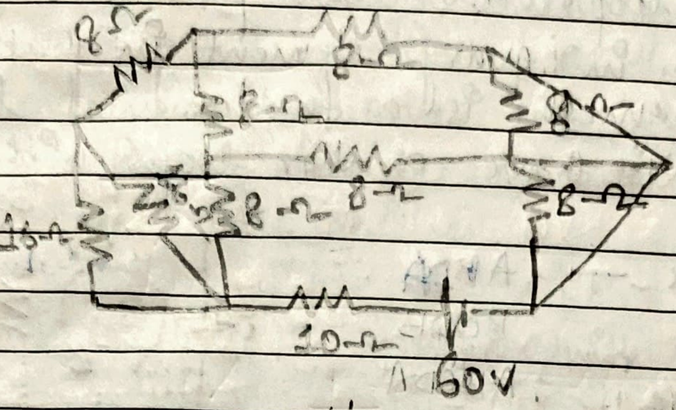
48Ω & 10Ω → ||

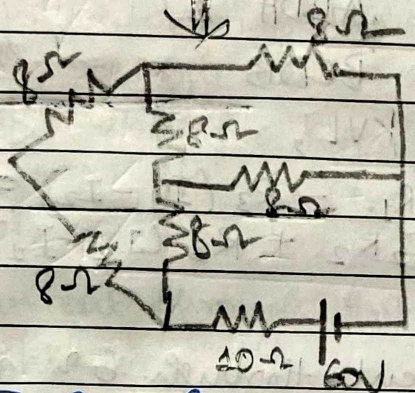


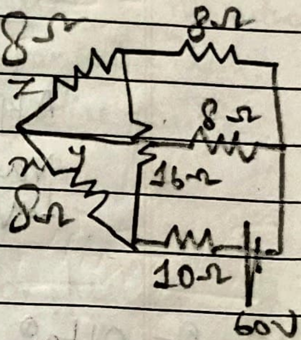
$$Req = 10.83 + 14$$

$$Req = 24.83\Omega$$

Q- Find Voltage drop across 10 Ω resistor.





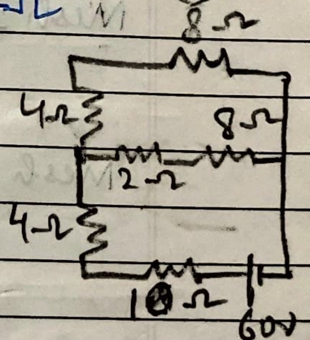


8Ω, 8Ω, 16Ω → Delta

$$R_x = \frac{8 \times 16}{32} = 4\,\Omega$$

$$R_y = \frac{8 \times 8}{32} = 2\,\Omega$$

$$R_z = \frac{8 \times 16}{32} = 4\,\Omega$$



8Ω & 4Ω → series

$R_1 = 12\,\Omega$.

8Ω & 2Ω → series

$R_2 = 10\,\Omega$.

R_1 & R_2 → parallel

$$1/R = 1/10 + 1/12$$

$$R = \frac{120}{22}$$

$$R = 60/11$$

10Ω & 4Ω → series

$R_3 = 14\,\Omega$.

$$R_{eq} = 60/11 + 14\,\Omega$$

$$R_{eq} = 19.45\,\Omega$$

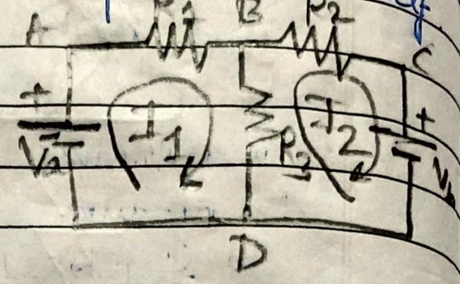
$$i = \frac{60}{19.45} = 3.08A$$

$$V_{eq} = 3.08 \times 10 = 30.84V$$

→ Mesh Analysis

→ A loop is a closed path with current flow in every element in that path

→ A mesh is a fundamental loop. It doesn't have smaller loops within itself



Loops → ABDA
BCDB
ABCDA

Mesh → ABDA
BCDB

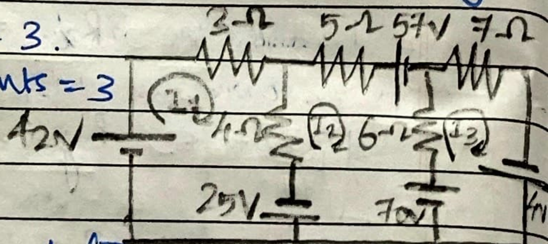
Applying KVL,

$V_a - I_1R_1 - R_3(I_1 - I_2) = 0$

$-V_b + I_2R_2 + R_3(I_2 - I_1) = 0$

Q- Obtain current through 6Ω resistor using Mesh Analysis.

<u>Ans:</u> Number of meshes = 3.
Number of mesh currents = 3
(I_1, I_2, I_3)



Apply KVL,

Mesh 1 → $42 - 3I_1 - 4(I_1 - I_2) + 25 = 0$

$-7I_1 + 4I_2 + 0I_3 + 67 = 0$ — ①

Mesh 2 → $-25 - 4(I_2 - I_1) - 5I_2 - 57 - 6(I_2 - I_3) - 70 = 0$

$+4I_1 - 15I_2 + 6I_3 - 152 = 0$ — ②

Mesh 3 → $70 - 6(I_3 - I_2) - 7I_3 + 4 + 0I_1 = 0$

$0I_1 + 6I_2 - 13I_3 + 74 = 0$ — ③

~~$I_1 = 22.467$ A $I_2 = 22.567$ A $I_3 = 16.108$ A~~

$I_1 = 5A$ $I_2 = -8A$ $I_3 = 2A$

Current through 6Ω $= I_3 - I_2 = 10A$

→ Mesh Analysis → KVLs by direct inspection

→ coefficient of same mesh current = sum of all resistances in that mesh

→ Coefficient of other mesh current = Negative of sum of all common resistances between the meshes.

→ Mesh Analysis in networks with current sources:

→ Procedure:

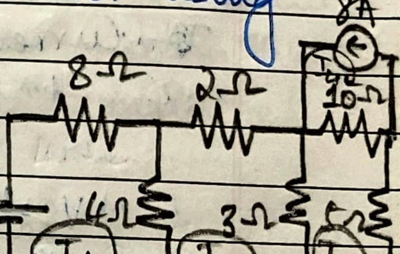
→ Step 1 → Identify no. of meshes in the network

→ Step 2 → One mesh current for each mesh.

→ Step 3 → write KVL ignoring the source.

→ Step 4 → Get the currents.

Q- Obtain current through 4-Ω resistor using Mesh analysis.



Ans:

Number of meshes = 4

Mesh currents → I_1, I_2, I_3, I_4

$I_4 = -8A$

Mesh 1 KVL,

$12I_1 - 4I_2 - 0I_3 = 100$ — ①

Mesh 2 KVL,

$9I_2 - 4I_1 - 3I_3 = 0$ — ②

Mesh 3 KVL,

$18I_3 - 3I_2 - 0I_1 - 10I_4 = 0$

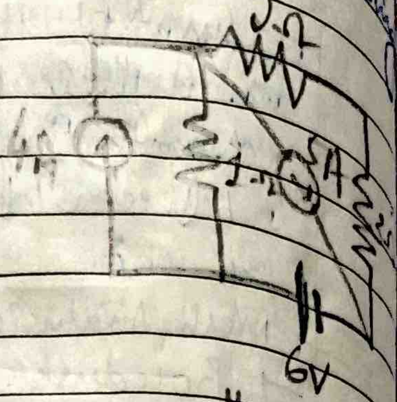
$18I_3 - 3I_2 - 0I_1 + 80 = 0$

$18I_3 - 3I_2 - 0I_1 = -80$ — ③

$I_1 = 9.26A, \quad I_2 = 2.79A, \quad I_3 = -3.97A$

$I_{4\Omega} = I_1 - I_2 = 6.47A$

Q- Obtain voltage across 3Ω resistor using Mesh analysis.



Ans: Number of meshes = 3

Mesh 1 ~~KVL~~ current eqn,

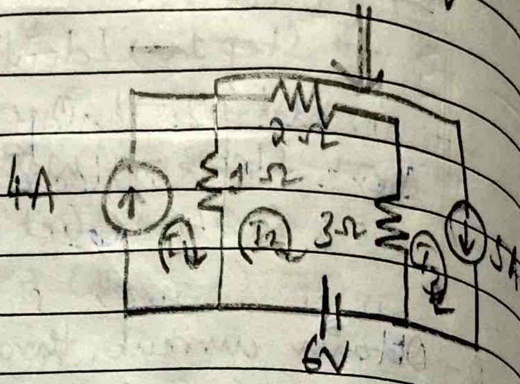
$1I_1$ ~~$-2I_2 - 0I_3$~~ $= 4A$. —(1)

Mesh 2 KVL,

$6I_2 - I_1 - 5I_3 = 6$ —(2)

Mesh 3 current eqn,

$I_3 = 5A$ —(3)



Sub. (1) & (3) in (2),

$I_2 = \frac{35}{6} A$

$I_2 = 5.83A$

Current through 3Ω resistor $= I_2 - I_3$

" $= 5.83 - 5$

" $= 0.83A$

$V_{3\Omega} = IR$.

$V_{3\Omega} = \frac{5 \times \cancel{3}}{\cancel{6}2}$

$V_{3\Omega} = 2.5V$

→ Linear element → when relation b/w V & I are linearly varying. Ex: Resistor, Inductor, capacitor.

~~Superposition Theorem~~

→ Linear circuits → Composed of linear elements, Independent sources & linear dependent sources.

◇(←) → Current-dependent source

◇(+−) → Voltage-dependent source

→ Superposition theorem → applicable to linear networks.

Statement → In a linear network, with more than one independent source, total response in any element is the algebraic sum of the individual responses caused by each individual source acting alone, while all other independent sources are replaced by their internal resistances.

→ Procedure to apply superposition theorem:

Step 1 → Consider one of the independent sources

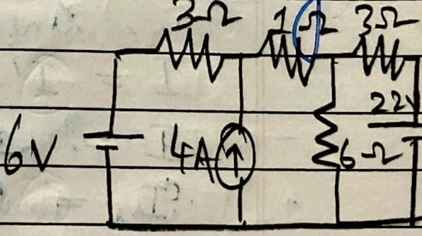
Step 2 → Replace all other independent voltage sources with short circuit & all other independent current sources with open circuit.

Step 3 → Find individual response in the desired element due to the considered source acting alone.

Step 4 → Repeat steps 1, 2, 3 until all the sources are considered.

Step5 → Add all responses algebraically to get the total response

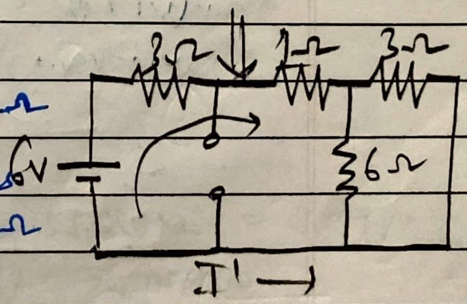
Q- Obtain current through 1Ω resistor using superposition theorem.



Ans: Consider 6V alone.

Short circuit → 22V

Open circuit → 4A



3Ω, 6Ω → parallel

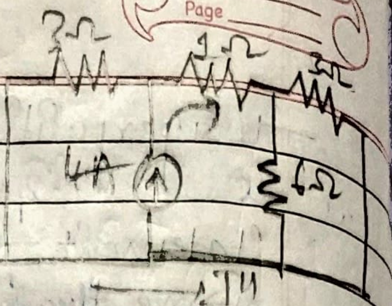
Equivalent resistance → 2Ω

Now, 3Ω, 1Ω, 2Ω → series

∴ Equivalent resistance → 6Ω

Now, $I' = \frac{\cancel{6}}{\cancel{6}}$ 1A

Consider 4A alone
Short circuit → 6V, 22V.



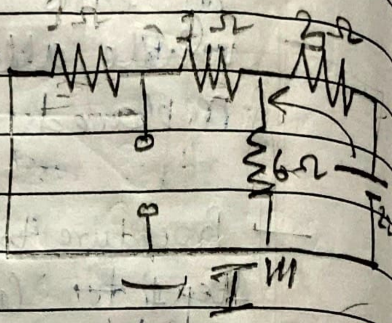
$$I'' = \left(\frac{3}{6}\right) \times 4A$$

(3+1+2)

(3Ω, 6Ω → parallel
2Ω → eq. resistance)

$$I'' = 2A.$$

Consider 22V alone
Short circuit → 6V
Open circuit → 4A.



3Ω, 1Ω → series
4Ω, 6Ω → parallel
Eq. R → 2.4Ω.
2.4Ω, 3Ω → series
Eq. R → 5.4Ω

$$I = \frac{22}{5.4}$$

$$I = 4.07A$$

$$I''' = \left(\frac{6}{3+1+6}\right) \times 4.07$$

$$I''' = \frac{6}{10} \times 4.07$$

$$I''' = (-)2.442\,A$$
↳ opp. direction

$$I = I' + I'' + I'''$$

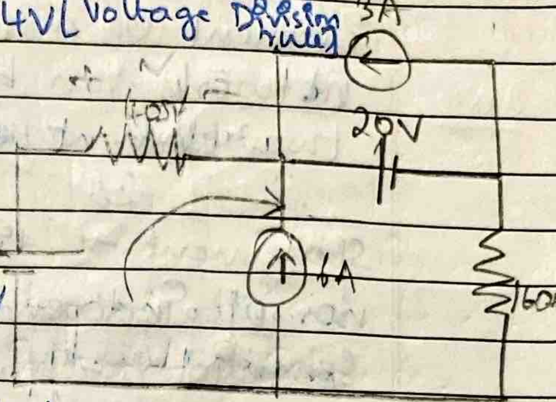
$$I = 1A + 2A - 2.442A$$

$$I = 0.558\,A$$

Q- Obtain V using Superposition theorem.

Ans: Consider 32V,

$V' = \frac{32 \times 40}{40+160} = 6.4V$ [Voltage Division rule]



Consider 6A,

$I_{40\Omega} = \frac{160}{200} \times 6 = 4.8A$

$V''_{(40\Omega)} = -4.8 \times 40 = -192V$

Consider 20V,

$V''' = \frac{20 \times 40}{200} = -4V$

Consider 3A,

$V'''' = 0V$

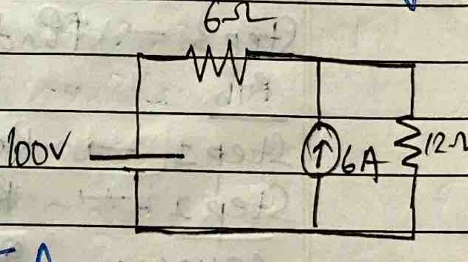
$V = V' + V'' + V''' + V''''$

$V = 6.4 - 192 - 4 + 0$

$V = -189.6V$

Q- Find power absorbed by 12Ω resistor using ~~12Ω res~~ Superposition Theorem.

Ans: Consider 100V,



$V' = \frac{100 \times 12}{18}$

$V' = 66.6V$

$I' = \frac{66.6}{12} = 5.55A$

Consider 6A,

$I'' = \frac{6 \times 6}{12+6}$

$I'' = 2A$

$I = (5.55 + 2)A$

$I = 7.55A$

$P = 7.55 \times 7.55 \times 12$

$P = 684.03W$

$P_1 = (I')^2 R = 5.55 \times 5.55 \times 12 = 369.63W$

$P_2 = (I'')^2 R = 2 \times 2 \times 12 = 48W$

$P \neq P_1 + P_2$ (as individual powers have quadratic relationship & not lin

Superposition theorem only linear powers

→ Thevenin's Theorem:

We are interested in response of particular element of a circuit. Remaining part of network can be replaced with simple two element series equivalent.

Statement → Linear network with large no. of independent & dependent sources & resistors b/w two ~~elements~~ terminals can be replaced with ~~two~~ simple two element series equivalent in which voltage source is called Thevenin's Equivalent Voltage (V_{Th}) in series with resistance called Thevenin's Equivalent Resistance (R_{Th}).

V_{Th}

Step 1 → Remove load resistance

Step 2 → Mark voltage across open load terminals & designate as V_{Th}.

Step 3 → Find V_{Th}

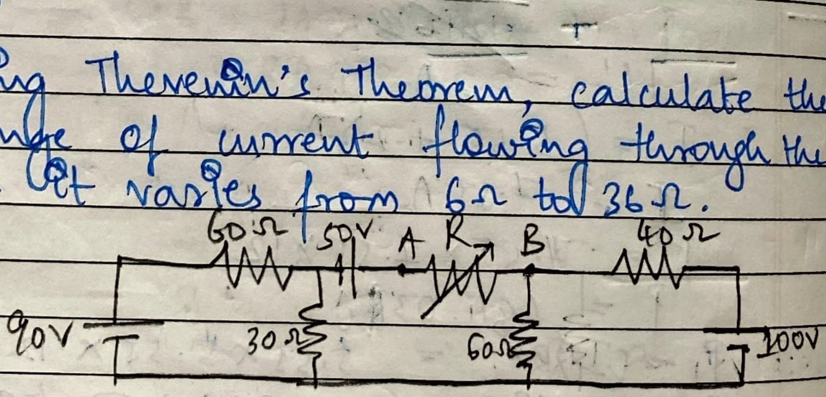
R_{Th}

Step 1 → Remove load resistance

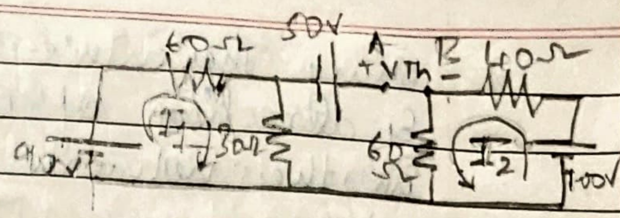
Step 2 → Replace all independent voltage sources with short circuits & all independent current sources with open circuits.

Step 3 → Find R_{Th}.

1. Using Thevenin's Theorem, calculate the range of current flowing through the R, as it varies from $6\,\Omega$ to $36\,\Omega$.



Ans: V_{Th}



$$I_1 = \frac{90}{60+30}$$

$$I_1 = 1A$$

$$I_2 = \frac{100}{60+40}$$

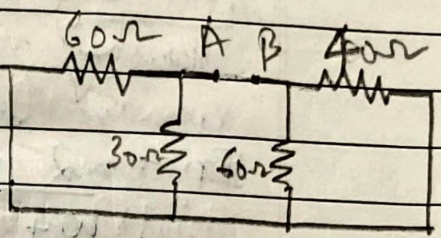
$$I_2 = 1A$$

Apply KVL,

$$50 - V_{Th} - 60 + 30 = 0$$

$$\boxed{V_{Th} = 20V}$$

R_{Th}



60Ω, 30Ω → parallel

$$1/R_1' = 1/60 + 1/30$$

$$1/R_1' = \frac{3}{60}$$

$$R_1' = 20Ω$$

40Ω, 60Ω → parallel

$$1/R_2' = \frac{1}{40} + \frac{1}{60}$$

$$1/R_2' = \frac{3+2}{120}$$

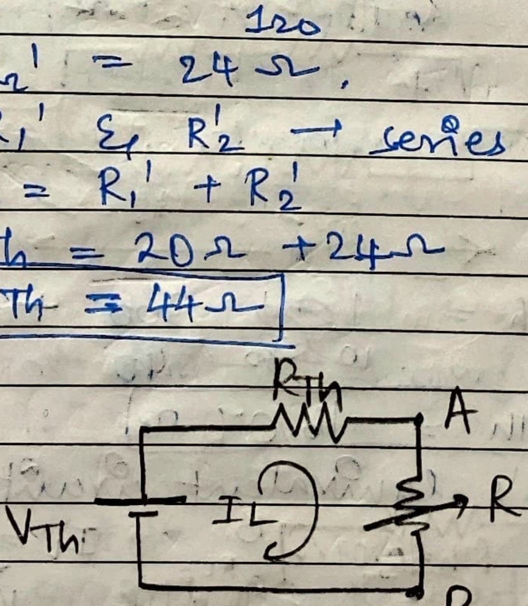
$$R_2' = 24Ω$$

R_1' & R_2' → series

$$R_{Th} = R_1' + R_2'$$

$$R_{Th} = 20Ω + 24Ω$$

$$\boxed{R_{Th} = 44Ω}$$



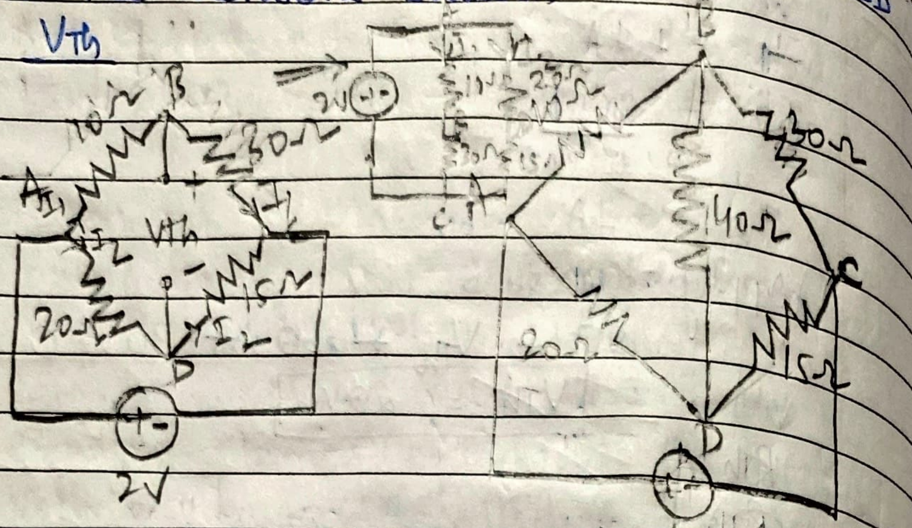
Case1: when, $R = 6Ω$, $I_L = V_{Th}/(R_{Th}+R) = 20/50 = 0.4A$

Case2: when, $R = 36Ω$, $I_L = V_{Th}/(R_{Th}+R) = 20/80 = 0.25A$

Hence, current ranges from 0.4A to 0.25A

2. Using Thevenin's theorem, find magnitude & direction of current in branch BD in the network shown.

Ans: V_{Th}



$$I_1 = \frac{2}{10+30} = \frac{1}{20} = 0.05A$$

$$I_2 = \frac{2}{20+15} = \frac{2}{35} = 0.057\,A$$

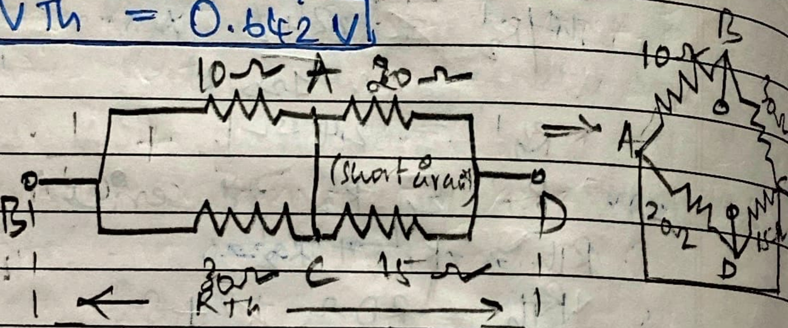
KVL for loop ABDA,

$$-10I_1 - V_{Th} + 20I_2 = 0$$

$$V_{Th} = \cancel{20}^{4} \times \frac{2}{\cancel{35}_{7}} - \cancel{10} \times \frac{1}{\cancel{20}_{2}}$$

$$\boxed{V_{Th} = 0.642\,V}$$

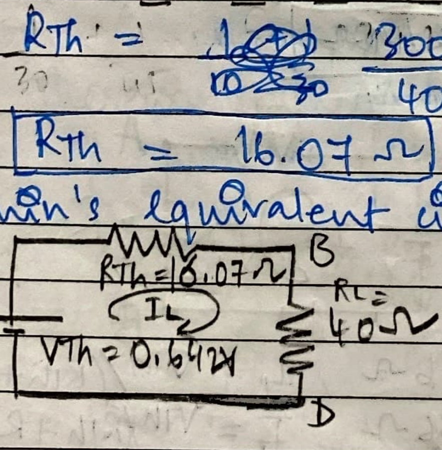
R_{Th}



$$R_{Th} = \frac{\cancel{10 \times 30}}{\cancel{10+30}} = \frac{300}{40} + \frac{300}{35}$$

$$\boxed{R_{Th} = 16.07\,\Omega}$$

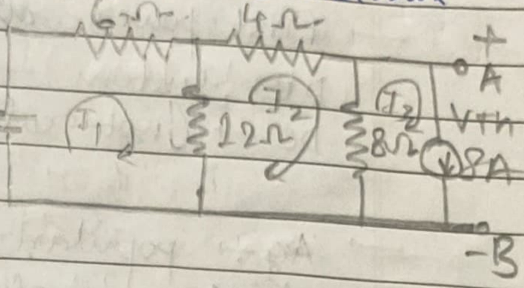
Thevenin's equivalent circuit:



$$I_L = \frac{0.64}{16.07+40} = 11.4mA$$

Direction B to D.

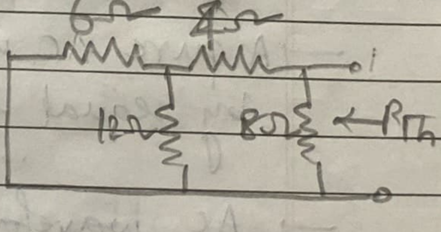
3. Obtain Thevenin's ~~equation~~ Equivalent across the terminals for the network given.



Ans: V_{Th}

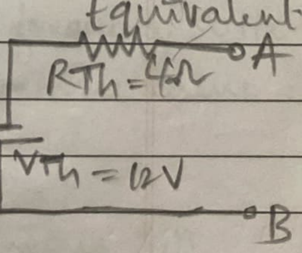
KVL for Mesh 1,
$$18I_1 - 12I_2 - 0I_3 = 60.$$
KVL for Mesh 2,
$$24I_2 - 12I_1 - 8I_3 = 0$$
~~KVL for Mesh 3~~ Current eqn for Mesh 3,
$$I_3 = 8A$$
$$36I_1 - \cancel{24I_2} = 120$$
$$-12I_1 + \cancel{24I_2} = 64$$
$$24I_1 = 184$$
$$I_1 = 7.66$$
$$\cancel{18}^{6} \times \frac{23}{\cancel{3}} - 12I_2 = 60$$
$$12I_2 = 78$$
$$I_2 = 6.5A$$
$$I_3 = 8A$$
$$V_{Th} = (I_2 - I_3) \times 8\Omega$$
(As Mesh 3 only has current source, Mesh 2 is taken as reference, so, $I_2 - I_3$)
$$V_{Th} = -1.5 \times 8$$
$$\boxed{V_{Th} = -12V}$$

R_{Th}



6Ω, 12Ω → parallel
$R_1 = 4\Omega$
~~4Ω, 8Ω → parallel~~
~~$R_2 = 2.66\Omega$~~
R_1, 4Ω → ~~parallel~~ series
$R_1' = 4\Omega + 4\Omega$
$R_1' = 8\Omega.$
R_1' & 8Ω → parallel
$$\boxed{R_{Th} = 4\Omega}$$

Thevenin's Equivalent



$[R_{Th} = ((12\Omega \| 6\Omega) + 4\Omega) \| 8\Omega) = 4\Omega]$