3/7/21

Unit-1

DC Networks

- Ohm's Law
- K.C.L / K.V.L
- Network Reduction Theorems
  - Thevenis Theorem
  - Nortons Theorem
- Specific quantity Theorems
  - SPT
  - Max P.T Theorems

→ Ohm's Law

The potential difference accross any two points of the conductore, will be directly proportional to the current flowing though it.

$$V \propto I$$

$$V = IR$$

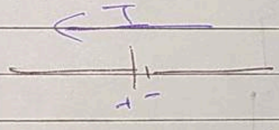
$R \rightarrow (\Omega)$ ohms

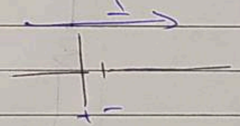
→ Kirchhoff's Laws :-

1) KVL – In any closed circuit or mesh, the algebric sum of all the emf's and voltage drops will be zero.

$$\Sigma \text{emf's} + \Sigma IR = 0$$

2) ~~KCL~~





Rise in potential (+)ive

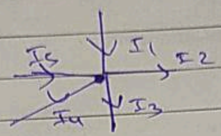
(Current from lower potential to higher ")

Drop in potential (potential/voltage drop) (-)ive

(current from higher to lower potential)

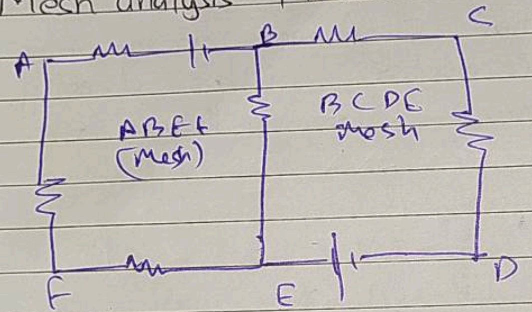
2) KCL- The algebric sum of all the currents meeting at a point or a junction will be zero.

$$\sum I = 0$$



$$I_1 - I_2 - I_3 + I_4 + I_5 = 0$$

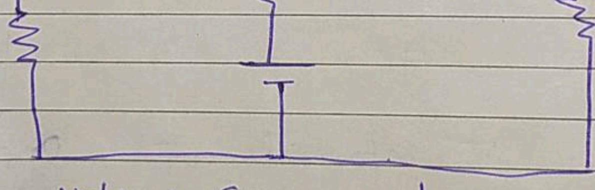
* Mesh analysis Method



Loop can have inner Loops
but Mesh can't have innerloops.

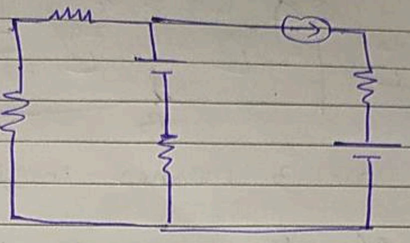
→ Numerical Types

1) Type - 1

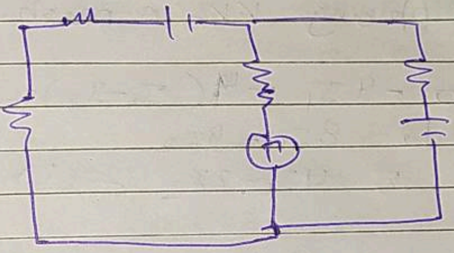


Having voltage Source and ~~Current~~ Resistance

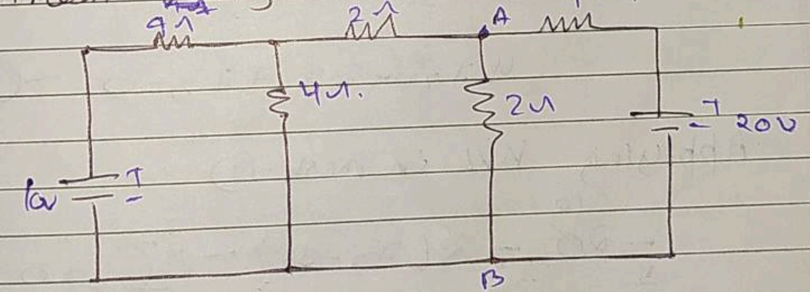
2) Type-2 Having Resistance and voltage source along with current source but in outer loop.



3) Type-3 Having Resistance and voltage Source along with current source in inner loop.

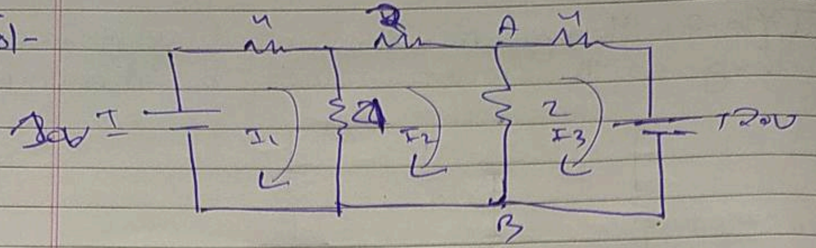


Q→1) Calculate the current in Branch A-B of 2Ω resistance for the given circuit using mesh analysis method.



Voltage across Resistance in KVL should always be taken (-)ive.

Sol-



There are 3 meshes in given circuit.

Let all the current be in CW dir.

$+20 - 4I_1 - 4I$

Applying KVL in mesh (1)

$$+10 - 4I_1 - 4(I_1 - I_2) = 0$$
$$10 = 8I_1 - 4I_2$$
$$5 = 4I_1 - 2I_2 \quad \text{—(i)}$$

Applying KVL in mesh (2)

$$-\cancel{2}I_2 - \cancel{2}(I_2 - I_3) - \overset{2}{\cancel{4}}(I_2 - I_1) = 0$$
$$-I_2 - I_2 - I_3 - 2I_2 + 2I_1 = 0$$
$$4I_2 - 2I_1 + I_3 = 0 \quad \text{—(ii)}$$

Applying KVL in mesh (3)

$$-\overset{10}{\cancel{20}} - \cancel{2}(I_3 - I_2) - \overset{2}{\cancel{4}}I_3 = 0$$
$$10 = -3I_3 + I_2 \quad \text{—(iii)}$$

$4I_2 - 2I_1 + I_2 - 10 = 0$

$5I_2 - 2I_1 = 10 \times 2 \Rightarrow 10 I_2 - 4I_1 = 20$

$-2I_2 + 4I_1 = 5 \qquad -2I_2 + 4I_1 = 5$

$8 I_2 = 25$

$I_2 = \frac{25}{8}$

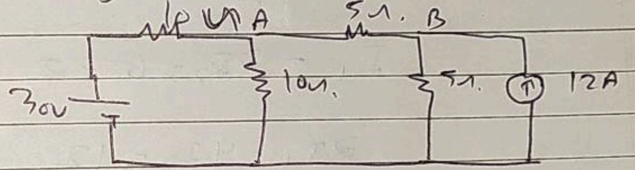
Solving eqn 1, 2, 3.

$I_1 = 1.093\,A \quad I_2 = -0.312\,A$

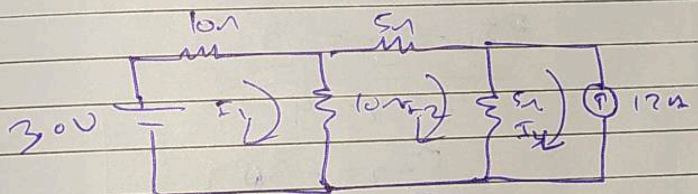
$I_3 = -3.437\,A$

$I_{AB} = I_2 - I_3 = 0.312 - (-3.437)$
$= 3.125\,A$

Q-2) Find the current in AB Branch using mesh analysis.



Sol-



3 Meshes.
Let all the current in C.W dirn.
Applying KVL in mesh ①

$+30 - 10I_1 - 10(I_1 - I_2) = 0$

$3 = 2I_1 - I_2 \quad —(i)$

Applying KVL in mesh ②

$+\cancel{8} I_2 + \cancel{5}(I_2 - I_3) + \cancel{10}^{2}(I_2 - I_1) = 0$

$4I_2 - 2I_1 - I_3 = 0$

($I_3 = -12A$ because we have assumed it in C.W dirn but actually it is flowing A.C.W Dirn (I) 12A)

$4I_2 - 2I_1 - (-12) = 0$

$2\cancel{4}I_2 - \cancel{2}I_1 + \cancel{12}^{6} = 0$

$I_1 - 2I_2 = 6 \quad -(ii)$

from eq 1 and 2

$I_1 - 2I_2 = 6 \times 2$

$2I_1 - 4I_2 = 12$

$2I_1 - I_2 = 3$

$-3I_2 = 9$

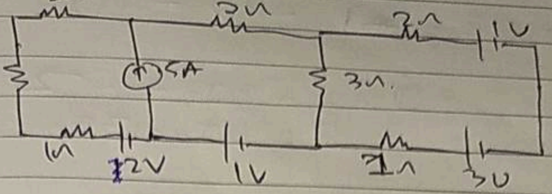
$\boxed{I_2 = -3A}$

$\boxed{I_1 = 0}$

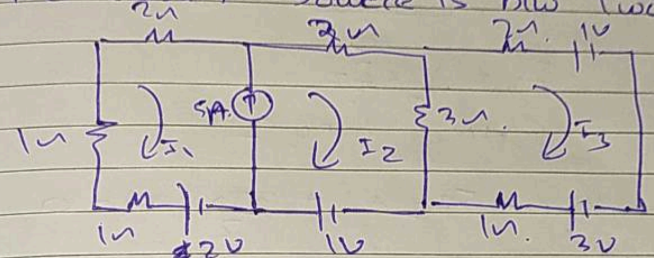
In AB branch

$= I_2 = -3A$

Q-3) Find the voltage across 3Ω resistor using KVL.

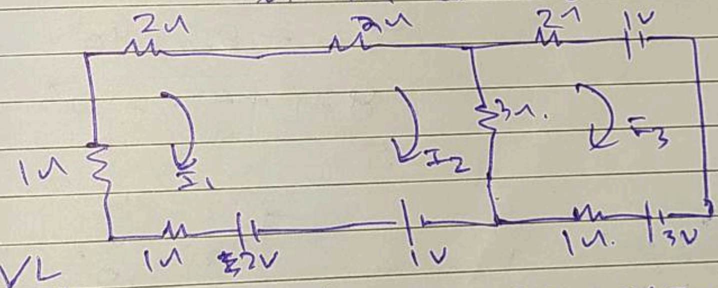


Sol- Method of Super Mesh (Used when the current source is b/w Two meshes).



$I_2 - I_1 = 5$ (By super mesh — (i) as I_2 and 5A dir is same)

(After this remove (5A) current source but I_1 and I_2 will remain)



Applying KVL in mesh 1 and 2 by Super Mesh

$-I_1(1) - 1(I_1) - 2I_1 - 2I_2 - 3(I_2 - I_3) - \ldots$

$-4I_1 - 5I_2 + 3I_3 + 1 = 0$ — (ii)

Applying KVL in mesh (3)

$-2I_3 - 1 + 3 - 1(I_3) - 3(I_3 - I_2) = 0$

$-6 I_3 + 3 I_2 = -2$

$2 = 6 I_3 - 3 I_2$ — (3)

From eq 1, 2 and 3

$I_3 = \frac{2 + 3 I_2}{6}$ — (3)

$I_3 = \frac{1}{3} + \frac{I_2}{2}$

Putting in eq 2

$-4I_1 - 5I_2 + 1 + \frac{3I_2}{2} + 1 = 0$

$-\frac{7I_2}{2} - 4I_1 + 2 = 0$

$4I_1 + \frac{7I_2}{2} = 2$

$8I_1 + 7I_2 = 4$

$-I_1 + I_2 = 5 \times 8$

$-8I_1 + 8I_2 = 40$

$8I_1 + 7I_2 = 4$

$15 I_2 = 44$

$I_2 = \frac{44}{15} = 2.93 A$

$I_2 - 5 = I_1$

$\frac{44}{15} - 5 = I_1$

$-\frac{31}{15} = I_1 = -2.06 A$

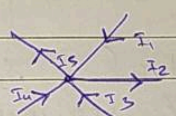
$$I_3 = \frac{1}{3} + \frac{88}{15}$$

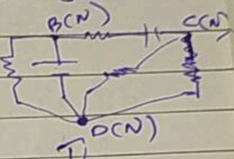
$$\frac{5+88}{15} = \frac{93}{15} = 6.2\,A$$

Voltage across 3Ω resistor

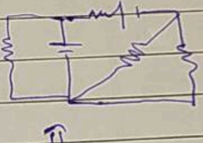
$$3(I_3 - I_2)$$
$$3(6.2 - 2.93)$$
$$3 \times 3.27 = 9.81\,V$$

2) KCL- The algebric sum of all the currents meeting at a point or junction will be zero.

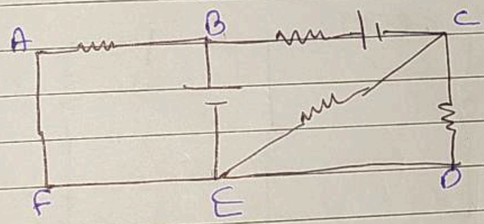


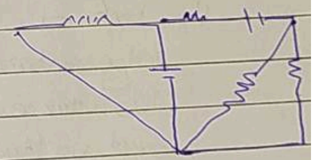


$$\Sigma I = 0 = I_1 - I_2 + I_3 + I_4 - I_5 = 0$$



→ Junction (J) and a node (N)





Junction → is a point in circuit where 3 or more branches combine (current must divide)

Node → where two or more branches combine (current may or may not divide)

→ Steps for solving numericals using nodal analysis—

1) Identify the principle nodes or junctions present in the network.

2) Assign a junction potential on each junction w.r.t the assigned reference junction having high value $V_0 = 0V$.

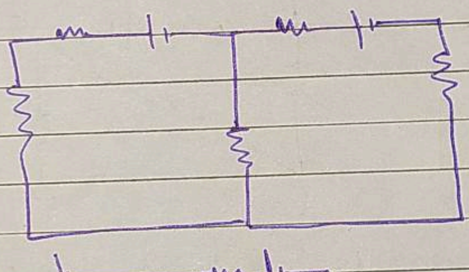
3) Assuming all the currents in outgoing direction from each juction form KCL equation.

4) Solve the equations to calculate the value of junction potentials.

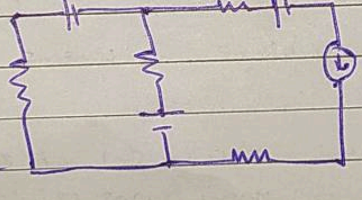
5) Using individual junction potentials find the value of required electrical quantity.

→ Variety of Numericals-

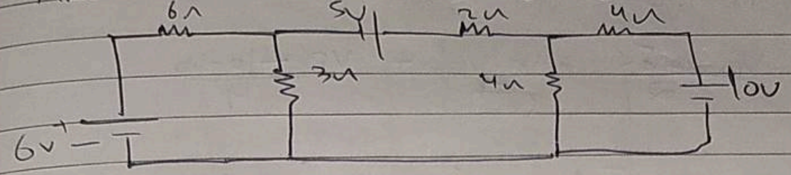
1) Type-1
only contain resistance and voltage source



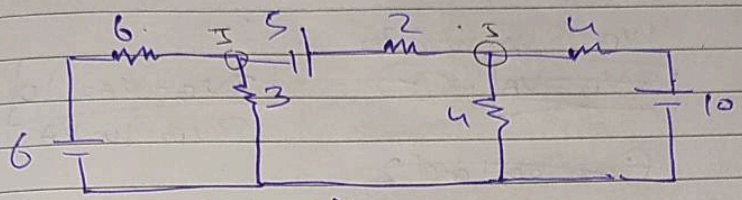
2) Type-2
also contain current source

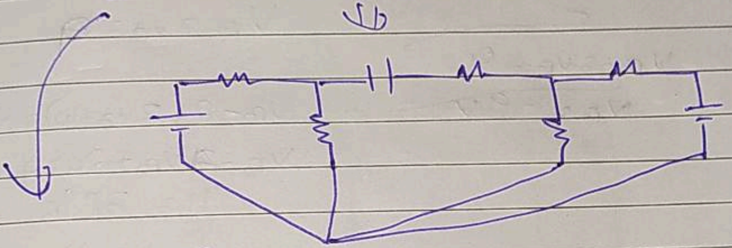


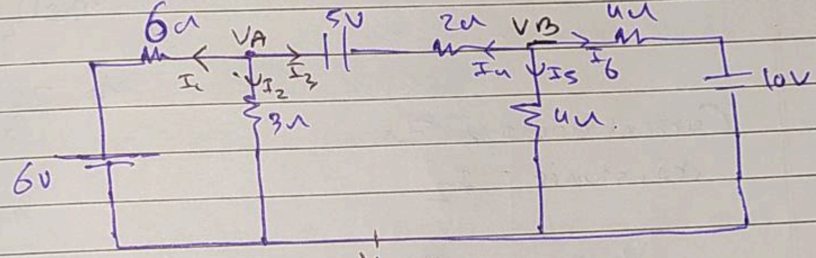
1) Find the current in 3Ω resistor using KCL.



Sol-







$V_0 = 0$

$I_1 = \frac{V_A - V_0 - 6}{6}$ (Not doing like this.) form a eqⁿ in systematic way

Applying KCL at Junction A

$$\underbrace{\frac{V_A - V_0 - 6}{6}}_{I_1} + \underbrace{\frac{V_A - V_0}{3}}_{I_2} + \underbrace{\frac{V_A - V_B + 5}{2}}_{I_3} = 0$$

$$\frac{V_A - V_0 - 6 + 2V_A - 2V_0 + 3V_A - 3V_B + 15}{6} = 0$$

$\boxed{V_B - 2V_A}$

$6V_A - 3V_0 - 3V_B + 9 = 0$

$6V_A - 3V_B + 9 = 0 \Rightarrow 2V_A - V_B = -$

Applying KCL at junct B

$\frac{V_B - V_A + 5}{2} + \frac{V_B - V_0}{4} + \frac{V_B - 10 - V_0}{4}$

$2V_B - 2V_A + 10 + V_B - V_0 + V_B - V_0 - 10 = 0$

$4V_B - 2V_A - 2V_0 = 0$

$\boxed{2V_B = V_A}$ — (2)

$\boxed{2V_B - V_A = 10}$ — (2)

$2V_B - 10 = V_A$

From eq 1 and 2

$V_B - 2V_A = 9$

$V_B - 2V_B = 9$

$V_B = -9V$

$V_B - 2(2V_B - 10) = 9$

$V_B - 4V_B + 20 = 9$

$11 = 3V_B$

$V_B = \frac{11}{3} = 3.66$

$V_A = \frac{22}{3} - 10$

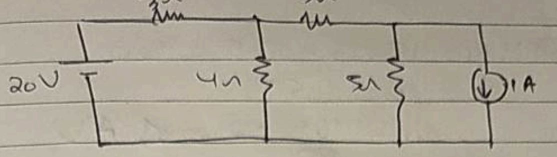
$= \frac{-8}{3} = -2.66$

Current across 3Ω resistance $= I_2$

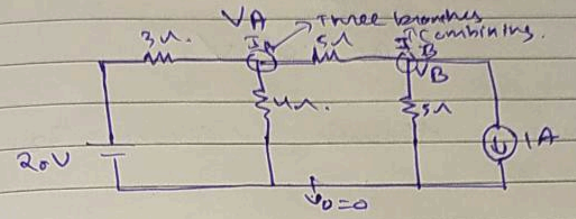
$\frac{V_A - V_0}{3} = \frac{-8}{9} A$

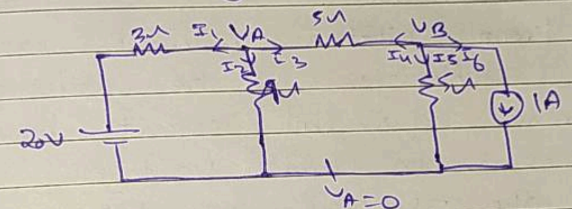
REDMI NOTE 8
AI QUAD CAMERA

Q.32) Using nodal analysis find the current in 4Ω branch.



Sol-





There are two junctions

Applying KCL at Junction A

$$\frac{VA-20-V_0}{3} + \frac{VA-V_0}{4} + \frac{VA-VB}{5} = 0$$

$$\cancel{5VA-100+3VA+3VA-3VB=0}$$

$$\cancel{+18VA}\ \cancel{11VA}$$

$$\frac{20VA-400+15VA+12VA-12VB}{60} = 0$$

$$47VA - 12VB = 400 \quad (1)$$

Applying KCL at Junction B

$$\frac{VB-VA}{5} + \frac{VB-V_0}{5} + 1 = 0$$

$$2VB - VA + 5 = 0 \quad (2)$$

from eq 1 and 2

$47(2V_B+5) - 12V_B = 400$

$94V_B - 12V_B + 235 = 400$

$82V_B = 165$

$V_B = \frac{165}{82} = 2.01\ V$

$V_A = 9.02\ V$

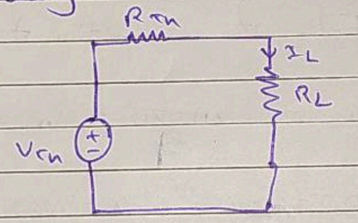
Current through 4Ω branch $= I_2 = \frac{V_A - V_0}{4}$

$= \frac{9.02}{4}$

$= 2.25A$

Thevenin's Theorem

Any linear bilateral network irrespective of its complexities can be reduced into a Thevinins equivalent circuit having the thevinins open circuit voltage 'V_{th}' in series with the Thevinins equivalent resistance R_{Th} along with Load Resistor R_L



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

51

→ Steps for solving

1) Identify the Load resistor R_L

2) Remove the Load resistor and calculate the open circuit potential across two open ends. This will be Thevinins equivalent voltage V_{Th}.

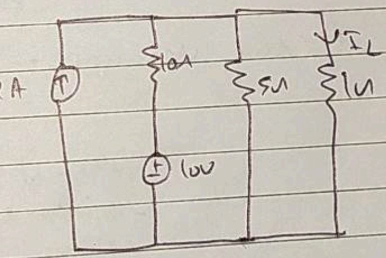
3) Again remove the load resistor and replace all the active sources by their internal resistances.

4) Calculate the equivalent resistance across the open ends. This will be Thevinins equivalent resistance R_{Th}.

5) Draw the Thevenins equivalent for given circuit

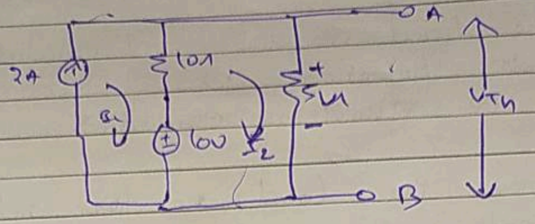
6) Calculate the load current I_L by using the identity. $\boxed{I_L = \frac{V_{Th}}{R_{Th} + R_L}}$

Q→1) Find the current through 1Ω resistor in the Given circuit using Thevinins Theorem-



Sol- $R_L = 1\Omega$. (Step 1)

Step-2 Removing R_L.



Mesh 1

$I_1 = 2A$

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

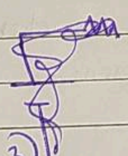
$10 - 10(I_2 - 2) - 5I_2 = 0$

$10 + 20 = 15I_2$

$I_2 = 2A$

Voltage across 5Ω is $5 \times 2 = 10V$

$\boxed{V_{Th} = 10V}$



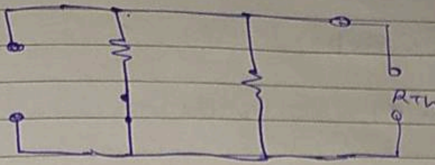
internal resistance 0Ω
replaced with short circuit branch

Step-3) and 4 Active resources → Voltage and current source

internal resistance ∞

replaced by open circuit branch.

~~Step-4 and 5~~

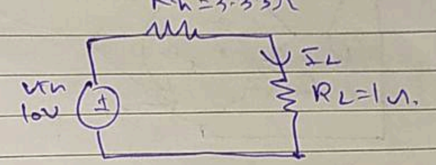


$R_{Th} = 10 \parallel 5$

$R_{Th} = \frac{10 \times 5}{10+5} = \frac{50}{15} = \frac{10}{3} = 3.33\Omega$

$\boxed{R_{Th} = 3.33\Omega}$

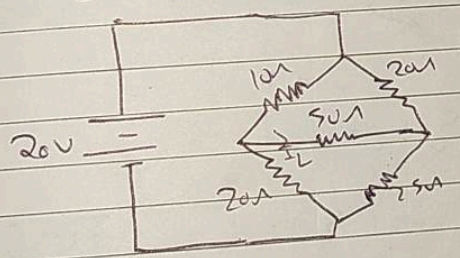
Step-5



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

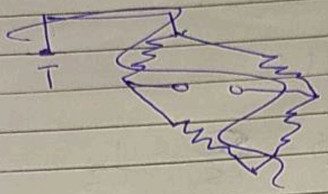
$I_L = \frac{10}{3.33+1} = \frac{10}{4.33}$ Am

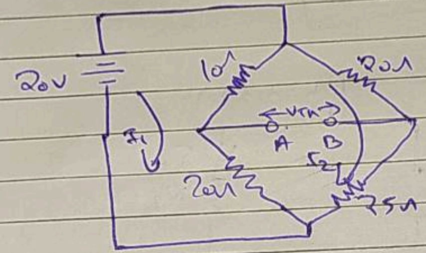
Q-2) Find the current through 50Ω resistor using the thevinins Theorem.



Sol- $R_L = 50\Omega$ (Step 1)

Step (2) Remove R_L Calculate V_{th}





$\cancel{+20 - 10I_1 - 20I_1 = 0}$

$\cancel{\frac{20}{30} = I_1 = 0.66A}$

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

$20 = 30I_1 - 30I_2$

$\frac{20}{30} = I_1 - I_2$

$-20I_2 - 25I_2 - 20(I_2 - I_1) - 10(I_2 - I_1) = 0$

$-75I_2 + 30I_1 = 0$

$\frac{5}{2}\frac{\cancel{75}}{\cancel{30}} I_2 = I_1$

$\cancel{I_1} = \frac{5}{2} I_2 - I_2 = \frac{2}{3}$

$I_2\left(\frac{3}{2}\right) = \frac{2}{3}$

$I_2 = \frac{4}{9} A$

$= 0.44A$

$I_1 = \frac{5}{2} \times \frac{4}{9}$

$I_1 = \frac{10}{9} A$

$= 1.11A$

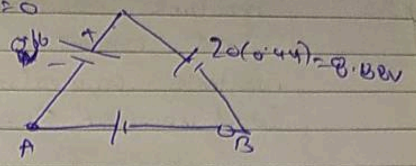
Assuming A o—|‖— o B, V_{Th}

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

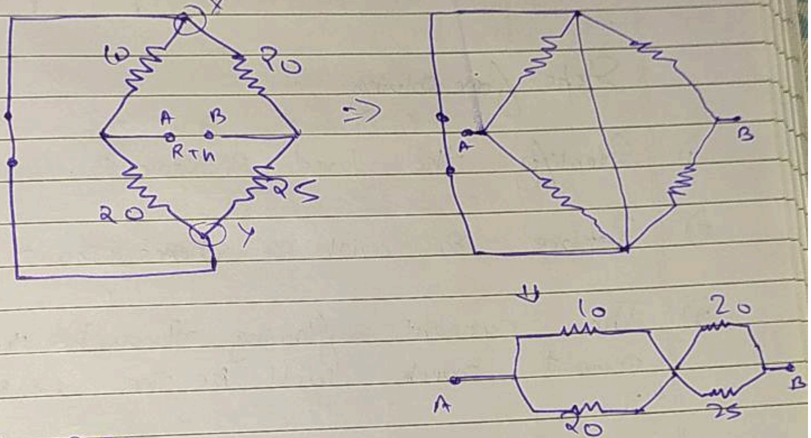
$+10(1.11 - 0.44) - 20(0.44) + V_{Th} = 0$

$+10(0.66) - 8.88 + V_{Th} = 0$

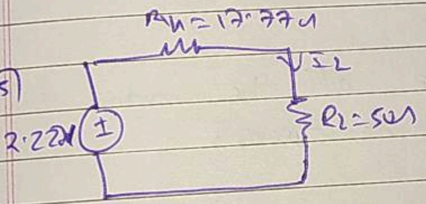
$V_{Th} = 2.22V.$



Step 4 Again removing R_L and replacing all the active sources by their internal resistances.



Step 5



$R_{Th} = \frac{10 \times 20}{30} + \frac{20 \times 25}{45}$

$R_{Th} = \frac{20}{3} + \frac{100}{9}$

$= \frac{60 + 100}{9}$

$R_{Th} = \frac{160}{9}$

$= 17.77\Omega$

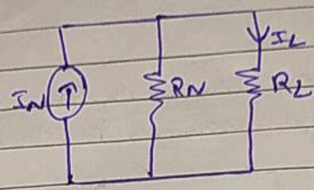
$I_L = \frac{2.22}{67.77} = \frac{V_{Th}}{R_{Th} + R_L}$

$\boxed{I_L = 0.032A}$

Norton's Theorem

Any linear bilateral network irrespective of its complexities can be reduced into a norton's equivalent circuit having a norton's short circuit current 'I_N' in parallel with Norton's equivalent resistance R_N in parallel with Load resistor R_L.

$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$$



Steps for solving

1) Identify the Load Resistor R_L.

2) Replace R_L with a short circuit Branch.

3) The current flowing through this short circuit branch will be the Norton's Current 'I_N'.

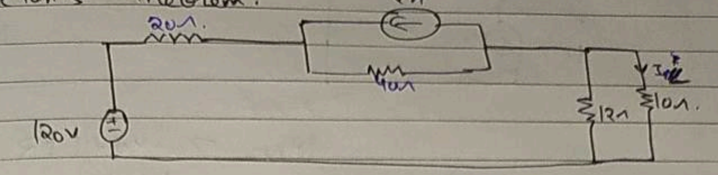
4) Remove R_L and replace all the active Sources by their internal resistances.

5) The equivalent resistance across the two open ends will be the norton's resistance R_N.

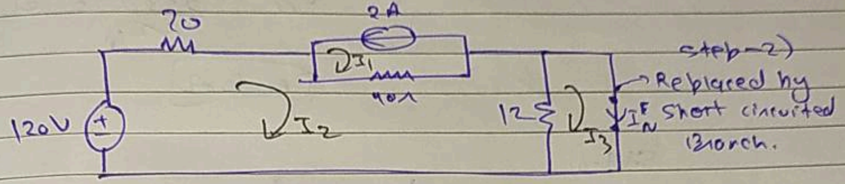
6) Draw the Norton's equivalent circuit

7) Calculate I_L by $I_L = \frac{R_N I_N}{R_N + R_L}$

Q-1) Find the current I in the given circuit by Norton's Theorem.



Sol- $10\Omega \rightarrow R_L$ (Load resistance) step 1



$I_1 = -2A$ (Mesh I)

Step-3

Applying KVL in Mesh 2.

$-72 I_2 + 40 I_1 + 12 I_3 = -120$

$12 I_3 - 72 I_2 = -40$ — (1)

Applying KVL in Mesh 3

$12(I_3 - I_2) = 0$

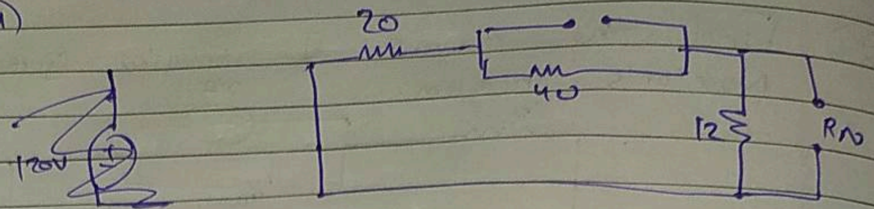
$I_3 = I_2$ — (2)

$+60 I_2 = +40$

$I_2 = \frac{2}{3} = 0.66A = I_3$

$I_N = I_2 = 0.66A$

Step-4)



Step-5)

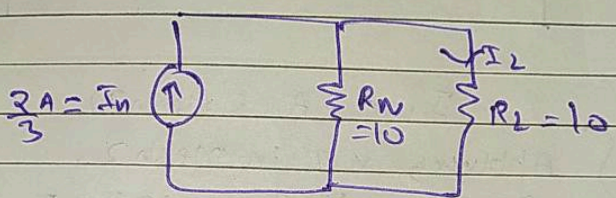
$R_N = 20+40 \parallel 12$

$= \dfrac{60\times12}{60+12}$

$R_N = \dfrac{\cancel{60}\times12}{\cancel{72}_{6}} = 10\,\Omega$

$\boxed{R_N = 10A}$

Step-6)

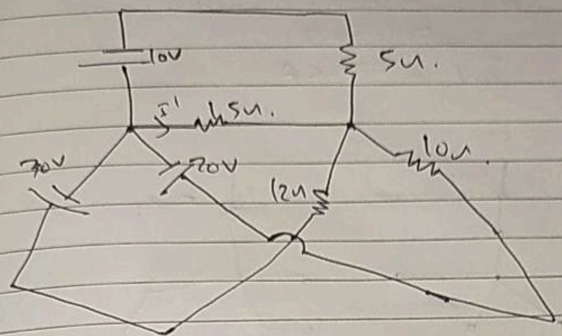


$I_2 = I_N \dfrac{R_N}{R_N+R_2}$

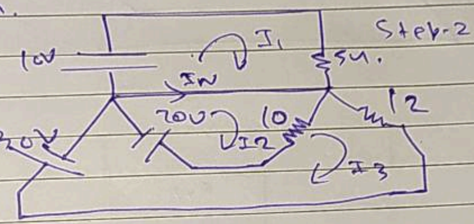
$\dfrac{2}{3} \times \dfrac{1\cancel{0}}{2\cancel{0}}$

$= 0.33A$

2) Find the current I' in the given circuit using Norton's Theorem



Sol- Step 1 $R_L = 15\Omega$.



Applying KVL in Mesh 1

$-5I_1 = +10$

$I_1 = -2A$

Applying KVL in Mesh 2

$-10I_2 + 10I_3 - 20 = 0$

$10(I_3 - I_2) = 20$

$I_3 - I_2 = 2$ — (1)

Applying KVL in Mesh 3

$-22I_3 + 10I_2 - 30 + 20 = 0$

$-22I_3 + 10I_2 = 10$

$-22I_3 + 10(I_3 - 2) = 10 \Rightarrow -12I_3 = 30 \Rightarrow I_3 = -2.5$

$I_2 = -4.5$

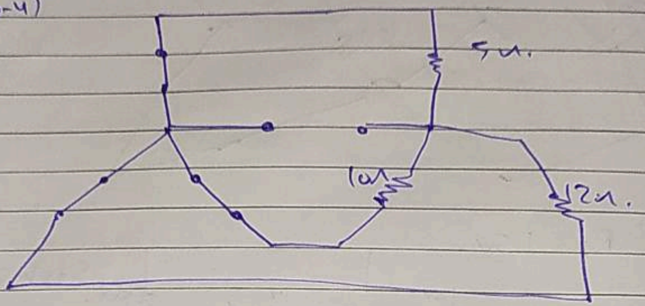
~~$I_N = -I_2 = 4.5A$~~

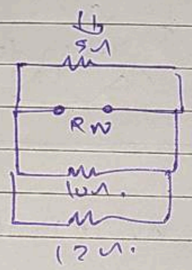
$I_N = I_2 - I_1$ (Amp)

$= -4.5 + 2$

$I_N = -2.5A$

Step-4)



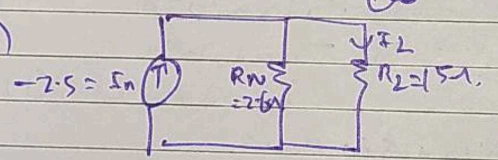


Step-5

$$R_N = \frac{1}{\frac{1}{5}+\frac{1}{10}+\frac{1}{12}}$$

$$R_N = \frac{1}{\frac{12+6+5}{60}} = \frac{60}{23} = 2.6\Omega.$$

Step-6)



$$I_L = I_N \frac{R_N}{R_N + R_2} = -2.5 \frac{2.6}{17.6}$$

$$= -0.37A$$

Superposition Theorem

In any linear, bilateral multisource network, the current or voltage across any branch can be calculated by taking the algebraic sum of values calculated by taking one source at a time and replacing the other active sources by their internal resistances

→ Steps for solving

1) Identify the branch and quantity to be calculated along with the presence of more than 1 active source.

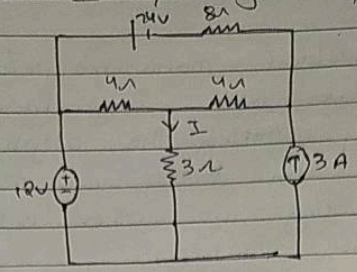
2) Consider any 1 active source and replace the remaining by their internal resistances.

3) Calculate the required electrical quantity for that particular source.

4) Repeat last two steps for all the active sources.

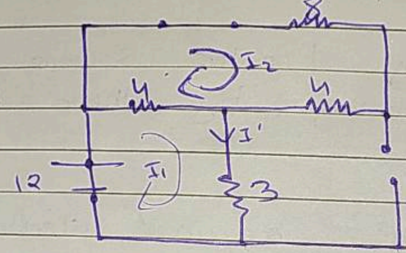
5) Algebraic sum of all these individual values will be the final value of required electrical quantity for all the sources working together.

Q→ Find I, using Superposition Theorem.



Sol There are 3 active sources in the given network.

→ Taking 12V source and replacing other A.S by their internal resistances.



Applying KVL in Mesh 1

$$-7I_1 + 12 + 4I_2 = 0$$

$$-7I_1 + 4I_2 = -12 \quad \text{—(1)}$$

KVL in mesh 2

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

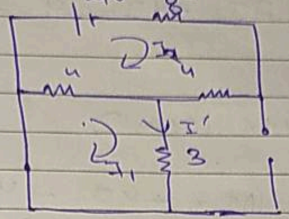
$$I_1 = 4I_2 \quad \text{—(2)}$$

From eq 1 and 2

$I_2 = 0.5$ A $\qquad I_1 = 2A$

$\boxed{I'_{12V} = 2A}$

→ Taking 24 V source and replacing other active sources by their internal resistances.



KVL in Mesh 1

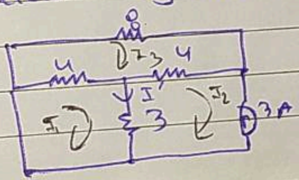
$$-7I_1 + 4I_2 = 0 \quad -(1)$$

KVL in Mesh 2

$$-24 - 16I_2 + 4I_1 = 0$$
$$4I_1 - 16I_2 = 24$$
$$I_1 - 4I_2 = 6 \quad -(2)$$
$$-6I_1 = 6$$
$$I_1 = -1A$$
$$I_2 = \frac{-7}{4}A = -1.75A$$

$\boxed{I'_{24V} = -1A = I_1}$

→ Taking 3A source and replacing other active sources by their internal resistance



$I_2 = -3A$

KVL in Mesh 1

$-7I_1 + 3I_2 + 4I_3 = 0$

$-7I_1 + 4I_3 = 9$ —— (1)

KVL in Mesh 2

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

$-4I_3 + I_2 + I_1 = 0$

$I_1 - 4I_3 = 3$ —— (2)

$-6I_1 = 12$

$I_1 = -2A$

$I_3 = -\frac{5}{4} = -1.25A$

$I'_{3A} = I_1 - I_2$

$\boxed{I'_{3A} = -2 + 3 = 1A}$

$I_T = I'_1 + I'_2 + I'_3$

$2 - 1 + 1$

$= 2A$

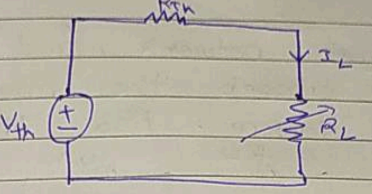
REDMI NOTE 8
AI QUAD CAMERA

For high efficiency ~~R...~~ $R_{Internal} < R_L$

For max Power transfer $R_{INTERNAL} = R_L$

Maximum Power Transfer Theorem

The condition for maximum power flow through Load resistor R_L can be achived ~~with~~ when the Load resistor equals the Thevinins equivalent resistance of the circuit.



Power through ~~R~~ R_L

$$P = I_L^2 R_L \quad \text{—} (1)$$

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

$$P = \left(\frac{V_{th}}{R_{th} + R_L}\right)^2 R_L \quad \text{—} (2)$$

Diff. w.r.t R_L

$$\frac{dP}{dR_L} = \left(\frac{V_{th}}{R_{th}+R_2}\right)^2 + 2R_L\left(\frac{V_{th}}{R_{th}+R_L}\right)\frac{0 - V_{th}}{(R_{Th}+R_2)^2}$$

$$= 0$$

$$1 \cancel{+} \frac{2R_2}{R_{Th} + R_2} = 0$$

$$R_{th} + R_L = 2R_L$$

$$\boxed{R_{Th} = R_L} \quad \text{—} (3)$$

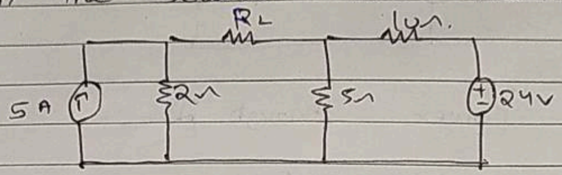
This is the required condition for max power flow

Putting the value of $R_L = R_{Th}$ in eq 2

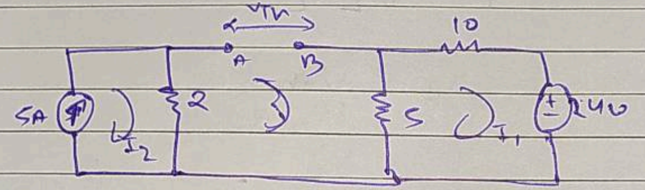
$$P_{Max} = \frac{V_{Th}^2}{4R_{Th}^2} \times \cancel{R_{Th}}$$

$$\boxed{P_{max} = \frac{V_{Th}^2}{4R_{Th}}}$$

Q-> In the given network, find the value of R_L which will absorb the maximum power from the source. Also the maximum power.



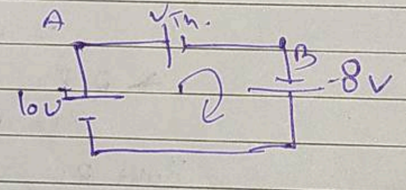
Sol-



$I_2 = 5A$

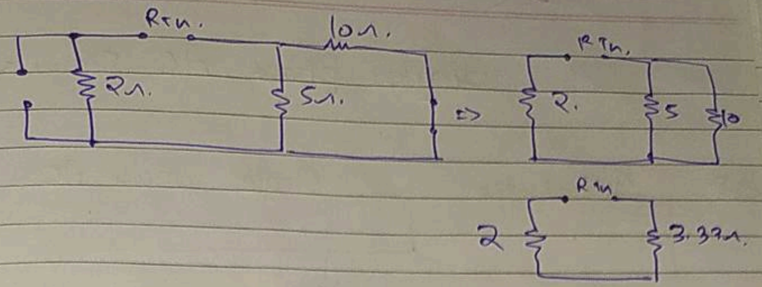
$-15I_1 = 24$

$I_1 = -\frac{8}{5} = -1.6A$



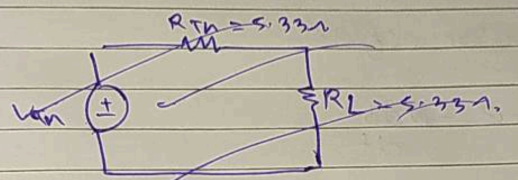
$-8 + 10 - V_{Th} = 0$

$\boxed{V_{Th} = 2V}$



$R_{Th} = 5.33\Omega.$

Ans. $\boxed{R_L = R_{Th} = 5.33\Omega}$



$$P_{max} = \frac{V_{Th}^2}{4 R_{Th}}$$

$$= \frac{2}{4(5.33)}$$

Ans. $\boxed{P_{max} = 0.187\ W}$