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16431

Subject - Linear Circuit Analysis

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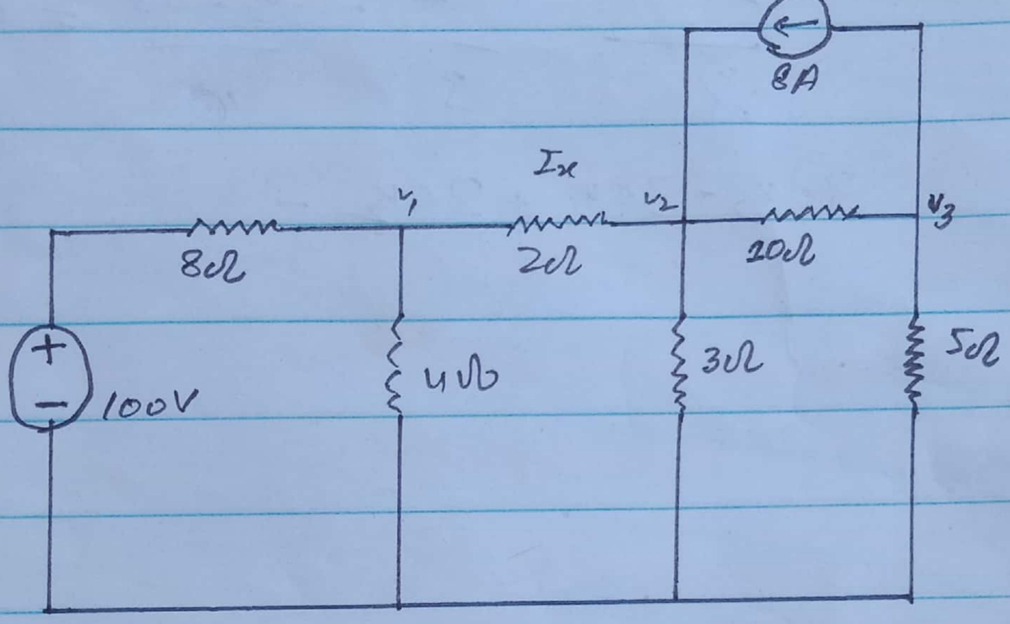
Paper : LCA.

QNO. 1

Find the value of i_x.

(i) Nodal Analysis:-



Solution:-

Applying KCL on node 1 n_1

$$\frac{v_1 - 100}{8} + \frac{v_1}{4} + \frac{v_1 - v_2}{2} = 0$$

$$\frac{v_1 - 100 + 2v_1 + 4v_1 - 4v_2}{8} = 0$$

$$\frac{7v_1 - 4v_2 - 100}{8} = 0$$

$$7v_1 - 4v_2 - 100 = 8 \times 0$$

$$7v_1 - 4v_2 - 100 = 0$$

$$7v_1 - 4v_2 = 100 \quad - \quad (1)$$

Now

Applying KCL on Node 2n.

$$\frac{V_2 - V_1}{2} + \frac{V_2}{3} + \frac{V_2 - V_3}{10} = 8$$

$$\frac{30V_2 - 30V_1 + 20V_2 + 3V_2 - 3V_3}{60} = 8$$

$$-30V_1 + 53V_2 - 3V_3 = 480 \quad -(2)$$

Applying KCL on node 3n

$$\frac{V_3 - V_2}{10} + \frac{V_3}{5} = -8$$

$$\frac{V_3 - V_2 + 2V_3}{10} = -8$$

$$-V_2 + 3V_3 = -80 \quad -(3)$$

Taking equation 2 1

$$7V_1 - 4V_2 = 100$$

$$7V_1 = 100 + 4V_2$$

$$\boxed{V_1 = \frac{100 + 4V_2}{7}} \quad - (a)$$

Taking equation 2

$$-V_2 + 3V_3 = -80$$

$$3V_3 = -80 + V_2$$

$$\boxed{V_3 = \frac{-80 + V_2}{3}} \quad - (b)$$

PuThing equation (a) and (b) in equation (2)

$$-30(0.57V_2 + 14.28) + 53V_2 - 3(0.33V_2 - 26.67) = 480$$

$$-17.1V_2 - 428.4 + 53V_2 - 0.99V_2 + 80.01 = 480$$

$$34.91V_2 = 828.39$$

$$v_2 = \frac{828.39}{34.91}$$

$$\boxed{v_2 = 20.31}$$

Putting in equation (a)

$$v_1 = \frac{100 + 4(20.31)}{7}$$

$$\boxed{v_1 = 25.89}$$

Now we can determine the current I_x, by Application Ohm's Law.

$$i_x = \frac{v_1 - v_2}{2}$$

$$i_x = \frac{25.89 - 20.31}{2}$$

$$\boxed{i_x = 2.79A}$$

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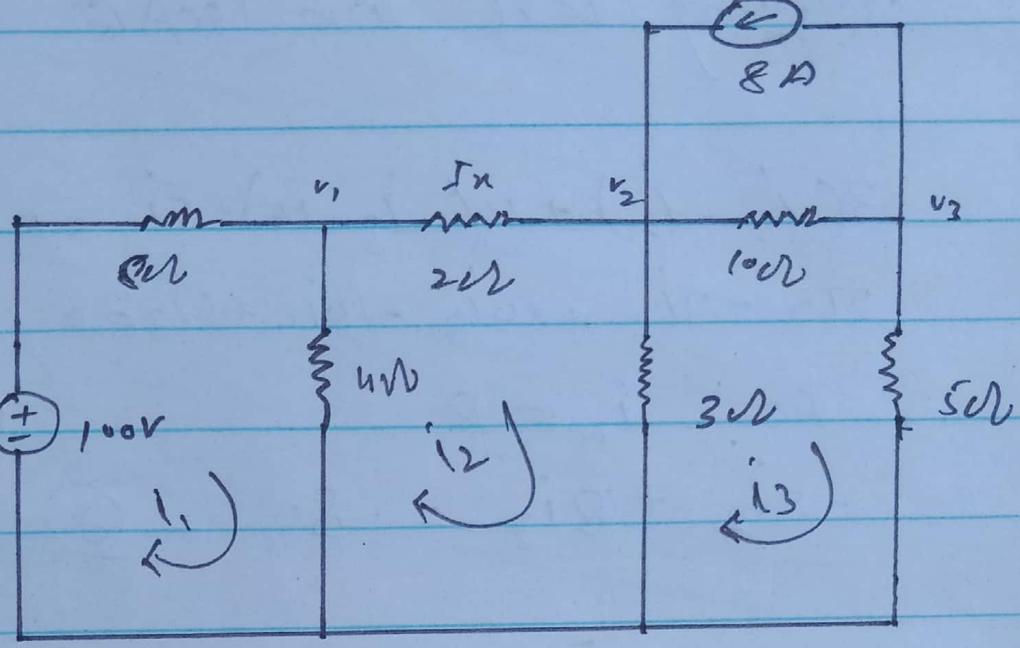
Mesh - Analysis :-



Solution :-

Applying KVL on loop 1

$$8i_1 + 4(i_1 - i_2) = 100$$

$$8i_1 + 4i_1 - 4i_2 = 100$$

$$12i_1 - 4i_2 = 100 \quad \text{--- (1)}$$

Applying KVL on loop 2.

$$2i_2 + 4(i_2 - i_1) + 3(i_2 - i_3) = 0$$

$$2i_2 + 4i_2 - 4i_1 + 3i_2 - 3i_3 = 0$$

$$-4i_1 + 9i_2 - 3i_3 = 0 \quad -(2)$$

Applying KVL on Loop (3)

$$3(i_3 - i_2) + 10(i_3 - i_4) + 5i_3 = 0$$

$$3i_3 - 3i_2 + 10i_3 - 10i_4 + 5i_3 = 0$$

As $i_4 = 8$

$$-3i_2 + 18i_3 = -80 \quad -(3)$$

Taking equation (1)

$$i_1 = \frac{4i_2 - 100}{12} \quad (a)$$

Taking equation (3)

$$-3i_2 + 18i_3 = -80$$

$$i_3 = \frac{-3i_2 + 80}{18} \quad -(b)$$

Putting equation (a) and (b) in equation (2)

$$-4(0.33i_2-8.33)+9i_2-3(0.16i_2+4.44)=0$$

$$-1.32i_2+33.32+9i_2-0.48i_2-13.32=0$$

$$7.2i_2=20$$

$$i_2=\frac{20}{7.21}$$

$$\boxed{i_2=2.79A}$$

$$\boxed{i_2=I_x}$$

So

$$\boxed{i_x=2.79A}$$

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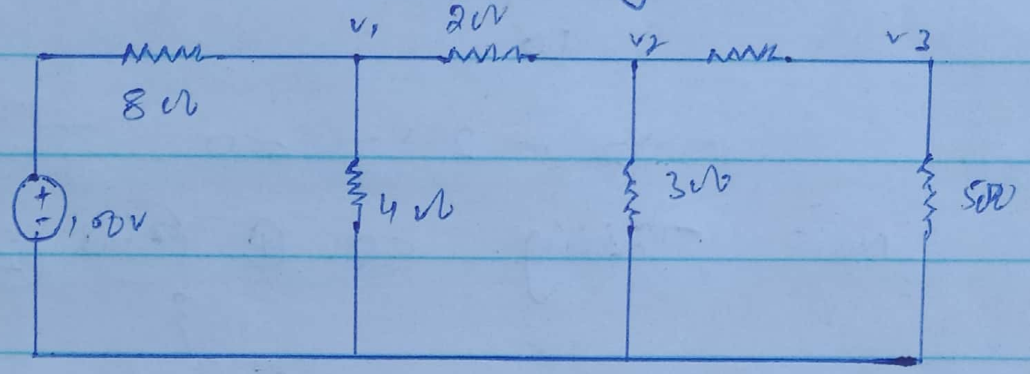
(iii) Super Position Theorem :-

First removing the current source and ~~removing~~ making it an open circuit.

~~Re draw.~~ Re-drawing the circuit :-



Applying KCL on node 1n,

$$\frac{-100+v_1}{8} + \frac{v_1 - v_2}{2} + \frac{v_1}{4} = 0$$

$$\frac{v_1 - 100 + 4v_1 - 4v_2 + 2v_1}{8} = 0$$

$$7v_1 - 4v_2 = 100 \quad \text{---} (1)$$

Now

Applying KCL on node 2n.

$$\frac{v_2 - v_1}{2} + \frac{v_2}{3} + \frac{v_2 - v_3}{10} = 0$$

So

$$-30v_1 + 53v_2 - 3v_3 = 0 \quad \text{---} (2)$$

Again

Applying KCl on node 3rd.

$$\frac{v_3 - v_2}{10} + \frac{v_2}{5} = 0$$

$$\frac{v_2 - v_2 - v_3}{10} = 0$$

$$-v_2 - 2v_3 = 0 \quad -(3)$$

Now Taking eq. (1) ~~and~~ (2)

&

$$7v_1 - 4v_2 = 100$$

$$7v_1 = 100 + 4v_2$$

or

$$v_1 = \frac{4v_2 + 100}{7} \quad -(a)$$

&

$$-v_2 + 3v_3 = 0$$

$$3v_3 = v_2$$

$$v_3 = \frac{1}{3}v_2 \quad -(b)$$

Putting a in equation (2)

$$-30(0.57v_2+14.28)-4v_2+2(0.3v_2)$$

$$-17.1v_2-428.4\;4v_2+0.60v_2=0$$

$$20.44\,v_2=428.4$$

or

$$v_2=\frac{428.4}{20.44}$$

$$\boxed{v_2=20.95\,V}$$

Put v_2 in eq. (a)

$$v_1=2.31$$

or

$$i_1=\frac{2.31+20.95}{2}$$

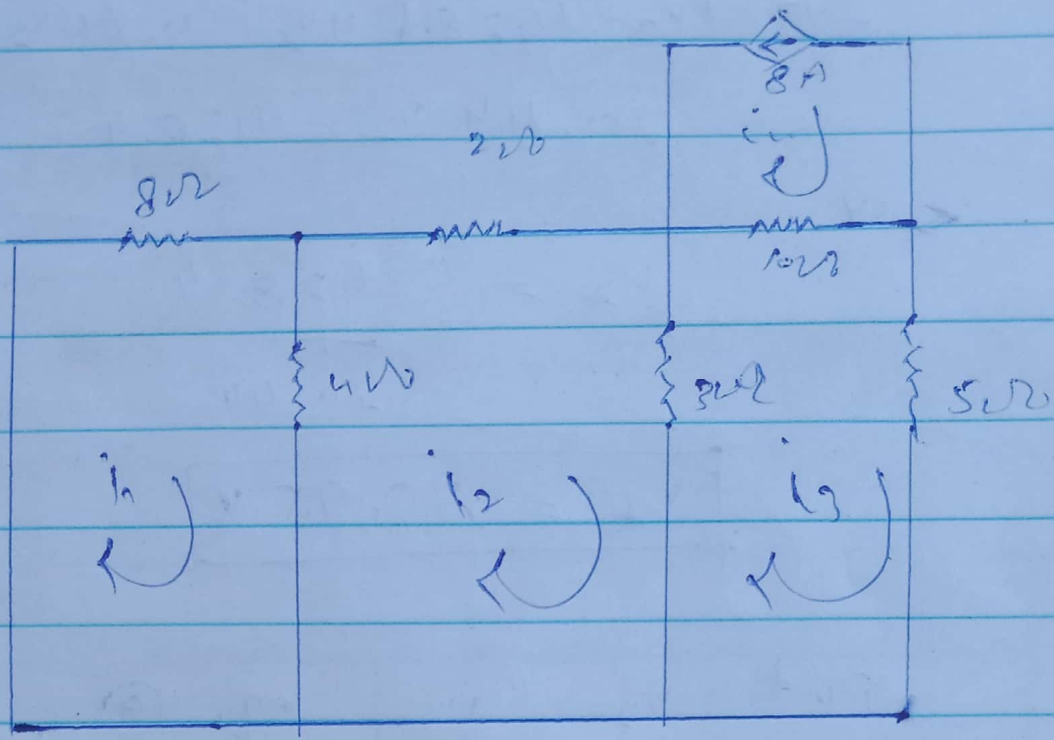
$$i_1=\frac{23.26}{2}$$

$$\boxed{i_1=11.63\,A}$$

Now

removing voltage source & making it short circuit.

Re-drawing the circuit.



$i_4 = 8A$

Applying KVL on loop 1.

$8i_1 + 4(i_1 - i_2) = 0$

$8i_1 + 4i_1 - 4i_2 = 0$

$12i_1 - 4i_2 = 0$

$\cancel{12 i_1}$

$4(3i_1 - i_2) = 0$

$\boxed{3i_1 - i_2 = 0}$ —— 1

Applying KVL on loop 2

$2i_2 + 3(i_2 - i_3) + 4(i_3 - i_1) = 0$

$2i_2 + 3i_2 - 3i_3 + 4i_3 - 4i_1 = 0$

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

$-4i_1+17i_2-3i_3=0$ — (3)

Now

Applying KVL on loop 3

$10i_3+5i_3+3i_3-3i_2+8(10)=0$

$-3i_2+18i_3=-80$ — (3)

Taking eq. (1)

$3i_1-i_2=0$

$\boxed{i_1=0.33i_2}$ — (a)

Taking equation (3)

$-3i_2+18i_3=-80$

$$\boxed{i_3=\frac{3i_2-80}{18}} \text{ — (b)}$$

$-4(0.33i_2)+9i_2-3(0.16i_2-4.44)=0$

$1.32i_2+9i_2-0.48i_2+13.8i_2=0$

$\boxed{i_2=1.354}$

Now $i_x=i_1+i_2=1.44+1.35$

$\boxed{i_x=2.79A}$

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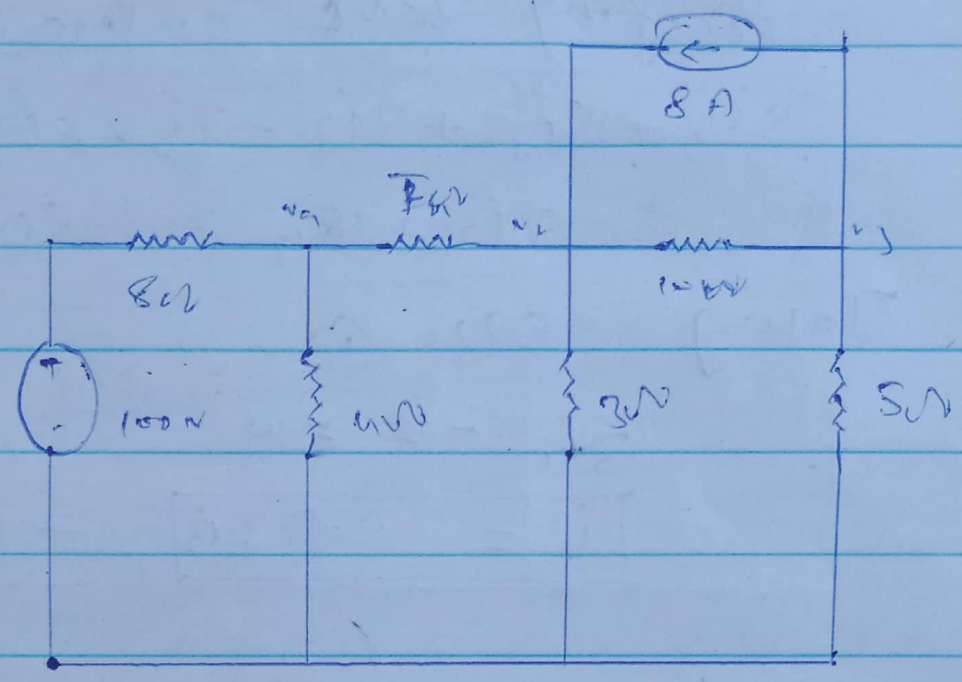
(iv) Compare the no. of steps & degree of easiness of all the ~~theme~~ three methods with each other.



Applying KCL on node 1n.

$$\frac{V_1 - 100}{8} + \frac{V_1}{4} + \frac{V_1 - V_2}{2} = 0$$

$$\frac{V_1 - 100 - 2V_1 + 4V_1 - 4V_2}{8} = 0$$

$$7V_1 - 4V_2 = 100 \quad \text{— (1)}$$

Now, Applying KCL on node 2n.

$$\frac{V_2 - V_1}{2} + \frac{V_2}{3} + \frac{V_2 - V_3}{10} = 8$$

$$\frac{30V_2 - 30V_1 + 20V_2 + 3V_2 - 3V_3}{60} = 8$$

$$-30V_1 + 53V_2 - 3V_3 = 480 \quad (2)$$

Now

Applying KCL on node 3.

$$\frac{V_3 - V_2}{10} + \frac{V_3}{5} = -8$$

$$\frac{V_3 - V_2 + 2V_2}{10} = -8$$

$$V_3 - V_2 = -80 \quad (3)$$

Taking equation (1)

$$7V_1 - 4V_2 = 100$$

$$\boxed{V_1 = \frac{100 + 4V_2}{7}} \quad (a)$$

Taking equation (2)

$$-V_2 + 3V_3 = -80$$

$$\boxed{V_3 = \frac{V_2 - 80}{3}} \quad (b)$$

Putting equation (a) and (b) in (2)

$$-30(0.57v_2+14.28)+53v_2-3(0.33v_2-26.67)=480$$

$$-17.2v_2-428.4+53v_2-0.99v_2=480$$

$$+80.01$$

$$34.91v_2 = 828.39$$

$$v_2 = \frac{829.39}{34.91}$$

$$\boxed{v_2 = 20.31\ v}$$

Putting in equation (a)

$$v_1 = \frac{4(20.31)+100}{7}$$

$$v_1 = 25.89$$

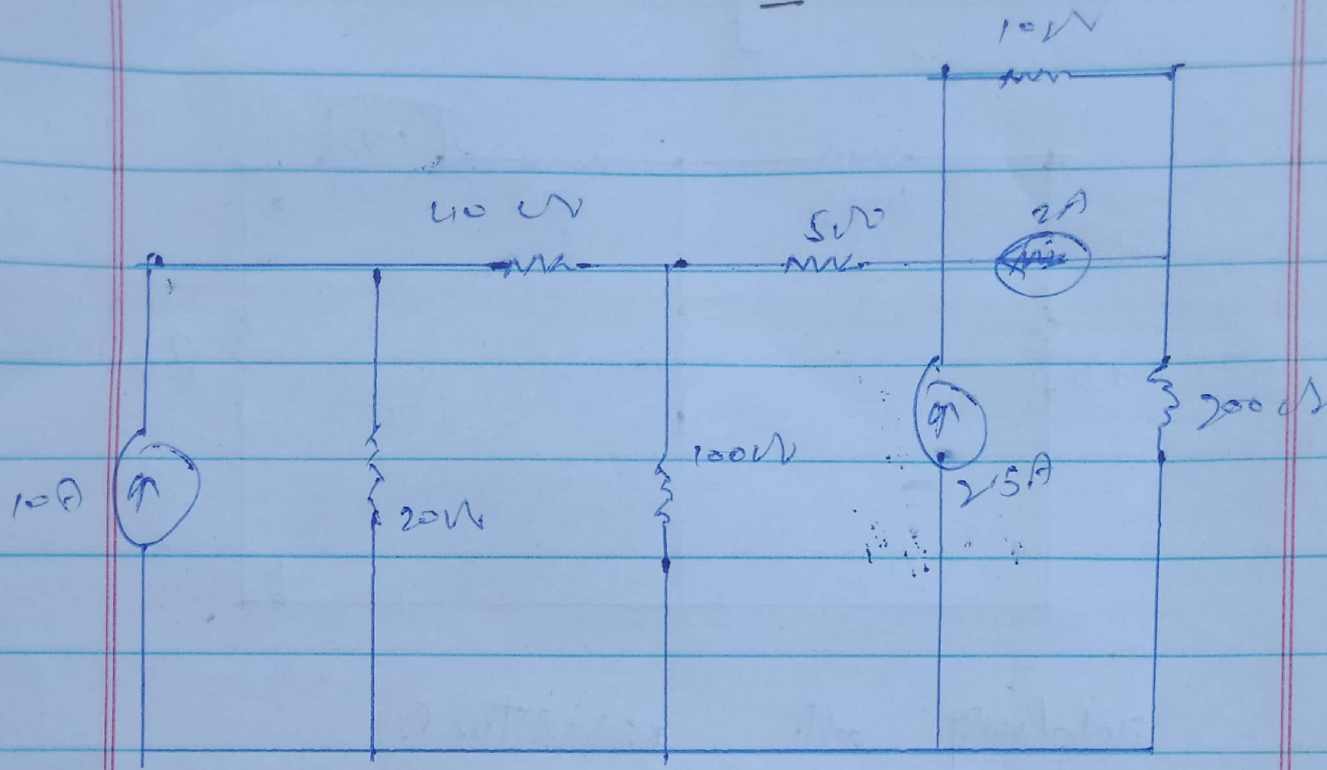
or $i_x = \frac{v_1 - v_2}{2}$

$$i_x = \frac{25.89 - 20.31}{2}$$

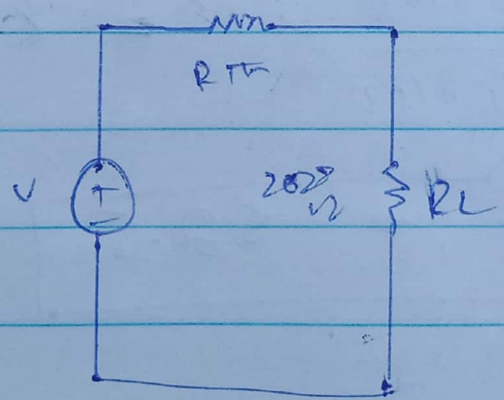
$$i_x = \frac{5.58}{2}$$

$$\boxed{i_x = 2.79\ A}$$

Q NO. 2

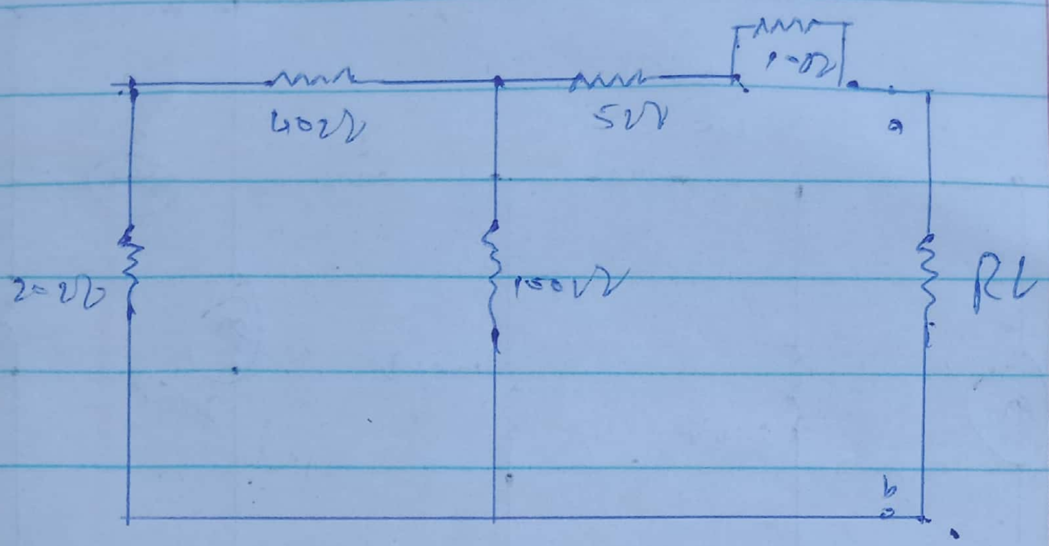


(i) Solving for Thevinen Theorem:-



we will find RTh for which we will remove all the current source & short circuit, the load resistor.

Re-drawing The circuit



adding all resistors.

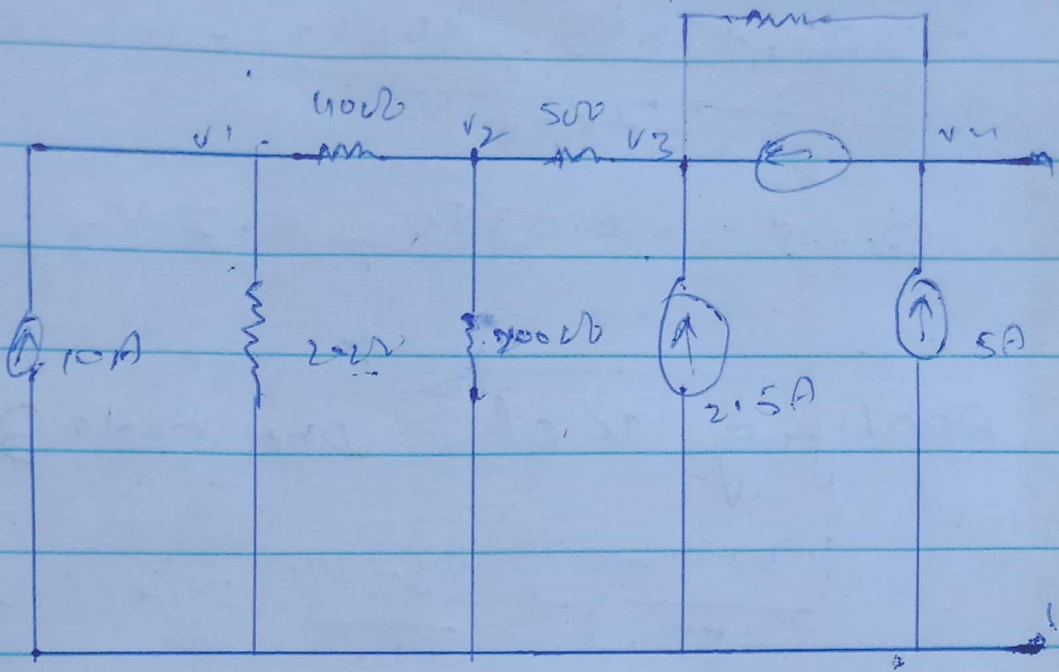
$20+40 \parallel 100+5+10$

$60 \parallel 100+5$

$\frac{60 \times 100}{60+100}+15 = 37.5+15$

$\boxed{R_{Th} = 52.5}$

For adding V_{Th} applying nodal Analysis.



Applying KCL on V_1.

$$\frac{V_1 - V_2}{40} + \frac{V_1}{20} = 10$$

$$\frac{V_1 - V_2 \cdot 2V_2}{4} = 10$$

$$V_1 + V_1 = 40 \quad \text{—} (1)$$

Applying KCL on node 2.

$$\frac{V_2 - V_1}{40} + \frac{V_2}{100} + \frac{V_2 - V_3}{5}$$

$$\frac{500V_2 - 50V_1 + 20V_2 + 400V_2 - 400V_3}{20000}$$

$$\frac{-50v_1 + 70v_2 - 400v_3}{2000} = 0$$

$$-0.05v_1 + 0.035v_2 - 0.2v_3 = 0 \quad \text{— (1)}$$

Applying KCL on node 3.

$$\frac{v_3 - v_2}{5} + \frac{v_3 - v_4}{10} = 2.5 + 2$$

$$\frac{2v_3 - 2v_2 + v_3 - v_4}{10} = 4.5$$

$$-2v_2 + 3v_3 - v_4 = 45 \rightarrow (3)$$

Applying KCL on node. (4).

$$\frac{v_4 - v_3}{10} = 5 - 2$$

$$v_4 - v_3 = 30 \quad \text{— (4)}$$

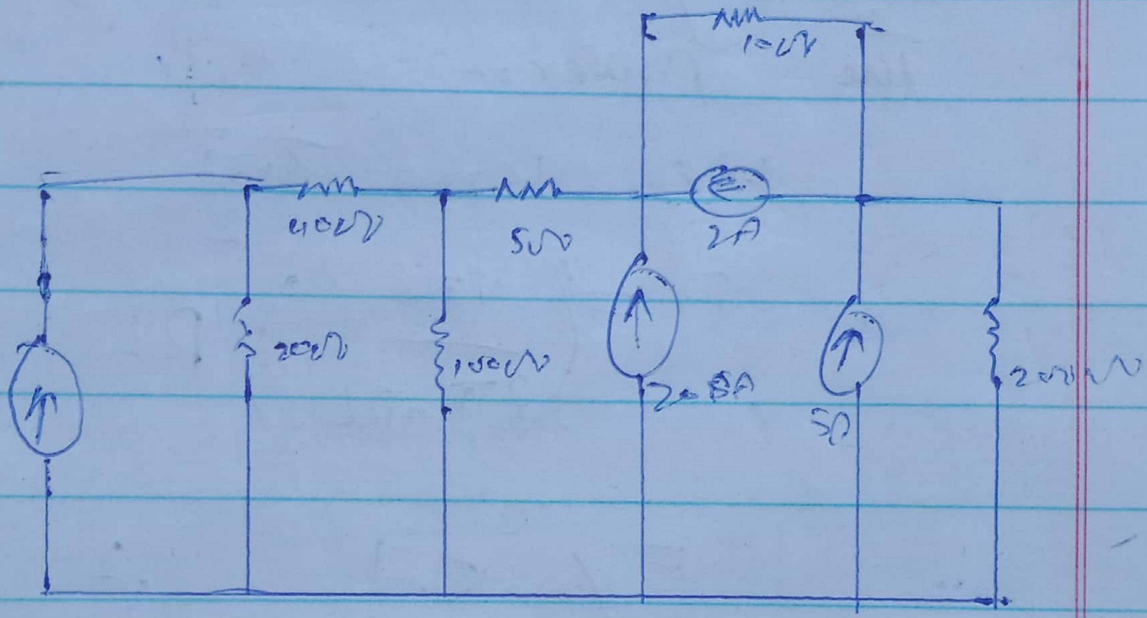
Solving by using calculator.

$$v_1 = 275$$
$$v_2 = -124.9$$
$$v_3 = -87.5$$
$$v_4 = -57.5$$

$$I_{th} = \frac{5.1}{52.5+200}$$

$$\boxed{I_{th} = 0.02}$$

(ii) For Nortom Theorem:-



For Rn will be the same

$$R_n = R_{in}$$

$$R_n = 52.5$$

find

$$I_n = \frac{V_{th}}{R_N}$$

$$\boxed{I_n = 0.09}$$

As The circuit is same so we find The directly

(iii) Using Thevinen for finding The power:-

we know That

$$P = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$

$$= \left(\frac{5.1}{52.5 + 200} \right)^2 200$$

$$\boxed{P = 0.08 W}$$

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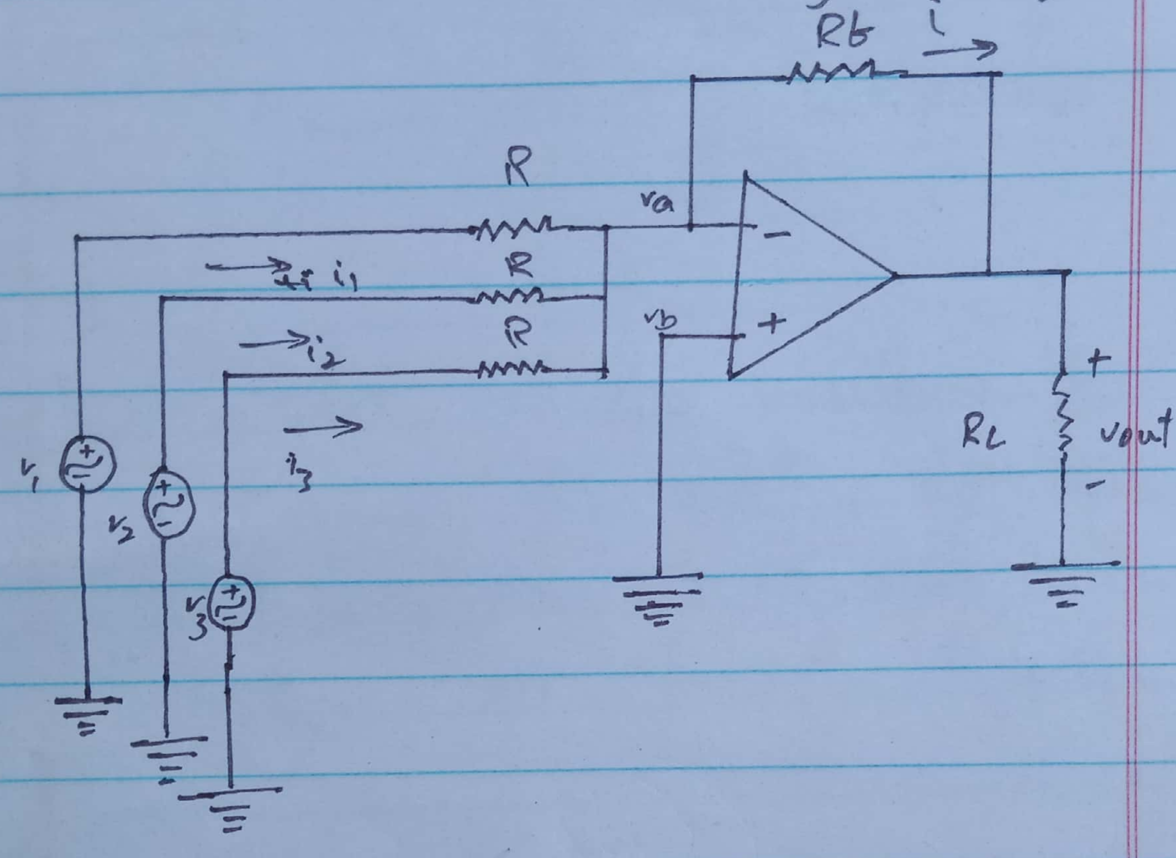
Q NO. 3

Obtain an expression for v_{out} in terms of v_1, v_2 and v_3 for op amp circuit, also known as a summing amplifier.



Solution:-

The goal is to obtain an expression for v_{out} in terms of the inputs (v_1, v_2, and v_3).

Since no current can flow into the inverting input terminal, we can write

$$i = i_1 + i_2 + i_3$$

Therefore, we can write the following equation at the node labeled v_a:

$$0 = \frac{v_a - v_{out}}{R_f} + \frac{v_a - v_1}{R} + \frac{v_a - v_2}{R} + \frac{v_a - v_3}{R}$$

As this equation contains both v_{out} and the input voltages but unfortunately it also contains the nodal voltage v_a.

Now we need to write an additional equation that related v_a to v_{out}, the input voltages, R_f, and R.

At this point we have not yet used ideal op amp rule 2, and that we will almost certainly require the use of both rules when analyzing an op amp circuit.

Thus

Since $v_a = v_b = 0$,

we can write following

$$0 = \frac{V_{out}}{R_f} + \frac{v_1}{R} + \frac{v_2}{R} + \frac{v_3}{R}$$

by Re-arranging we obtain the following expression for V_{out}.

$\cancel{V_{out}} = R$

$$V_{out} = -\frac{R_f}{R}\left(v_1 + v_2 + v_3\right)$$

In this case, where $v_2 = v_3 = 0$ we see that our result agrees, which was derived for essentially the same circuit.