K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
DC CIRCUITS

Numerical 1:
Introduce the ground terminal, write nodal equations, and solve for the node voltages for the current shown in the figure calculate the current through the resistance Rx and show its derivation in the figure.

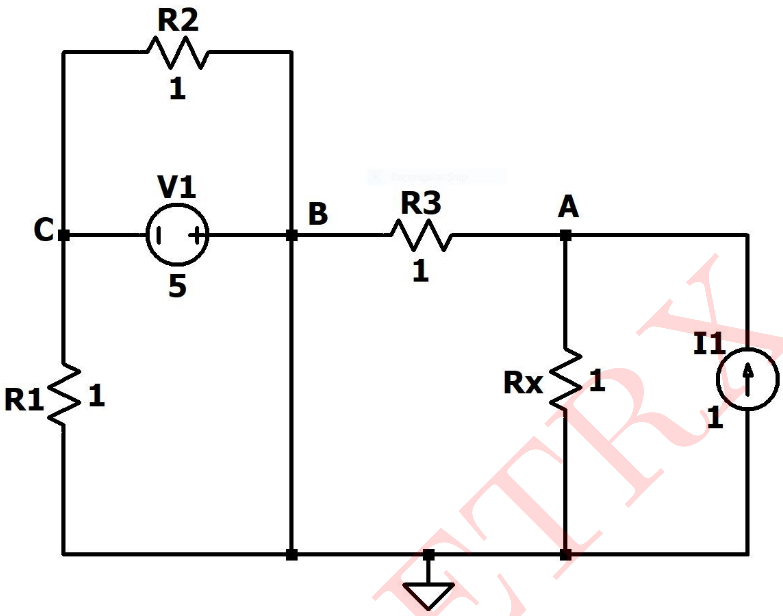

Figure 1: Circuit 1

Solution:

Using nodal analysis:

Node B is directly connected to ground, hence it get short and potential here is zero.

$\therefore V_\mathrm{B} = 0$

As $\mathrm{V_B} = 0$, node C is directly connected to a voltage source of 5V.

$\therefore V_\mathrm{C} = -5\mathrm{V}$

Applying KCL at node A

$$\frac{V_\mathrm{A} - V_\mathrm{B}}{1} + \frac{V_\mathrm{A}}{1} = 1$$

$\therefore 2V_\mathrm{A} = 1\mathrm{V}$ ...[$\because \mathrm{V_B} = 0$]

$\therefore V_\mathrm{A} = 0.5\mathrm{V}$

Current through resistance $R_X = \dfrac{V_A}{1}$

$\therefore I_{Rx} = 0.5A$

Simulated Circuit:

The given circuit is simulated in LTspice and the results obtained are as follows:

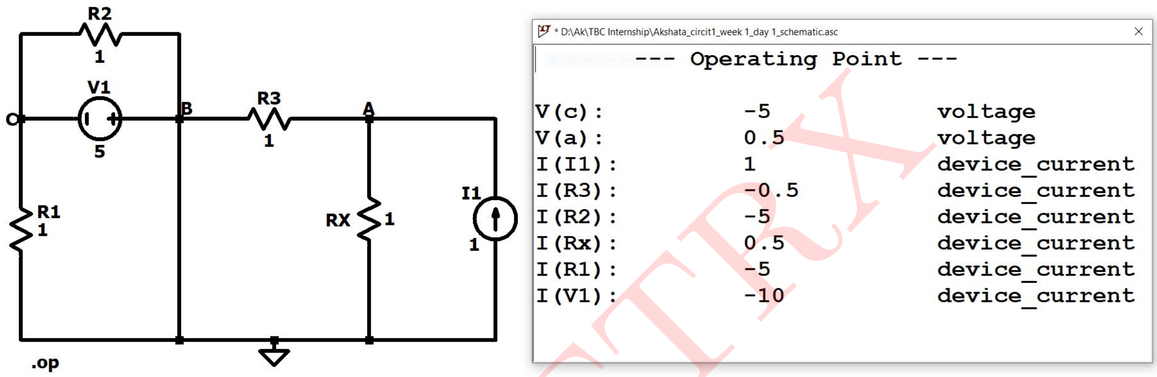

Figure 2: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_{Rx}	0.5A	0.5A
V_A	0.5V	0.5V
V_B	0V	0V
V_C	-5V	-5V

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Numerical 2:
Use source transformation to find the current flowing through the 2 Ω resistor in the following circuit 2.

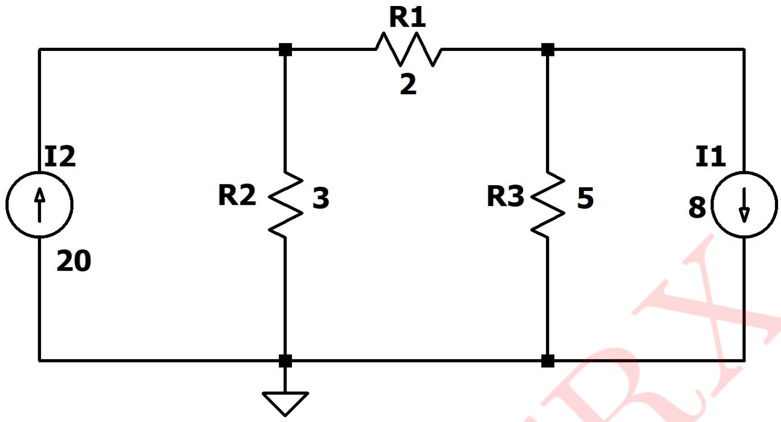

Figure 3: Circuit 2

Solution:

By applying source transformation, the circuit is reduced as,

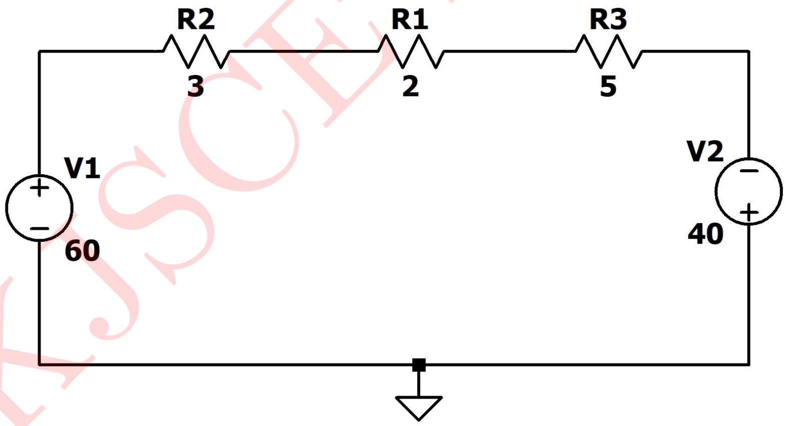

Figure 4: Modified circuit 1a after source transformation

After applying source transformation, 20A current source and parallel resistors gets converted to voltage source of 60V and a series resistance of 3 Ω

V = I $\times R$

V = 20 $\times$3

V = 60V

After applying source transformation, 8A current source and parallel resistors gets converted to voltage source of 40V and a series resistance of 5 Ω

V = I $\times R$

V = 8 $\times 5$

V = 40V

Now, Applying KVL to the entire loop

Assume current I flows in anticlockwise direction, We get

$-60 - 3i - 2i - 5i - 40 = 0$

$-100 - 10i = 0$

$i = -\dfrac{100}{10}$

$i = -10A$

$\mathbf{R_{2\Omega} = -10A}$

Hence the current flowing through 2 Ω resistor is −10A.

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

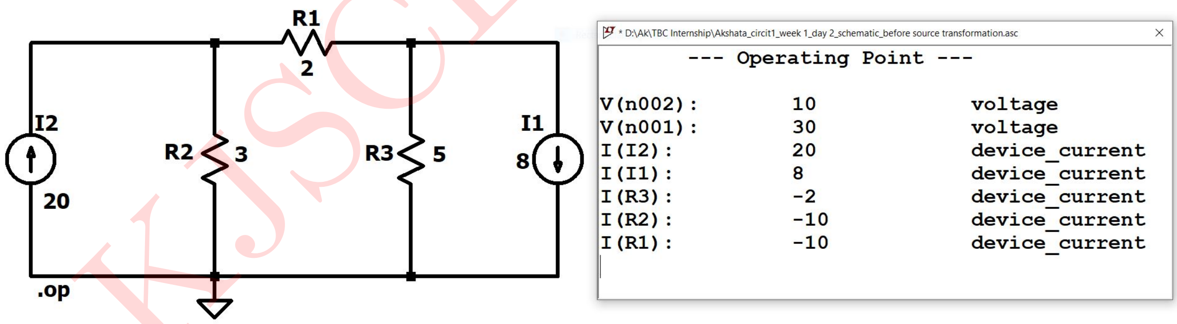

Figure 5: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$I_{2\Omega}$	−10A	−10A

Numerical 3:

With the help of nodal analysis, calculate the values of nodal voltages V1 an V2 the circuit 3.

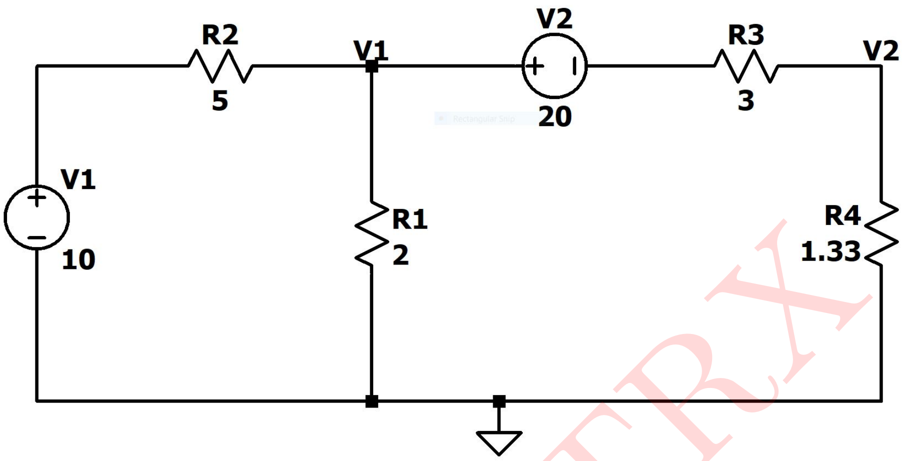

Figure 6: Circuit 3

Solution:

Assuming the current are moving away from the nodes

Applying KCL at V1,

$$\frac{V_1 - 10}{5} + \frac{V_1}{2} + \frac{V_1 - 20 - V_2}{3} = 0$$

$31\mathrm{V}_1 - 10\mathrm{V}_2 = 260$ ......(i)

Applying KCL at V2,

$$\frac{V_2 + 20 - V_1}{3} + \frac{V_2}{4/3} = 0$$

$-4\mathrm{V}_1 + 13\mathrm{V}_2 = -80$ ......(ii)

Solving equations (1) and (2) we get,

V1 = 7.107V

V2 = 3.966V

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

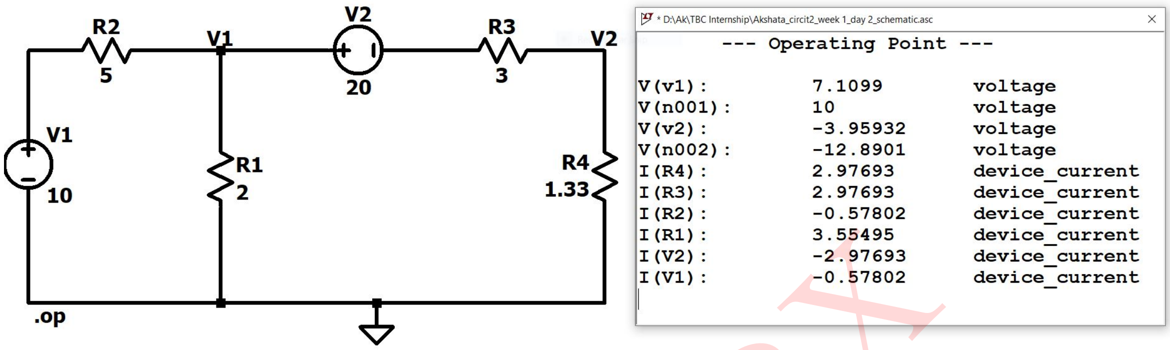

Figure 7: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_1	7.107V	7.1099V
V_2	-3.966V	-3.95932V

Numerical 4:

For the circuit shown below, find the equivalent resistance. All resistors are 22Ω.

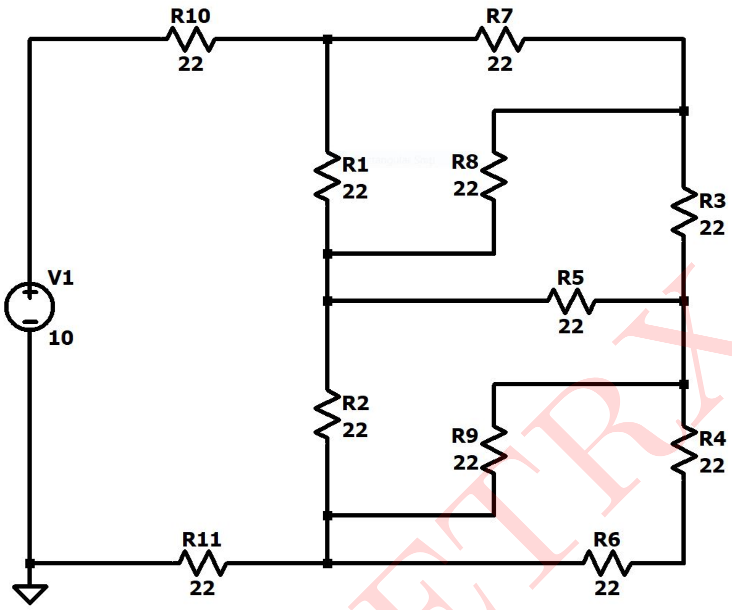

Figure 8: Circuit 4

Solution:

Converting Delta configuration of resistor to Star for Resistors R_1, R_7 and R_8.

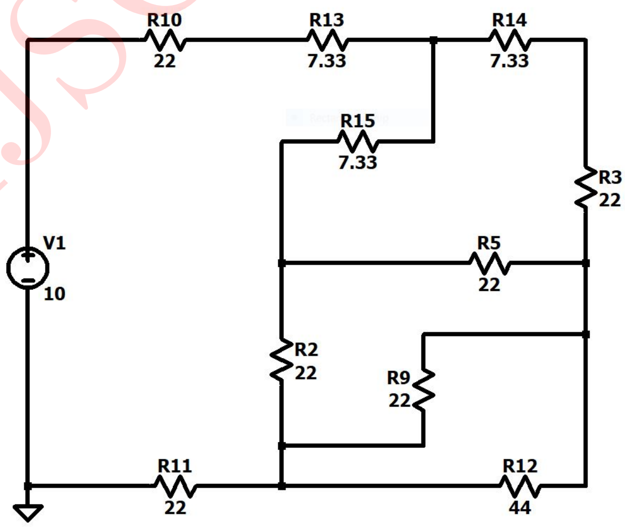

Figure 9: Modified circuit for figure 8

Adding resistances R_{10} and R_{13}, R_{14} and R_3 in series.

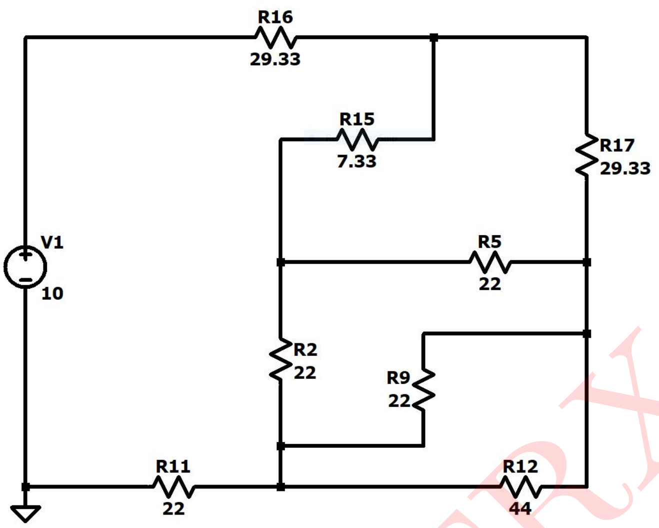

Figure 10: Circuit after adding the series resistances

Applying Delta to Star Conversion on R_5, R_{15} and R_{17}.

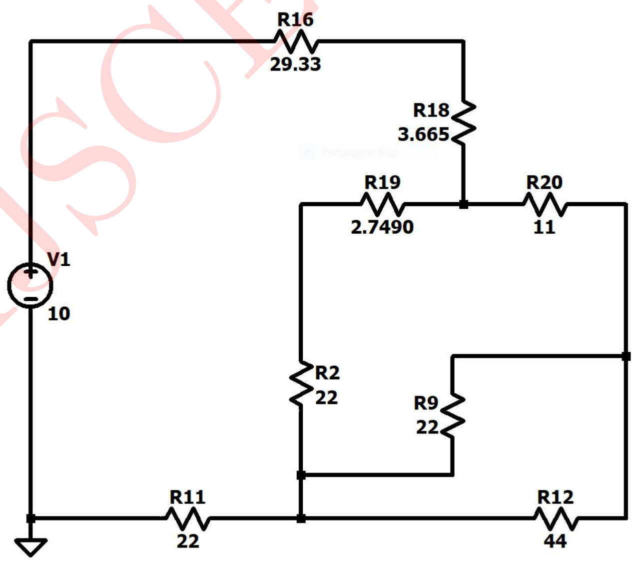

Figure 11: Modified circuit after delta to star conversion

Adding resistances R_{16} *and* R_{18}, R_2 *and* R_{19} in series, R_9 *and* R_{12} in parallel.

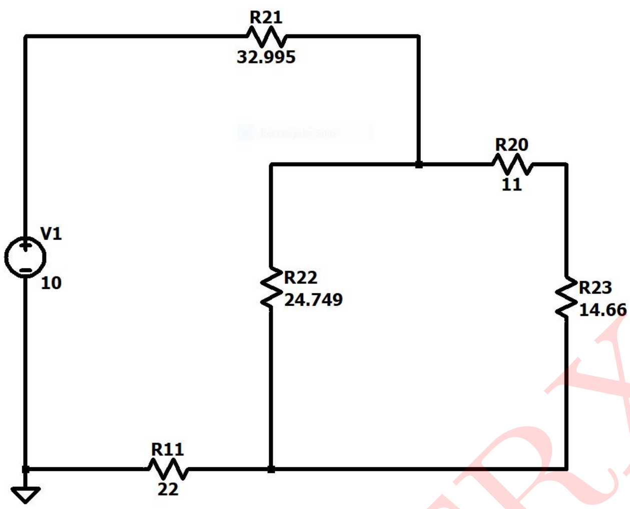

Figure 12: Modified circuit after series and parallel combination

Adding resistance R20 and R23 from Figure 2.12, we get:

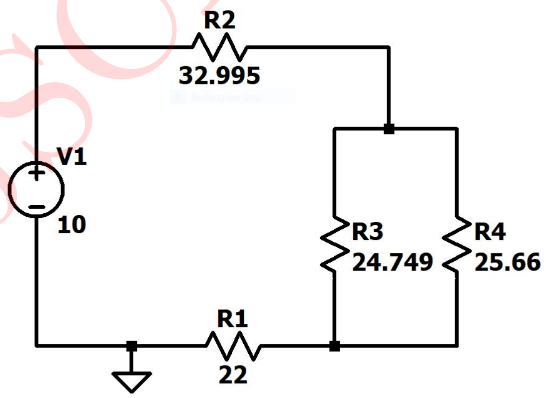

Figure 13: Modified circuit for previous figure

Finally, after solving the last series and parallel resistances from Figure 2.13, we get:

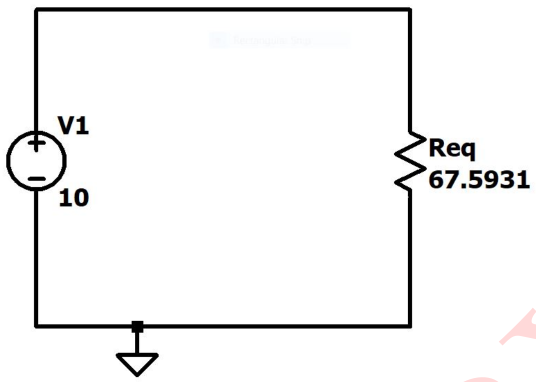

Figure 14: Modified circuit for calculating Equivalent Resistance

Hence, Equivalent Resistance $R_{eq} = 184.36364\Omega$

SIMULATED RESULTS:
The following circuit has been simulated in LTspice and the readings obtained are as follows:

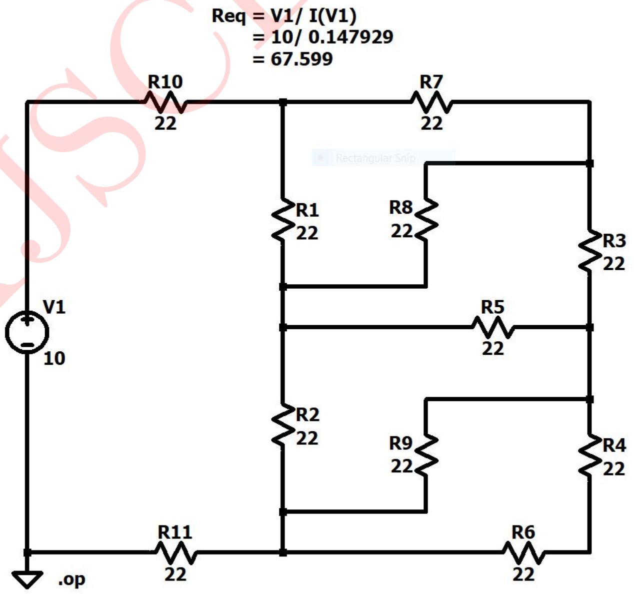

Figure 15: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Quantity	Calculated Value	Simulated Value
R_{eq}	67.5931Ω	67.599Ω

Numerical 5:

Find Norton's equivalent circuit for the network shown in the figure 16. Verify it through its Thevenin's equivalent circuit.

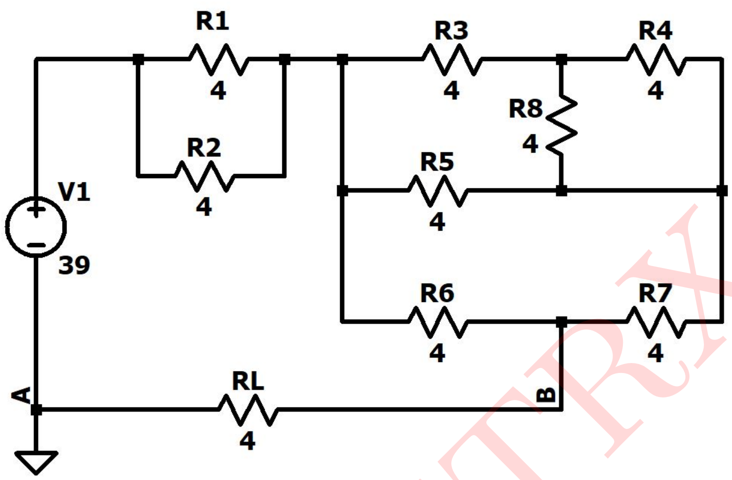

Figure 16: Circuit 5

Solution:

Replacing R_L by wire to calculate I_N and applying star delta transformation,

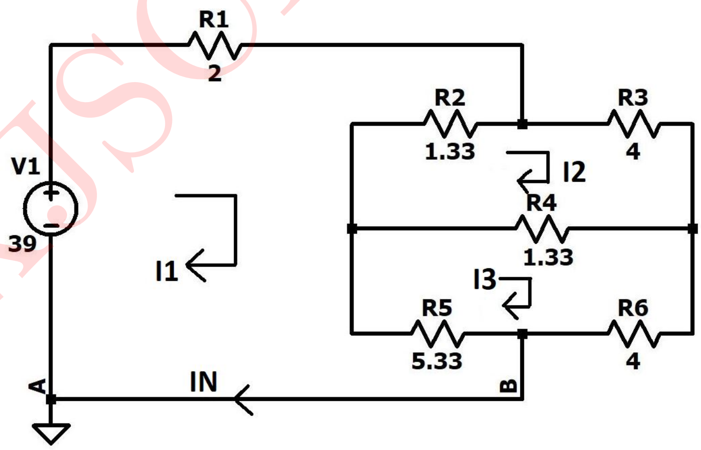

Figure 17: Modified circuit from previous figure

Applying KVL to loop (1),

$$39 - 2I_1 - \frac{4}{3}I_1 + \frac{4}{3}I_2 - \frac{16}{3}I_3 + \frac{16}{3}I_3 = 0$$

$$-\frac{26}{3}I_1 + \frac{4}{3}I_2 + \frac{16}{3}I_3 = 0 \qquad ......(i)$$

Applying KVL to loop (2),

$$\frac{4}{3}I_2 - \frac{20}{3}I_2 + \frac{4}{3}I_3 = 0 \qquad ......(ii)$$

Applying KVL to loop (3),

$$\frac{16}{3}I_1 + \frac{4}{3}I_2 - \frac{22}{3}I_3 = 0 \qquad ......(iii)$$

By solving equation (i), (ii) and (iii),

$\mathbf{I_1 = 7.24828A}$

$\mathbf{I_2 = 2.22857A}$

$\mathbf{I_3 = 3.90A}$

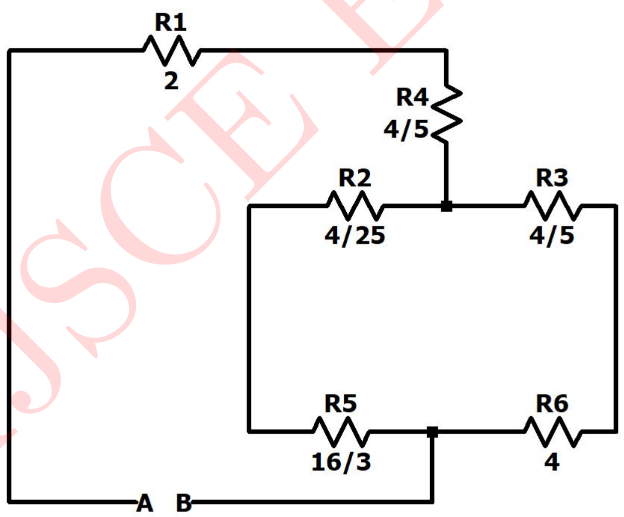

Figure 18: Circuit for calculating R_N

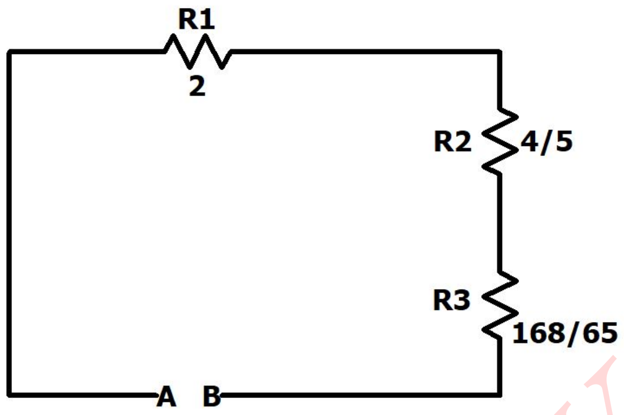

Figure 19: Modified circuit from previous figure

$\mathrm{R_N} = 2 + \frac{4}{5} + \frac{168}{65} = \frac{70}{13}$

$\mathbf{R_N = 5.3846\Omega}$

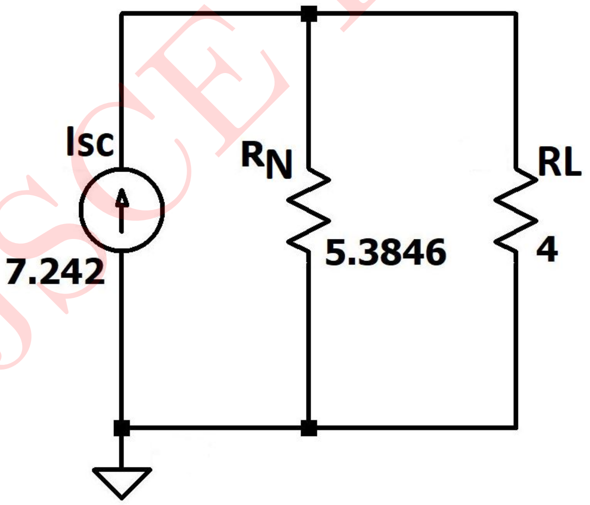

Figure 20: Norton's equivalent circuit

$$\mathrm{I_L} = 7.242 \times \frac{\frac{70}{13}}{\frac{70}{13}+4}$$

$$\mathbf{I_L = 4.153\ \Omega}$$

Verification using Thevenin's therorm,

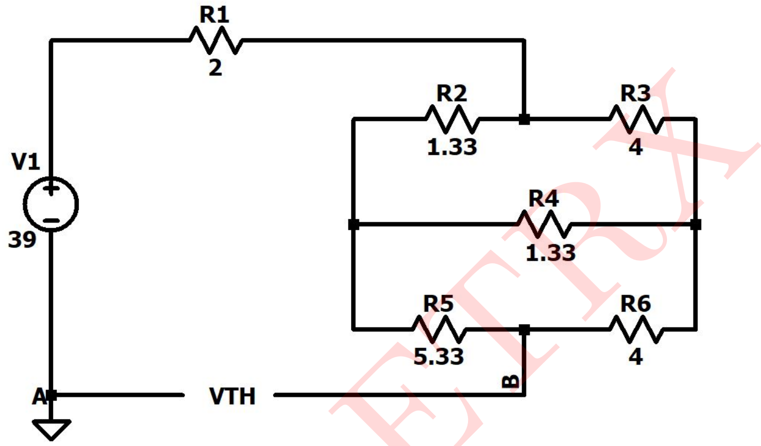

Figure 21: For calculating $\mathrm{V_{TH}}$

$\mathrm{V_{TH}} = \mathrm{V_1}$

$\mathrm{V_{TH}} = 39\mathrm{V}$ $\quad \because [V_1 = 39V]$

$\mathrm{R_{TH}} = 5.3846\Omega$

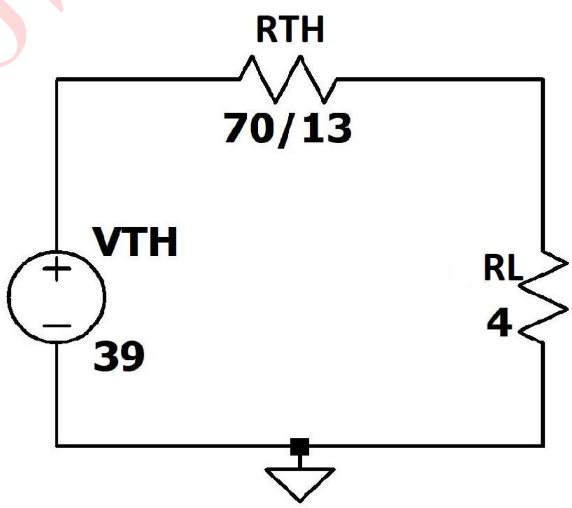

Figure 22: Thevenin's equivalent circuit

$$I_L = \frac{39}{\frac{70}{13} + 4}$$

$$\mathbf{I_L = 4.155A}$$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

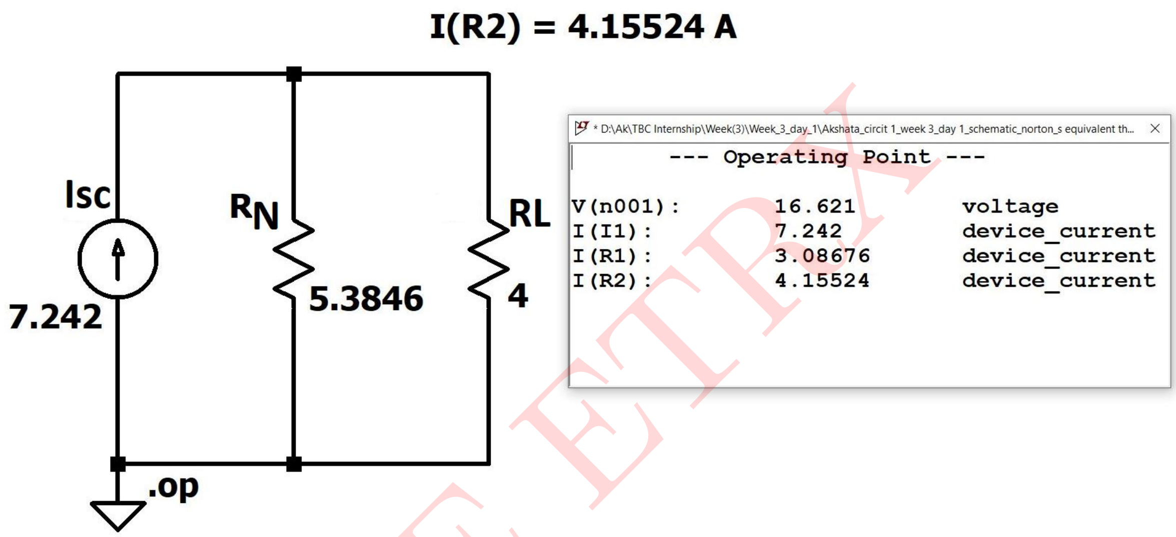

Figure 23: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_L	4.153A	4.1552A

Numerical 6:

Find the current and voltage in circuit 6 shown below.

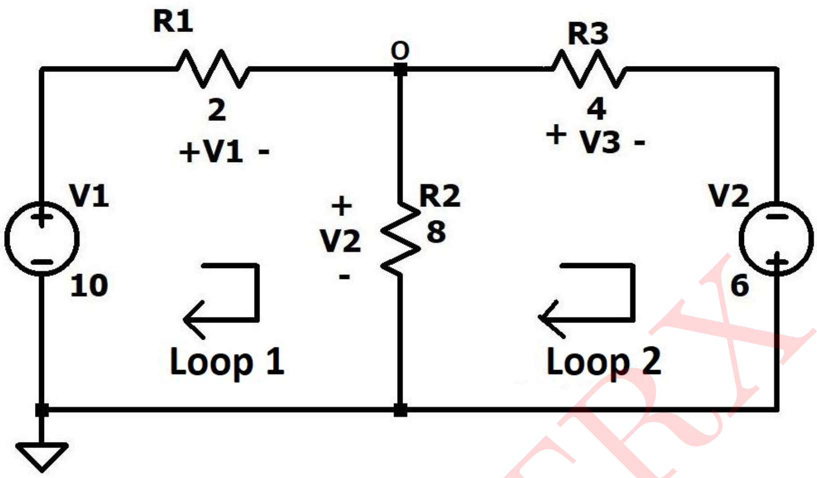

Figure 24: Circuit 6

Solution:

By Ohm's law,

$V_1 = 2i_1$

$V_2 = 8i_2$

$V_3 = 4i_3$

At node O, applying KCL

$i_1 = i_2 + i_3$

$i_1 - i_2 - i_3 = 0$ ......(1)

Applying KVL to loop I,

$10 + V_1 - V_2 = 0$

$2i_1 + 8i_2 = 10$ ......(2)

Applying KVL to loop II,

$-V_3 + 6 + V_2 = 0$

$-8i_2 + 4i_3 = 6$ ......(3)

Solving equations (1), (2) and (3), we get

$i_1 = 3A$

$i_2 = 0.5A$

$i_3 = 2.5A$

$\because V_1 = 2i_1 = 2 \times 3$

$\mathbf{V_1 = 6V}$

$\because V_2 = 8i_2 = 8 \times 0.5$

$\mathbf{V_2 = 4V}$

$\because V_3 = 4i_3 = 4 \times 2.5$

$\mathbf{V_3 = 10V}$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

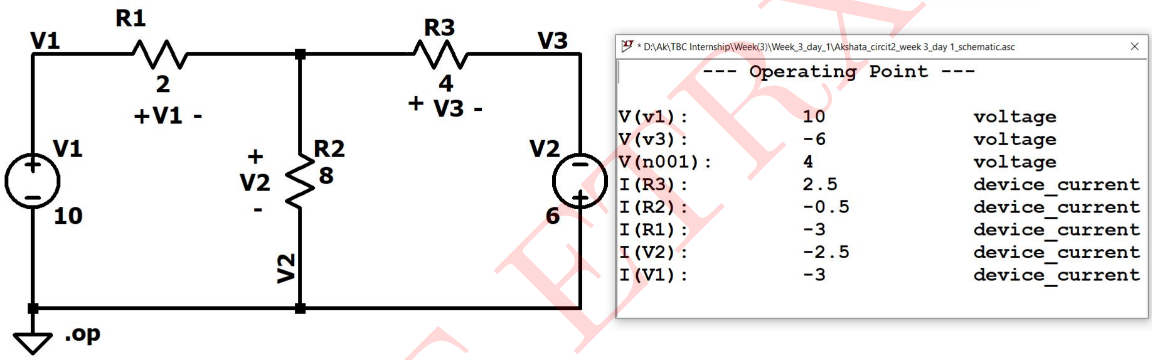

Figure 25: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_1	6V	6V
V_2	4V	4V
V_3	10V	10V
I_1	3A	3A
I_2	0.5A	0.5A
I_3	2.5A	2.5A

Numerical 7:

Find V_x in the circuit 7 given below.

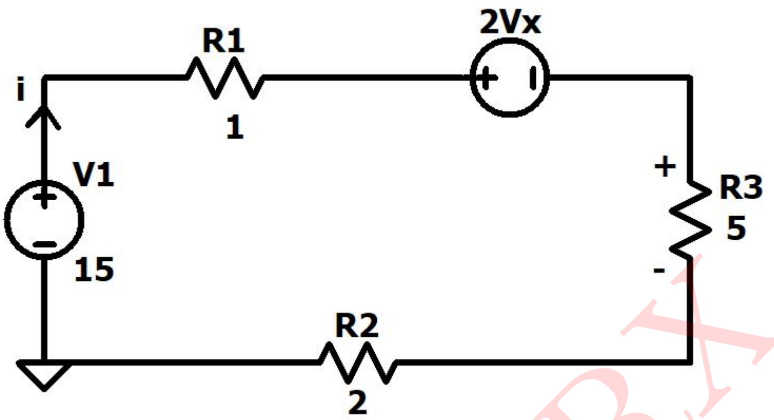

Figure 26: Circuit 7

Let i be the current flows through the circuit, applying KVL

$-1(\mathrm{i})\ -2\mathrm{V_x}\ -5(\mathrm{i})\ -\ 2(\mathrm{i})\ +\ 15 = 0$

$-8(\mathrm{i})\ +\ 15\ -2\mathrm{V_x} = 0$

Also,

$\mathrm{V_x} = 5\mathrm{i}$

$-8\mathrm{i}\ +\ 15\ -2\mathrm{V_x} = 0$

$-8\mathrm{i}\ +\ 15\ -2\ \times 5i = 0$

$-18\mathrm{i}\ +\ 15 = 0$

$\mathrm{i} = \frac{15}{18} = \frac{5}{6}\mathrm{A}$

$\mathrm{V_x} = 5\ \times i = 5 \times\ \frac{5}{6}$

$\mathbf{V_x\ =\ 4.167A}$

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

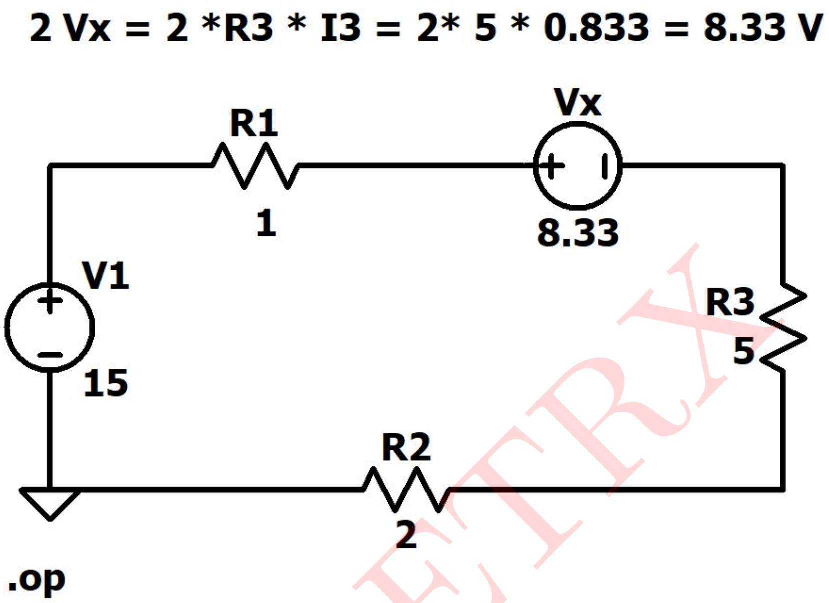

Figure 27: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_x	4.167V	4.16V
i	8.33Ω	8.33Ω

Numerical 8:
Find:
a) Thevenin voltage
b) Thevenin resistance
for two terminal network shown in the following figure 28
when, $R_1 = R_2 = R_3 = 1k\Omega$, $V_{s1} = V_{s2} = 10V$

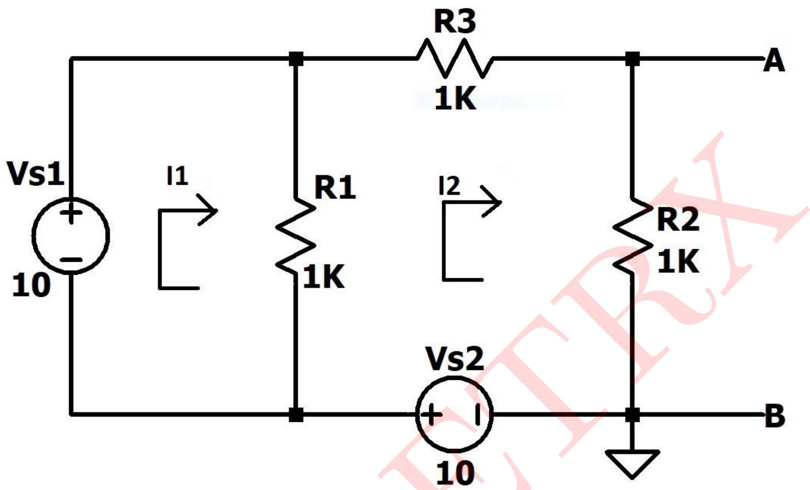

Figure 28: Circuit 8

Solution:

Applying KVL to loop (1),

$-I_1 + I_2 + 10 = 0$

$-I_1 + I_2 = -10$ ......(i)

Applying KVL to loop (2),

$-3I_2 + I_1 + 10 = 0$

$I_1 - 3I_2 = -10$ ......(ii)

By solving equation (i) and (ii),

$I_1 = 20A$

$I_2 = 10A$

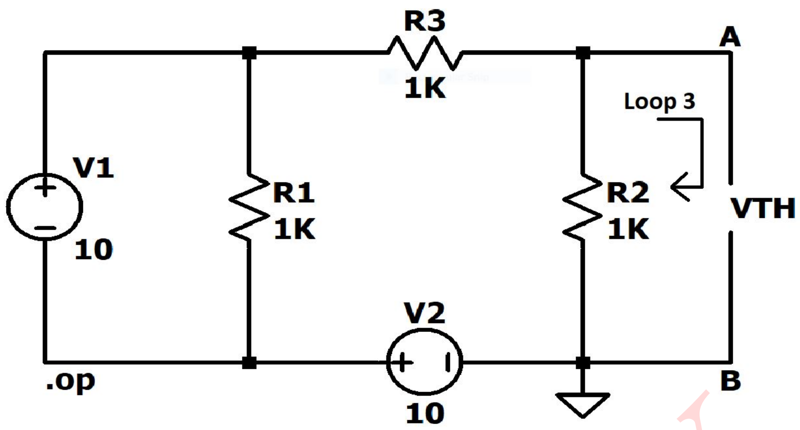

Figure 29: Circuit for calculating Thevenin's voltage

Applying KVL to loop (3),

$-\mathrm{V}_{\mathrm{TH}} + \mathrm{I}_2 = 0$

$\therefore V_{\mathrm{TH}} = I_2$

$\therefore V_{\mathbf{TH}} = \mathbf{10V}$

For finding Thevenin's equivalent resistance, voltage source becomes short circuit and current source becomes open circuit.

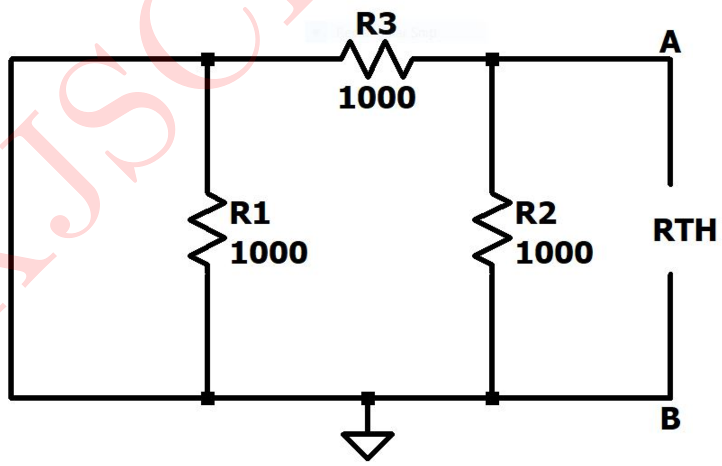

Figure 30: Circuit for calculating Thevenin's equivalent resistance

R_1 resistance gets shorted as it is connected in parallel with wire

$$\therefore R_{\text{eq}} = \frac{1}{\frac{1}{1} + \frac{1}{1}} = \frac{1}{2}$$

$\therefore R_{\text{TH}} = 0.5 \text{ k } \Omega$

$\therefore \boldsymbol{R_{\text{TH}} = 500}\ \Omega$

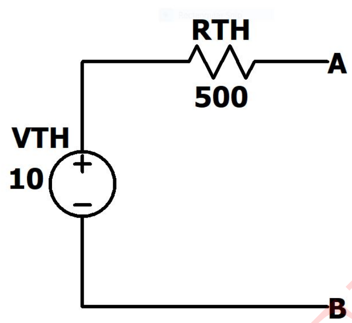

Figure 31: Thevenin's equivalent circuit for circuit 8

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

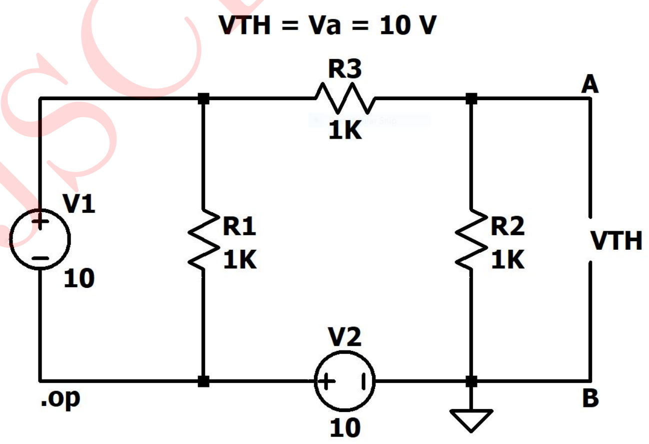

Figure 32: Circuit schematic and Simulated results for V_{TH}

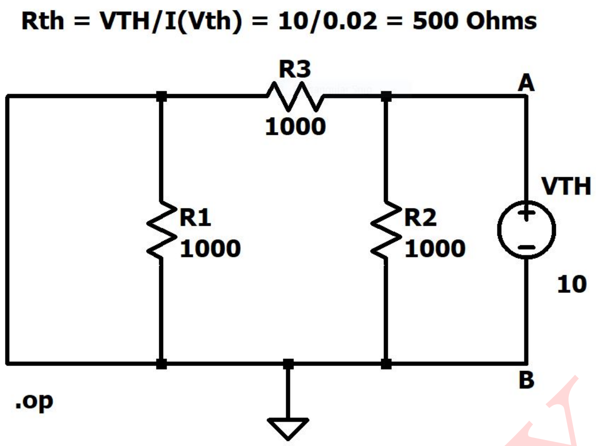

Figure 33: Circuit schematic and Simulated results for R_{TH}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{Th}	10V	10V
R_{Th}	500Ω	500Ω

Numerical 9:

Given the circuit 9 obtain the Norton equivalent as viewed from terminal C - D.

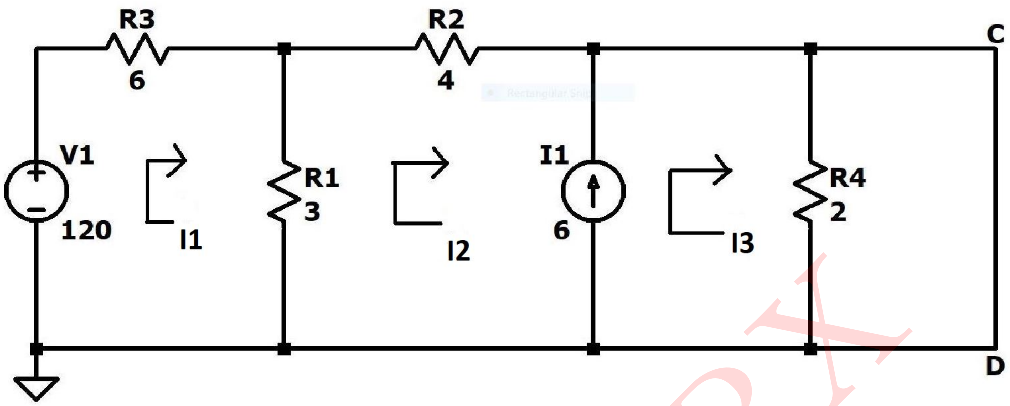

Figure 34: Circuit 9

Solution:

For finding Norton's current I_N applying mesh analysis,

From loop (1),

$-9I_1 + 3I_2 = -120$ ......(i)

From loop (2),

Solving Supermesh,

$I_2 - I_3 = -6$ ......(ii)

$-3I_1 - 7I_2 - 2I_3 + 2I_N = 0$ ......(iii)

From loop (3),

$2I_3 - 2I_N = 0$ ......(iv)

Solving above equations, we get

$I_1 = \frac{140}{9}$

$I_2 = \frac{20}{3}$

$I_3 = \frac{38}{3}$

$I_N = \frac{38}{3}$

Norton current $I_N = \frac{38}{3} = 12.66A$

For finding Norton equivalent resistance, voltage source becomes short circuit and current source becomes open circuit.

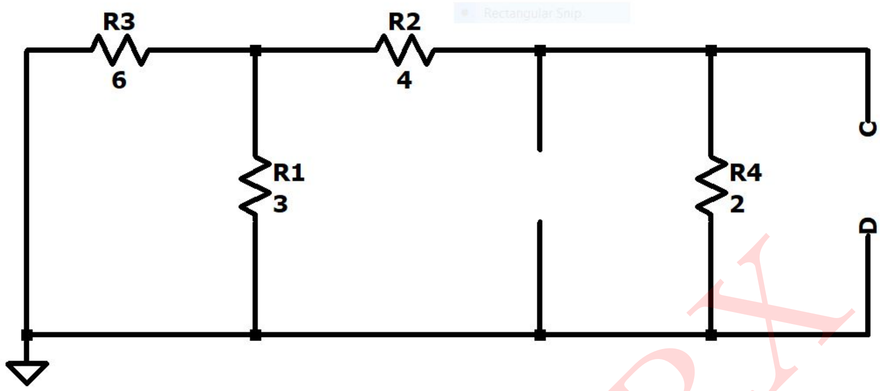

Figure 35: For calculating Norton's equivalent resistance

$R_N = [(6 \parallel 3) + 4] \parallel 2 = \dfrac{3}{2}$

$\therefore \mathbf{R_N = 1.5\ \Omega}$

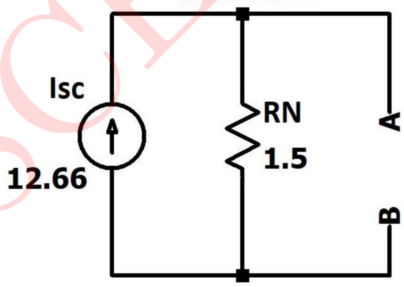

Figure 36: Norton's equivalent circuit

SIMULATED RESULTS:

The given circuit is simulated in LTspice and the results obtained are as follows:

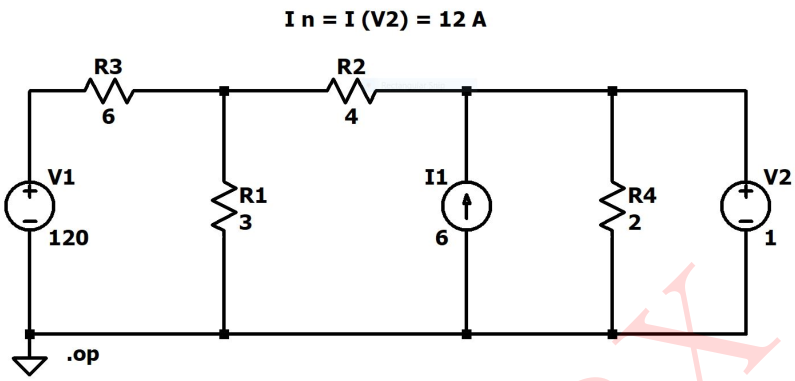

Figure 37: Circuit schematic and Simulated results for I_N

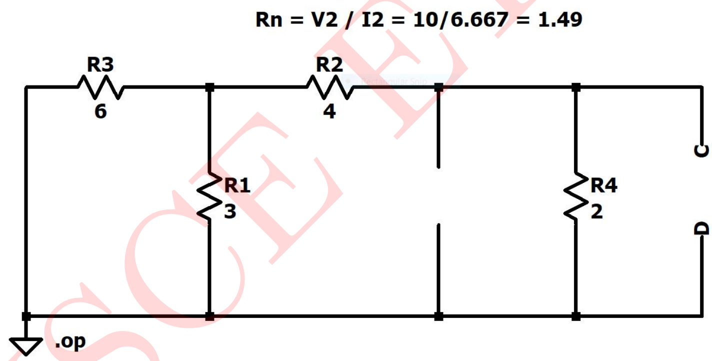

Figure 38: Circuit schematic and Simulated results for R_N

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_N	12.6V	12V
R_N	1.5Ω	1.49Ω

Numerical 10:
Find the value of R_L between A and B terminal for maximum power transfer theorem.

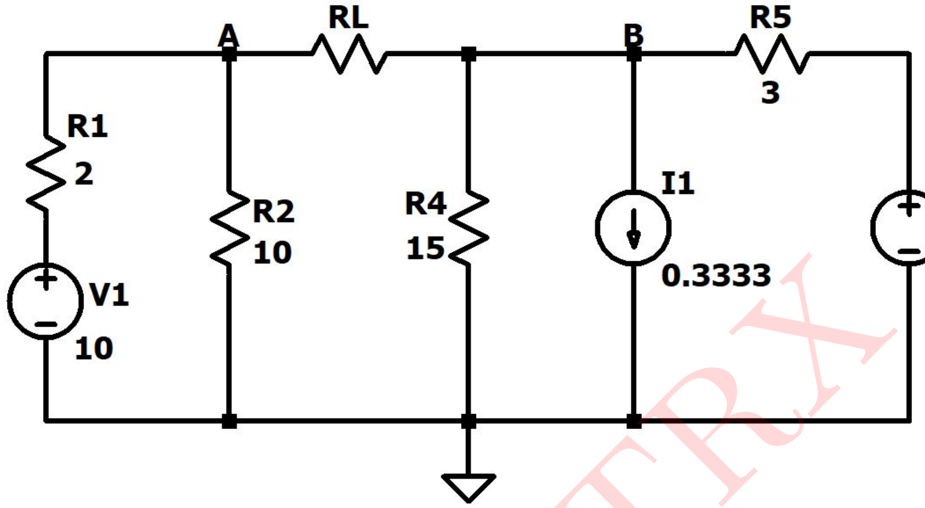

Figure 39: Circuit 10

Solution:

For finding V_{TH}, applying mesh analysis

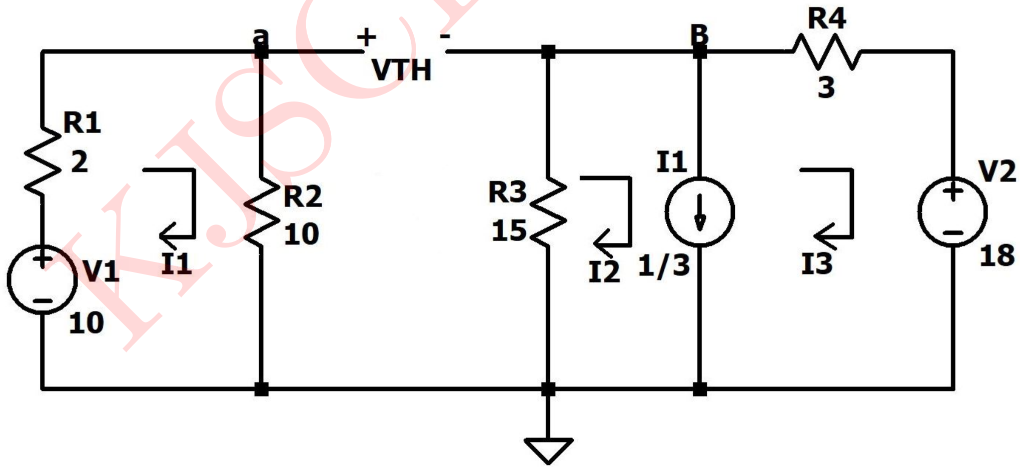

Figure 40: For calculating V_{TH}

From loop (1),

$12I_1 + 10 = 0$

$\therefore \mathbf{I_1 = 0.8333A}$ ......(i)

Solving supermesh of loop (2) and (3),

$$\mathrm{I_2} - \mathrm{I_3} = \frac{1}{3} \qquad ......(ii)$$

$$-15\mathrm{I_2} - 3\mathrm{I_3} + 18 = 0 \qquad ......(iii)$$

On solving (ii) and (iii), we get

$\therefore I_\mathbf{2} = \mathbf{-0.944A}$

$\therefore I_\mathbf{3} = \mathbf{-1.277A}$

Now,

$-\mathrm{V_{TH}} + 15\mathrm{I_1} + 10\mathrm{I_1} = 0$

$\therefore V_\mathbf{TH} = \mathbf{5.8266V}$

For finding $\mathrm{R_{TH}}$, voltage source becomes short circuit and current source becomes open circuit.

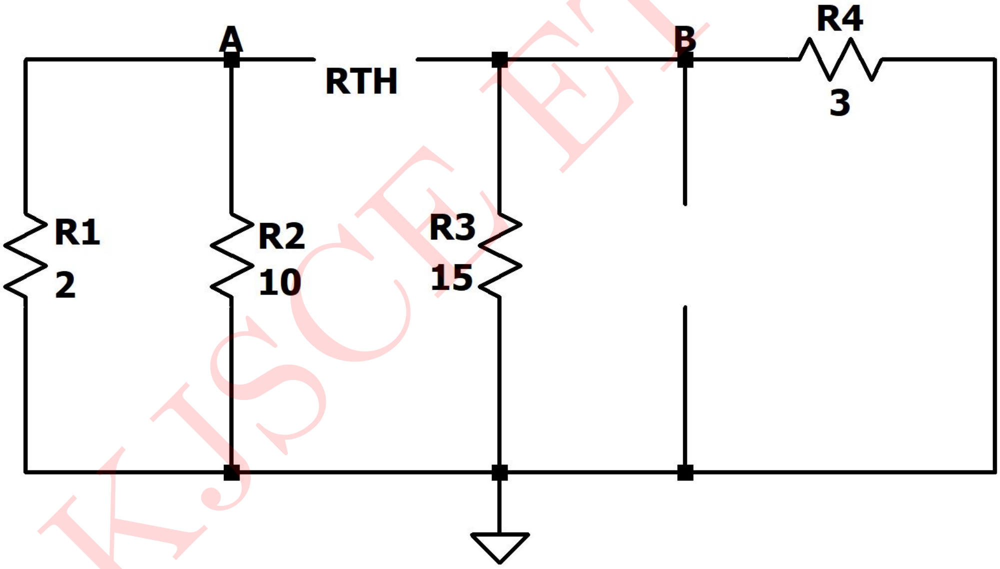

Figure 41: For calculating $\mathrm{R_{TH}}$

$$(2 \mid\mid 10) + (3 \mid\mid 15) = \frac{5}{3} + \frac{5}{2} = \frac{25}{6}$$

$\therefore R_\mathbf{TH} = \mathbf{4.1666}\ \Omega$

$\therefore$ **Maximum power:**

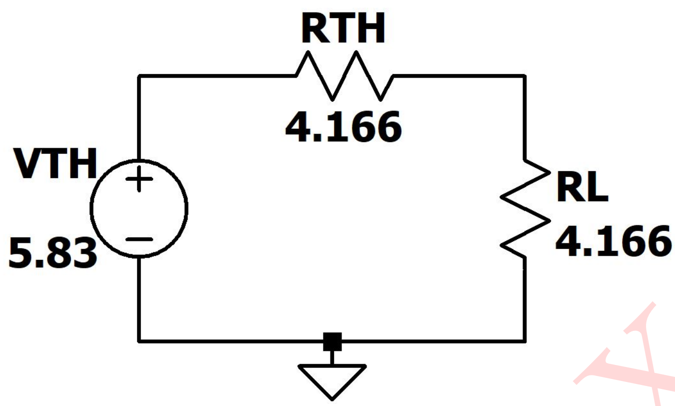

Figure 42: For calculating maximum power

$$P_{MAX} = \frac{{V_{TH}}^2}{4 \times R_{TH}}$$

$$P_{MAX} = \frac{(5.82)^2}{4 \times 4.1666}$$

$\therefore$ $\mathbf{P_{MAX} = 2.032}$ **Watt**

Simulated Circuit:

The given circuit is simulated in LTspice and the results obtained are as follows:

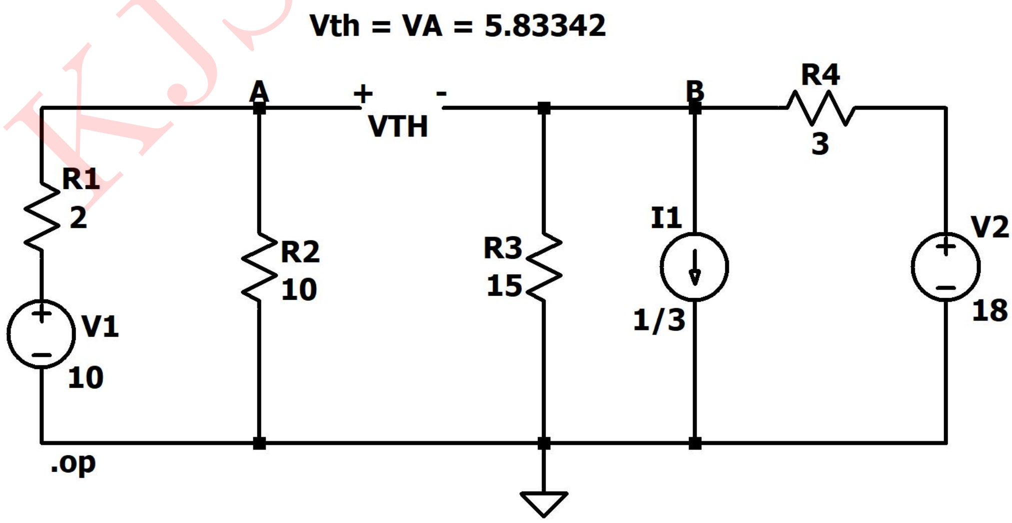

Figure 43: Circuit schematic and Simulated results for V_{TH}

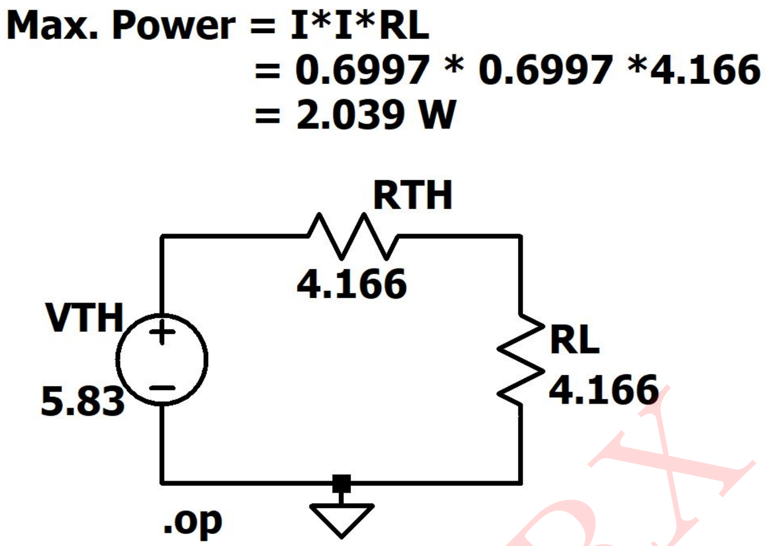

Figure 44: Circuit schematic and Simulated results for P_{MAX}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	5.82V	5.833V
R_{TH}	4.166Ω	4.166Ω
P_{MAX}	2.032W	2.039W

Numerical 11:
Find the value of resistor R_L for maximum power transfer theorem and maximum power.

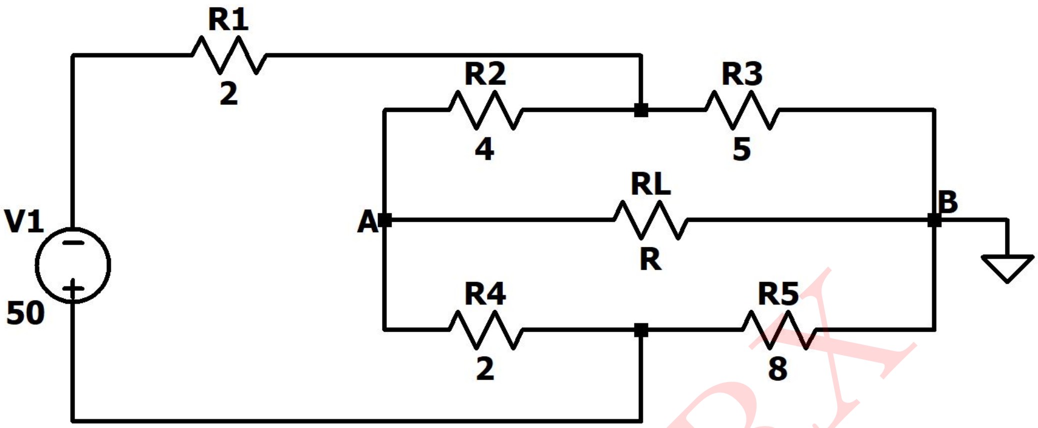

Figure 45: Circuit 11

Solution:

For finding V_{TH}, applying mesh analysis

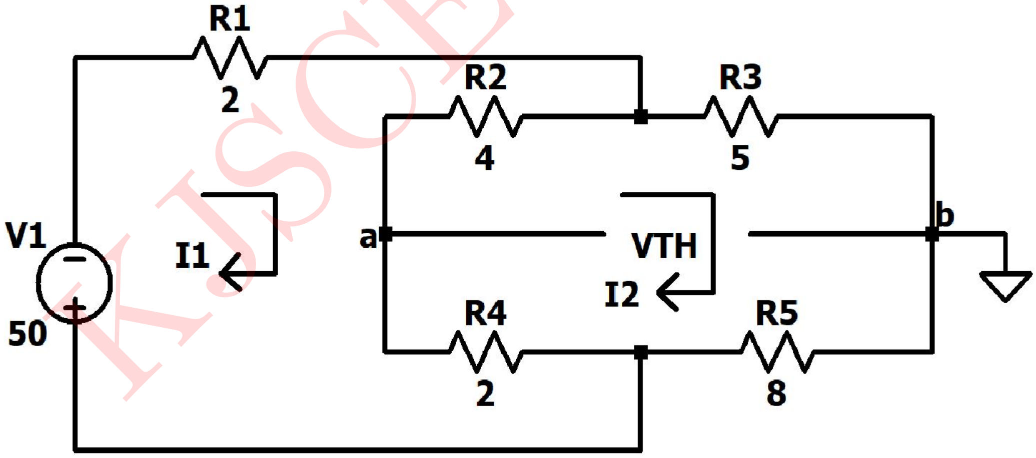

Figure 46: For calculating V_{TH}

From loop (1),

$8I_1 - 6I_2 = 50$ ......(i)

$6I_1 - 19I_2 = 0$ ......(ii)

On solving (i) and (ii), we get

$\therefore I_1 = \mathbf{8.189A}$

$\therefore I_2 = \mathbf{2.586A}$

Now,

$-V_{TH} + 2I_1 - 10I_2 = 0$

$V_{TH} = 2I_1 - 10I_2 = 0$

$\therefore V_{TH} = \mathbf{-9.482V}$

For finding R_{TH}, voltage source becomes short circuit.

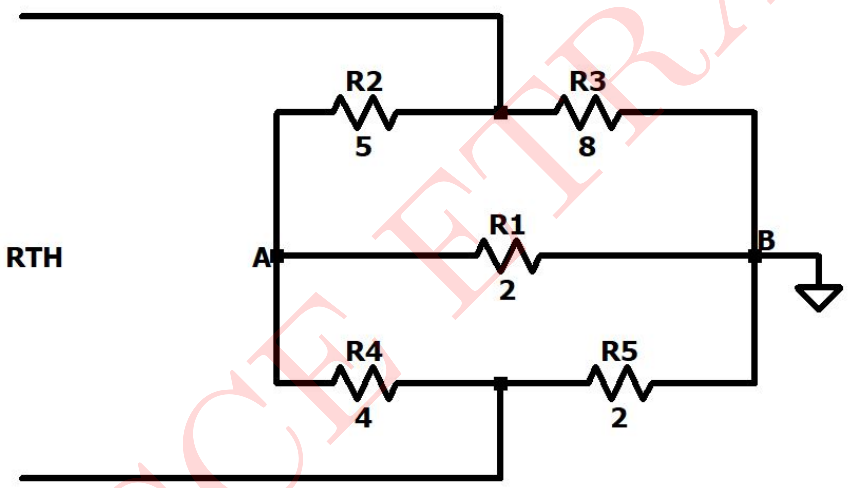

Figure 47: For calculating R_{TH}

After applying star delta transformation to 5Ω, 8Ω and 2Ω, we get

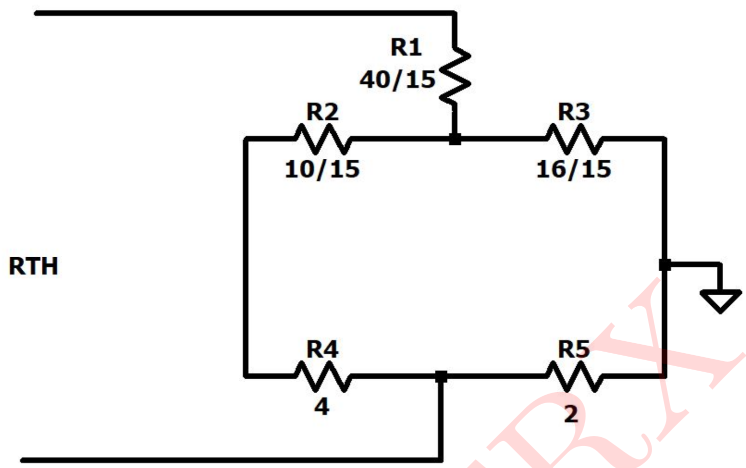

Figure 48: Modified circuit form previous figure

Applying series parallel transformation to R_2, R_3, R_4 and R_5, we get

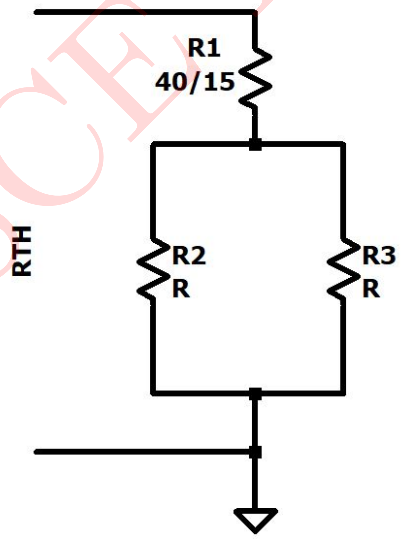

Figure 49: Modified circuit for calculating R_{TH}

$$\mathrm{R_{TH}} = \frac{40}{15} + (\frac{14}{3} \mid\mid \frac{46}{15})$$

$\therefore$ $\mathbf{R_{TH} = 4.51\ \Omega}$

$\therefore$ **Maximum power :**

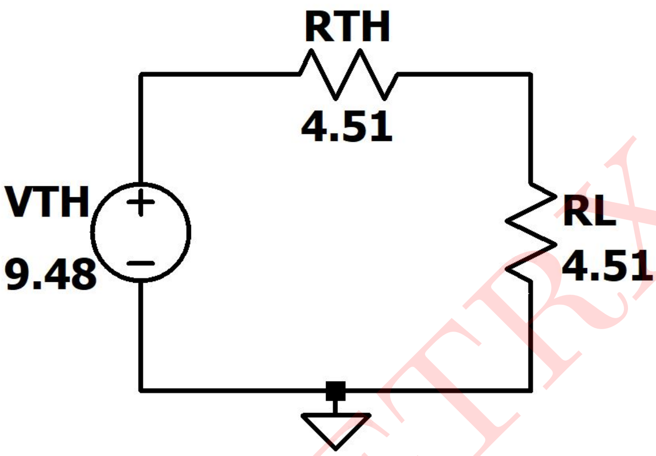

Figure 50: For calculating maximum power

$$\mathrm{P_{MAX}} = \frac{V_{\mathrm{TH}}{}^2}{4 \times R_{\mathrm{TH}}}$$

$$\mathrm{P_{MAX}} = \frac{(9.482)^2}{4 \times 4.51}$$

$\therefore$ $\mathbf{P_{MAX} = 4.98\ Watt}$

Simulated Circuit:

The given circuit is simulated in LTspice and the results obtained are as follows:

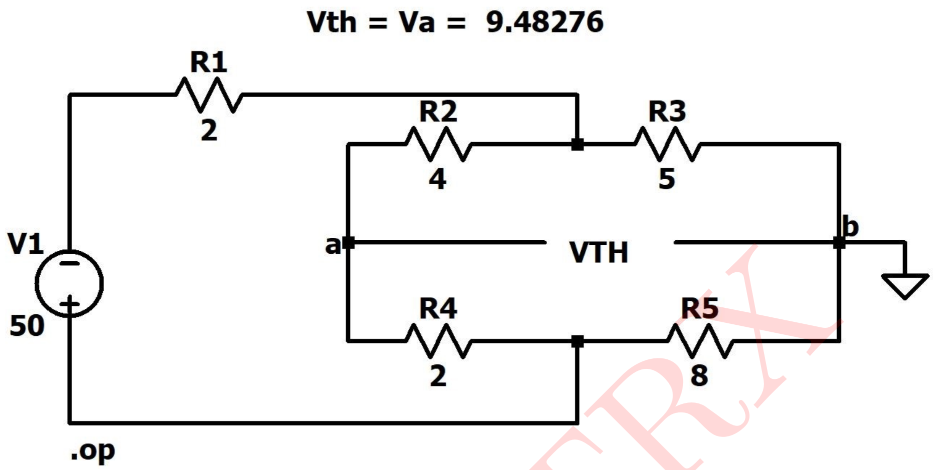

Figure 51: Circuit schematic and Simulated results for V_{TH}

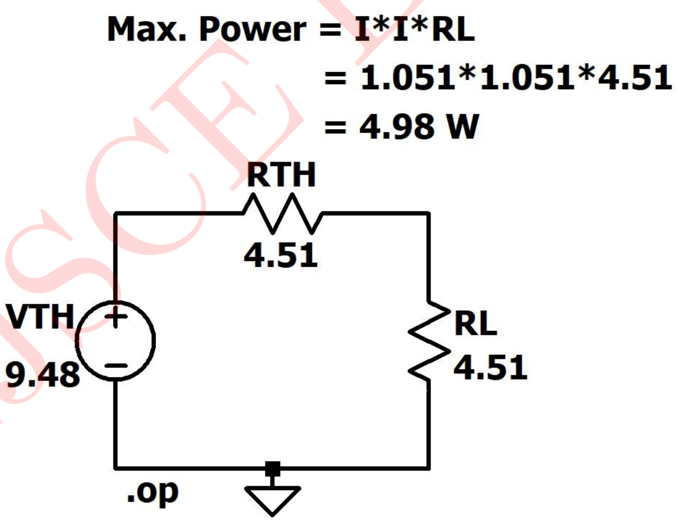

Figure 52: Circuit schematic and Simulated results for P_{MAX}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	9.48V	9.48V
R_{TH}	4.51Ω	4.51Ω
P_{MAX}	4.98W	4.98W