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

Numerical 1: Introduce the ground termination, write the nodal equations, and solve for the node voltages for the circuit shown in the following figure. Calculate the current I shown in the Figure 1.

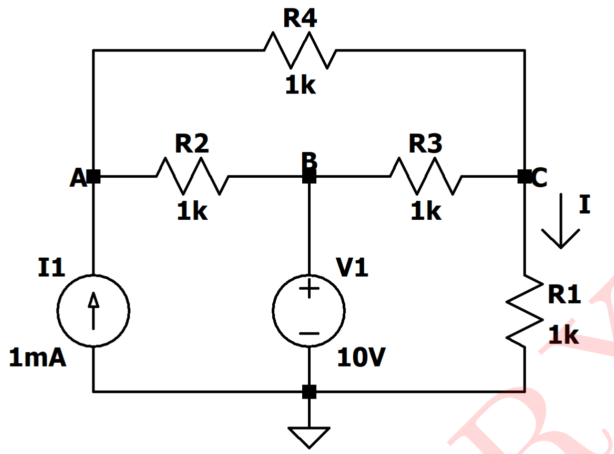

Figure 1: Circuit 1

Solution:

From Figure 1 Circuit 1,

$V_B = 10V$ ... (1)

For node A,

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at A,

$$-(1\times10^{-3}) + \frac{V_A - V_B}{1\times10^3} + \frac{V_A - V_C}{1\times10^3} = 0$$

$-1 + V_A - V_B + V_A - V_C = 0$

$2V_A - V_B - V_C = 1$ ... (2)

For node C,

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at C,

$$\frac{V_C - 0}{1\times10^3} + \frac{V_C - V_B}{1\times10^3} + \frac{V_C - V_A}{1\times10^3} = 0$$

$V_C + V_C - V_B + V_C - V_A = 0$

$3V_C - V_B - V_A = 0$ ... (3)

From (1), (2) and (3) we get,

$V_A = 8.6$V

$V_B = 10$V

$V_C = 6.2$V

By Ohm's Law,

$$I = \frac{V_C - 0}{1 \times 10^3} = \frac{6.2 - 0}{10^3}$$
$$I = \mathbf{6.2mA}$$

SIMULATED RESULTS

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

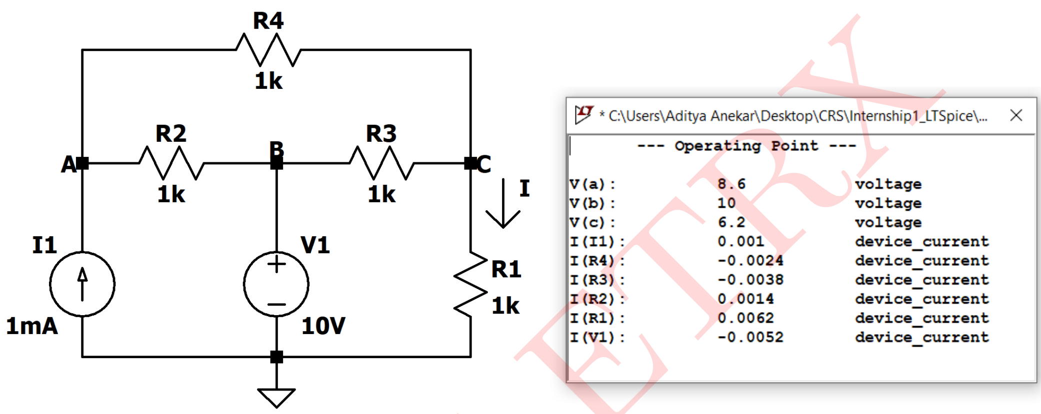

Figure 2: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_A	8.6V	8.6V
V_C	6.2V	6.2V
I	6.2mA	0.0062A

Table 1: Numerical 1

Numerical 2: Using nodal voltage method, find the magnitude and direction of current I in the network of the circuit given in Figure 3.

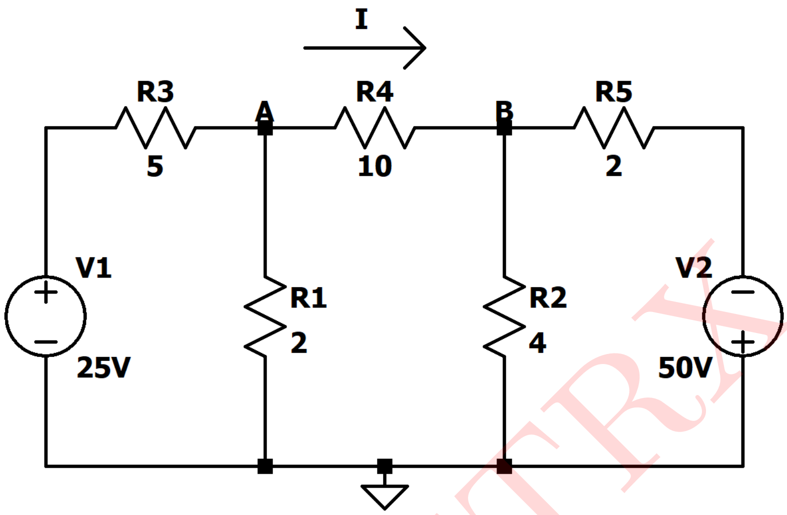

Figure 3: Circuit 2

Solution:

In Figure 3 Circuit 2,

Applying Source Transformation to Voltage Sources $V1$ and $V2$,

$$I_1 = \frac{V_1}{R_3} = \frac{25}{5} = 5A$$

$$I_2 = \frac{V_2}{R_5} = \frac{50}{2} = 25A$$

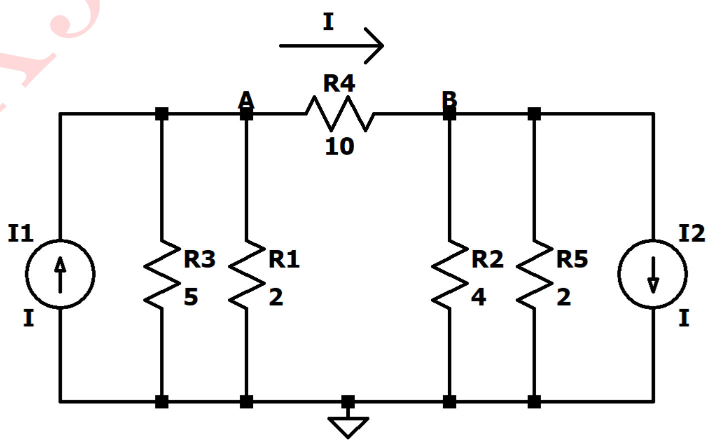

Figure 4: Modified Circuit 2a after Source Transformation

Combining parallel resistances,

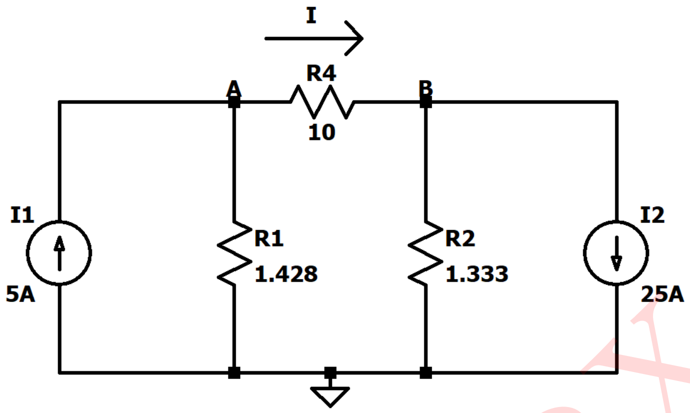

Figure 5: Modified Circuit 2b after Combining parallel resistances

Applying nodal analysis,

For node A,

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at A,

$$-5 + \frac{V_A - 0}{1.428} + \frac{V_A - V_B}{10} = 0$$

$$10V_A + 1.428(V_A - V_B) = 71.4$$

$$11.428V_A - 1.428V_B = 71.4 \; ... \; (1)$$

For node B,

Applying Kirchhoff's Current Law(KCL) and Ohm's Law at B,

$$25 + \frac{V_B - 0}{1.333} + \frac{V_B - V_A}{10} = 0$$

$$10V_B + 1.333(V_B - V_A) = -333.325$$

$$11.333V_B - 1.333V_A = -333.325 \; ... \; (2)$$

From (1) and (2) we get,

$V_A = 2.611\text{V}$

$V_B = -29.1\text{V}$

By Ohm's Law,

$$I = \frac{V_A - V_B}{10} = \frac{2.611 - (-29.1)}{10} = \frac{31.711}{10}$$

$$I = \mathbf{3.1711A}$$

SIMULATED RESULTS

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

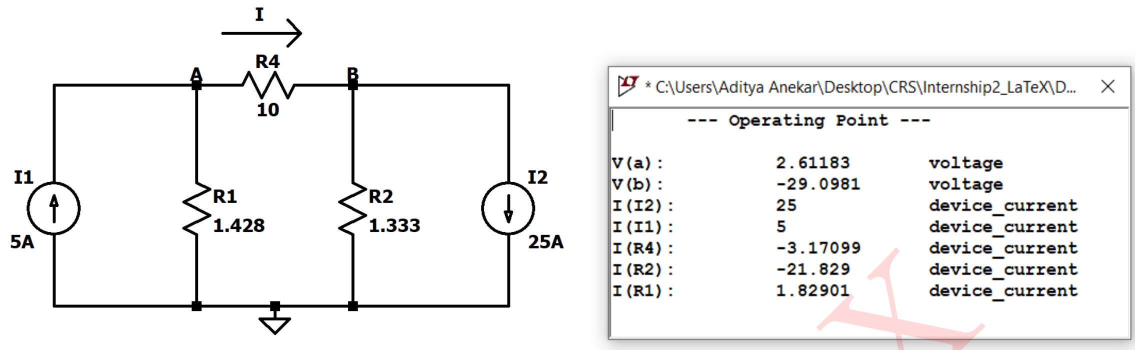

Figure 6: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Parameter	Calculated Value	Simulated Value
V_A	$2.611V$	$2.61183V$
V_B	$-29.1V$	$-29.0981V$
I	3.1711A	3.17099A

Table 2: Numerical 2

Numerical 3: By using repeated source transformations, find the value of voltage V in the network given in Figure 7.

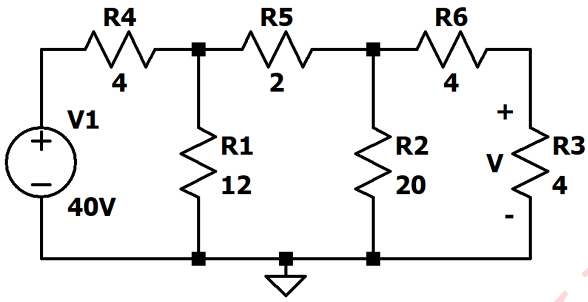

Figure 7: Circuit 3

Solution:

In Figure 7 Circuit 3,

Applying Source Transformation to Voltage Source $V1$,

$I_1 = \dfrac{V_1}{R_4} = \dfrac{40}{4} = 1A$

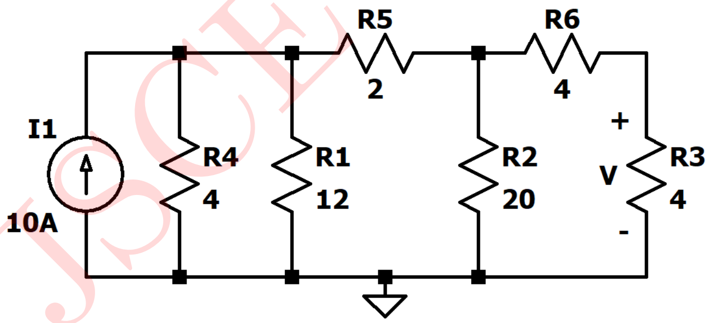

Figure 8: Modified Circuit 3a after Source Transformation

Combining parallel resistances,

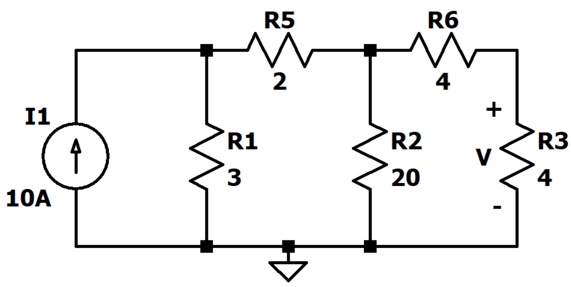

Figure 9: Modified Circuit 3b after Combining parallel resistances

Applying Source Transformation to Current Source $I1$,

$V_1 = \mathrm{V}_1 \times R_1 = 10 \times 3 = 30V$

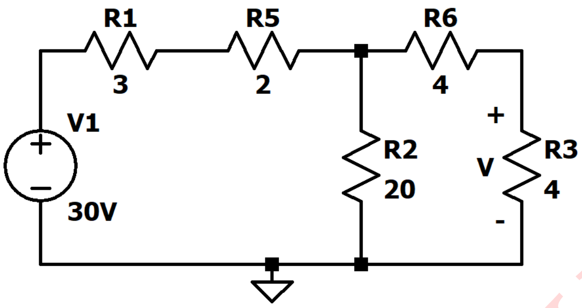

Figure 10: Modified Circuit 3c after Source Transformation

Combining series resistances,

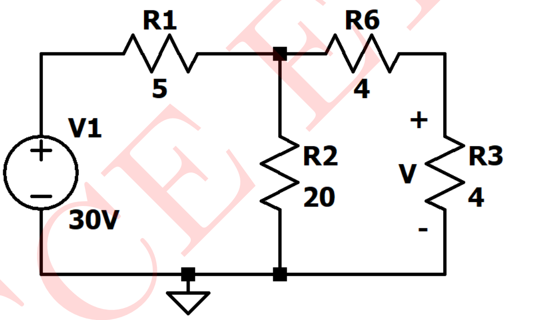

Figure 11: Modified Circuit 3d after Combining series resistances

Applying Source Transformation to Voltage Source $V1$,

$I_1 = \dfrac{V_1}{R_1} = \dfrac{30}{5} = 6A$

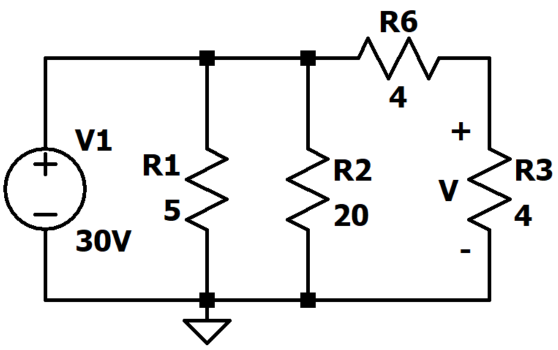

Figure 12: Modified Circuit 3e after Source Transformation

Applying Source Transformation to Current Source $I1$,

$$V_1 = \text{I}_1 \times \frac{R_1 \times R_2}{R_1 + R_2} = 6 \times 4 = 24V$$

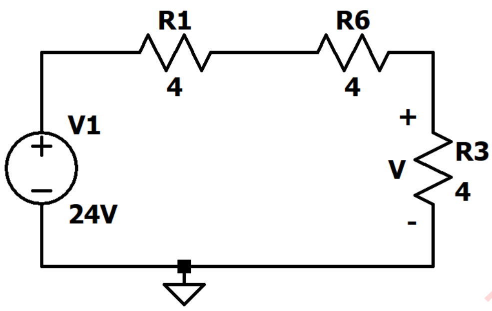

Figure 13: Modified Circuit 3f after Source Transformation

Combining series resistances,

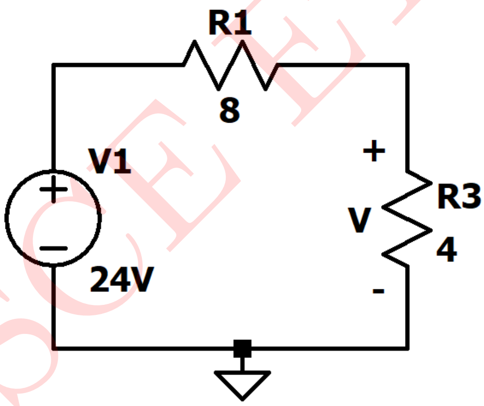

Figure 14: Modified Circuit 3g after Combining series resistances

To find V,

Using Voltage Division Rule,

$$V = 24 \times \frac{4}{4+8}$$

$$V = \mathbf{8V}$$

SIMULATED RESULTS

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

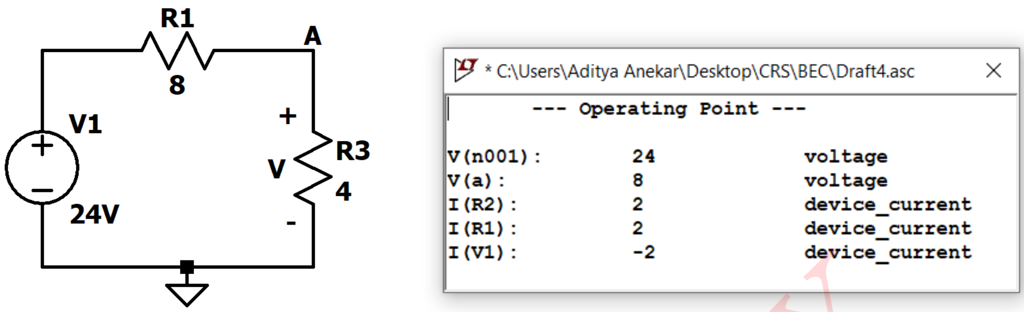

Figure 15: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Parameter	Calculated Value	Simulated Value
V	8V	8V

Table 3: Numerical 3

Numerical 4: Find R_{ab} in the four way power divider circuit given in Figure 16. Each resistance is of 3Ω

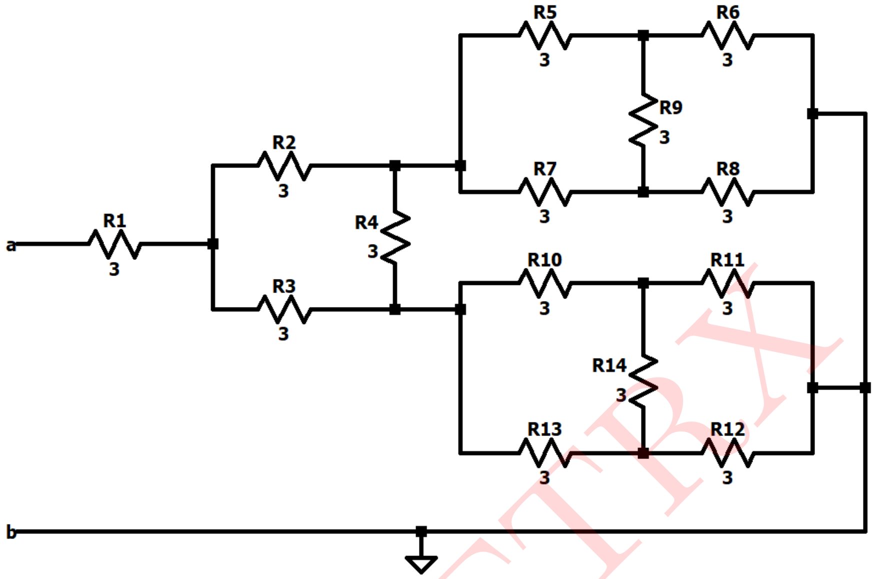

Figure 16: Circuit 4

Solution:

In Figure 16 Circuit 4,

Converting the resistances connected in Delta in the network to Stars,

$$R_{star} = \frac{3 \times 3}{3+3+3}$$

$\mathbf{R}_{star}$ =**1**Ω

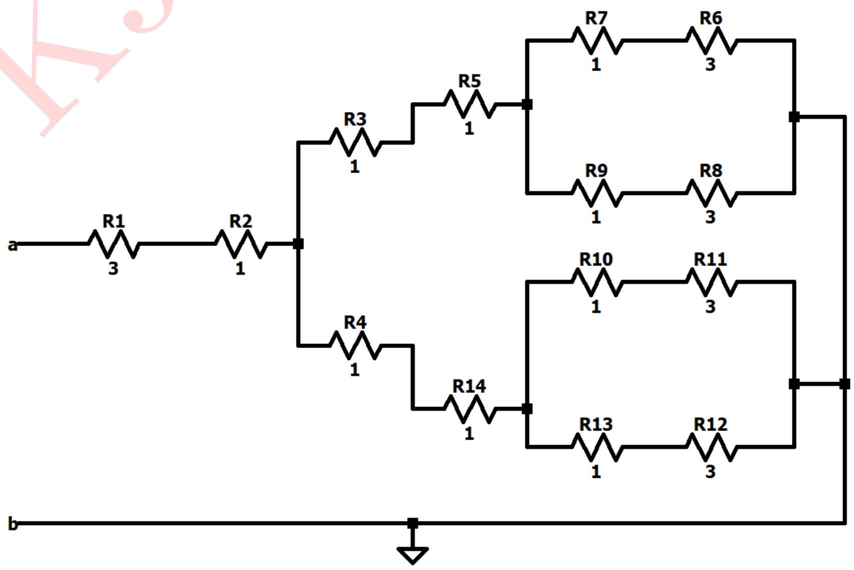

Figure 17: Modified Circuit 4a after Delta to Star

Combining series and parallel resistances and simplifying the circuit,

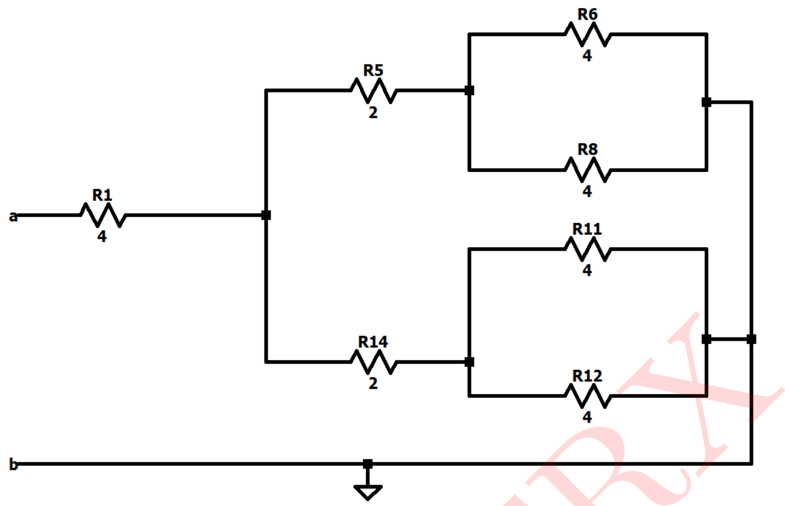

Figure 18: Modified Circuit 4b after Combining series resistances

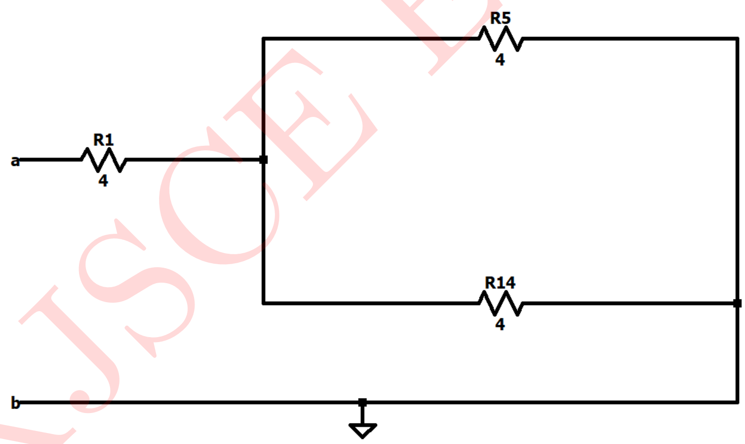

Figure 19: Modified Circuit 4c after Combining series and parallel resistances

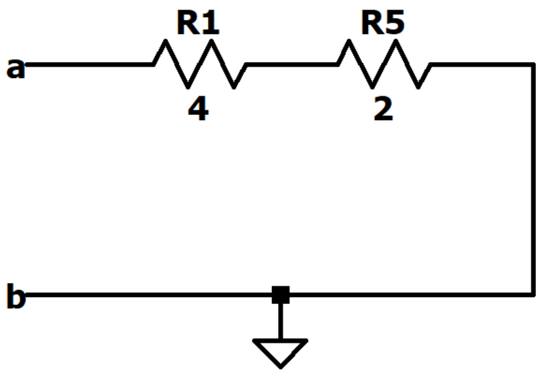

Figure 20: Modified Circuit 4d after Combining series resistances

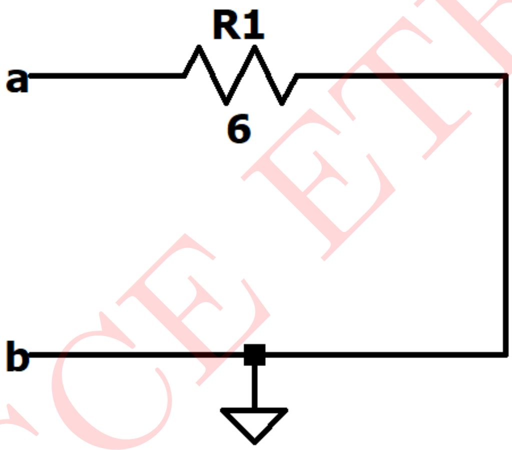

Figure 21: Modified Circuit 4e after Combining series resistances

SIMULATED RESULTS

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

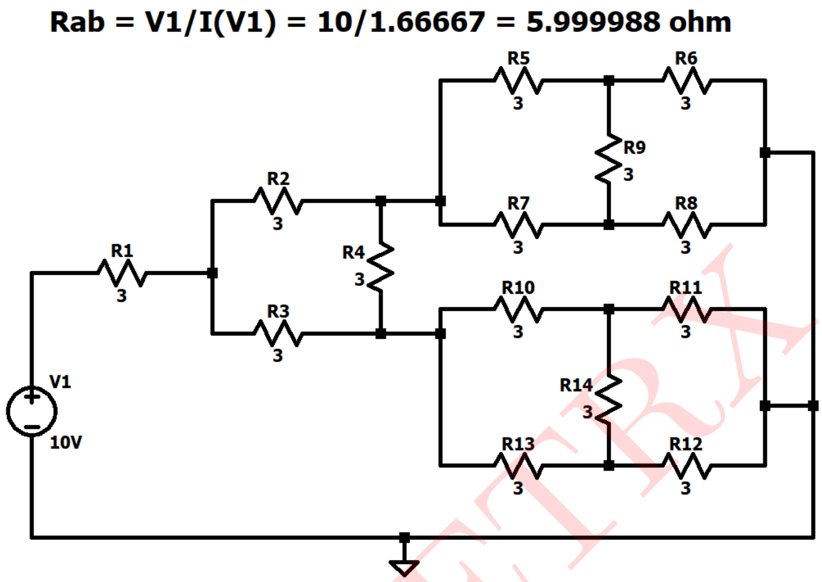

Figure 22: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Parameter	Calculated Value	Simulated Value
R_{ab}	6Ω	5.999988Ω

Table 4: Numerical 4

For finding R_{ab} by simulation, we use $Ohm's\ Law$,

i) We first connect a $10V$ voltage source across the terminals a and b.

ii) Find the current flowing through the $10V$ voltage source.

iii) Then use R = $\frac{V}{I}$ [$Ohm's\ Law$]

Numerical 5: Find the Norton equivalent circuit for the active linear network shown in the Figure 23. [Hint : It would be easier to first find Thevenin's equivalent circuit].

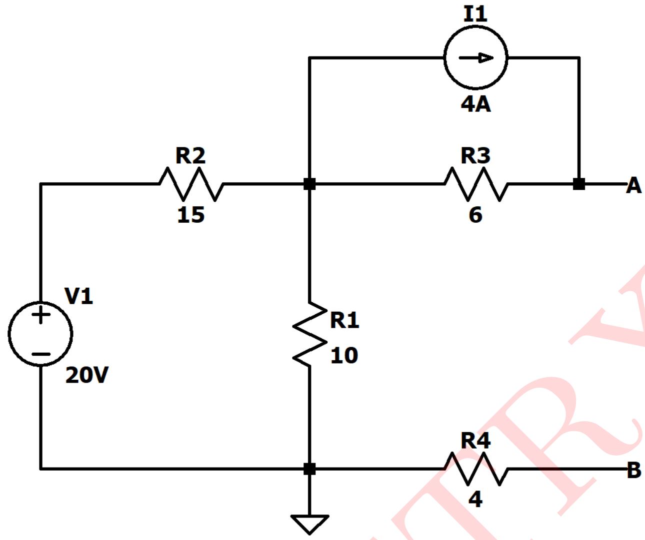

Figure 23: Circuit 5

Solution:

Finding R_{Th},

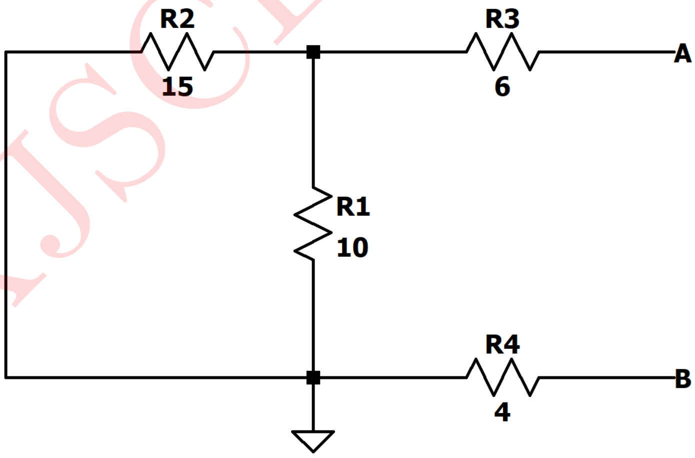

Figure 24: Modified Circuit 5a for finding R_{Th}

Further simplifying we get,

$R_{Th} = R_N = 16\Omega$

Applying Source Transformation,

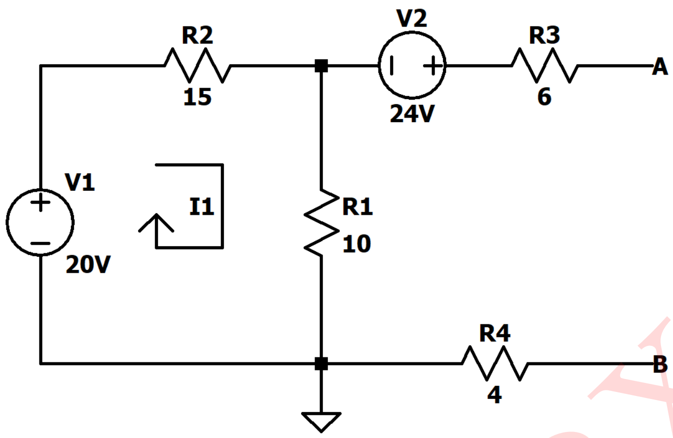

Figure 25: Modified Circuit 5b after Source Transformation

Applying Kirchhoff's Voltage Law (KVL),

$20 - 15I_1 - 10I_1 = 0$

$25I_1 = 20$

$I_1 = 0.8\text{A}$

Finding voltage across R_1,

$V_{R1} = I_1 \times \text{R}_1 = 0.8 \times 10$

$V_{R1} = \mathbf{8V}$

$V_{Th} = 8 + 24$

$\therefore \text{V}_{Th} = 32\text{V}$

Thevenin's Equivalent Circuit

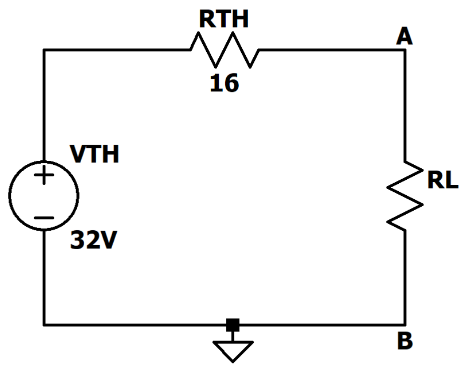

Figure 26: Thevenin's Equivalent Circuit

Nortons's Equivalent Circuit

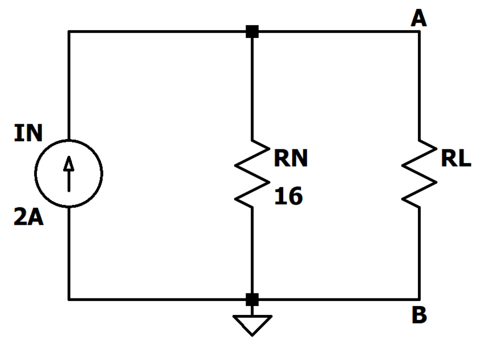

Figure 27: Nortons's Equivalent Circuit

SIMULATED RESULTS

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

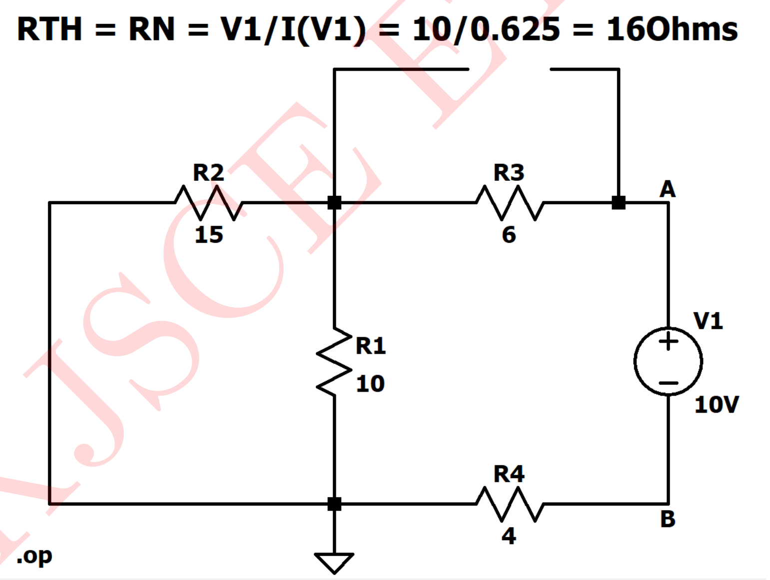

Figure 28: Modified Circuit 5c for finding R_{Th} by simulation

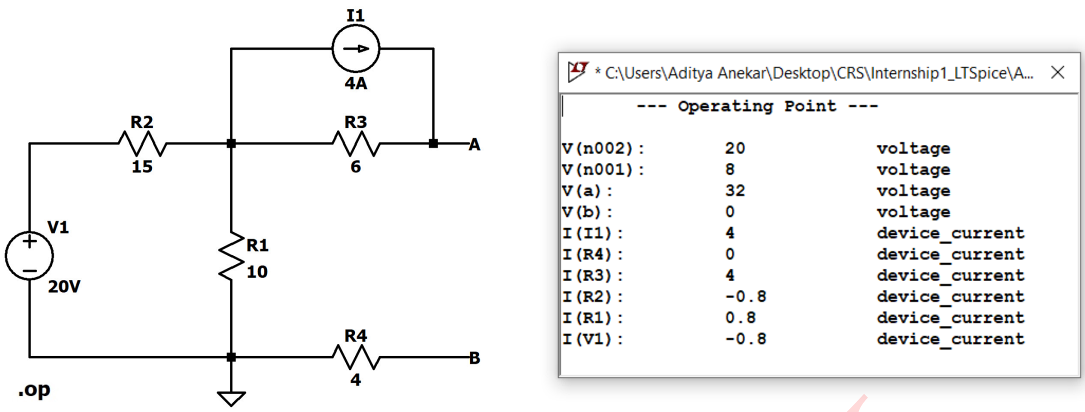

Figure 29: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
R_N	16Ω	16Ω
V_{Th}	32V	32V
I_N	2A	2A

Table 5: Numerical 5

Numerical 6: Find the currents I_1, I_2, I_3 and voltages V_1, V_2, V_3 shown in the Figure 30.

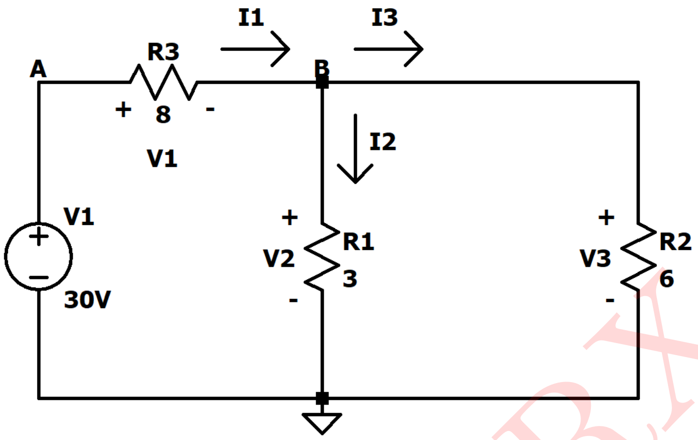

Figure 30: Circuit 6

Solution:

Considering Loops 1 and 2,

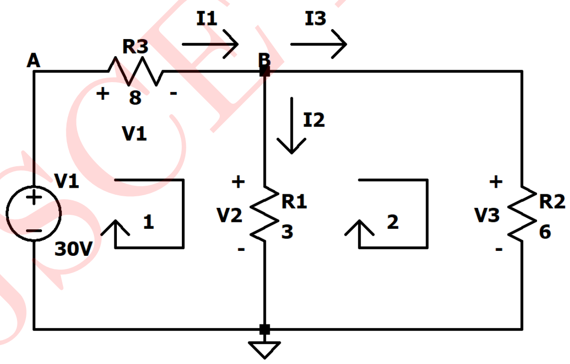

Figure 31: Loops 1 and 2 in Circuit 6

By Ohm's Law,

$V_1 = 8I_1$; $V_2 = 3I_2$; $V_3 = 6I_3$

$I_1 = I_2 + I_3$ ....(1)

Applying KVL to Loop 1,

$30 - 8I_1 - 3I_2 = 0$

$8I_1 + 3I_2 = 30$ ....(2)

Applying KVL to Loop 2,

$-3I_2 + 6I_3 = 0$

$I_2 = 2I_3$ ....(3)

From (1), (2) and (3),

$I_1 = 3A$

$I_2 = 2A$

$I_3 = 1A$

Hence,

$V_1 = 8I_1 = 8 \times 3 = 24$V

$V_2 = 3I_2 = 3 \times 2 = 6$V

$V_3 = 6I_3 = 6 \times 1 = 6$V

SIMULATED RESULTS

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

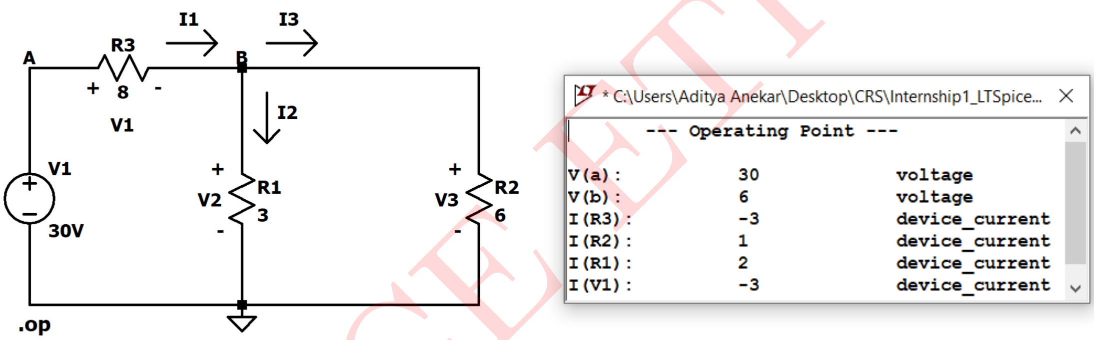

Figure 32: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I_1	3A	3A
I_2	2A	2A
I_3	1A	1A
V_1	24V	24V
V_2	6V	6V
V_3	6V	6V

Table 6: Numerical 6

Numerical 7: Find the current I_o shown in the Figure 33

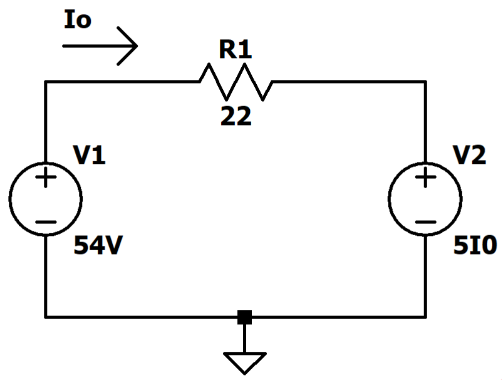

Figure 33: Circuit 7

Solution:

V_2 is a current dependant voltage source,

Applying KVL,

$54 - 22I_o - 5I_o = 0$

$I_o = 2A$

SIMULATED RESULTS

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

For simulation, we check the total current in the circuit(I_o) by substituting $I_o = 2$A in $5I_o$. Hence, replacing it with 10V.

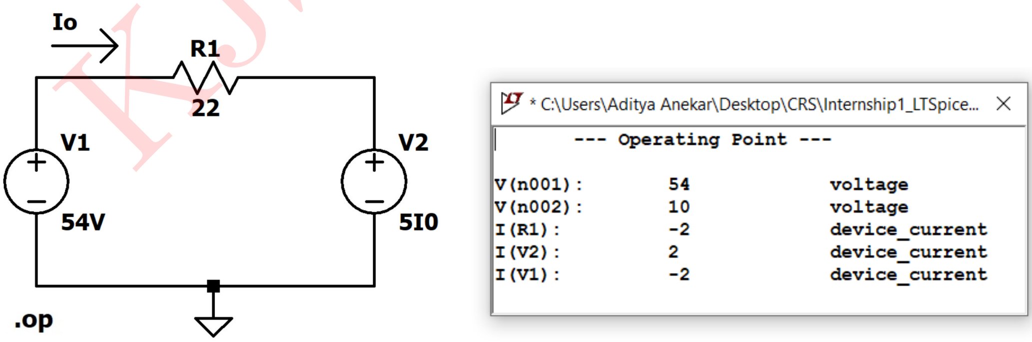

Figure 34: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I_o	2A	2A

Table 7: Numerical 7

Numerical 8: Find

i) Thevenin Equivalent Voltage

ii) Thevenin Equivalent Resistance

for the networks shown in the Figure 35 and 36.

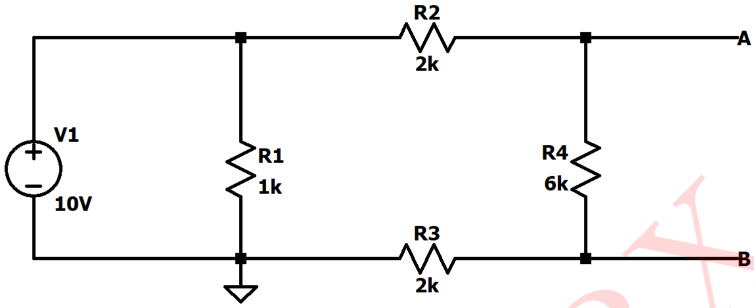

Figure 35: Circuit 8

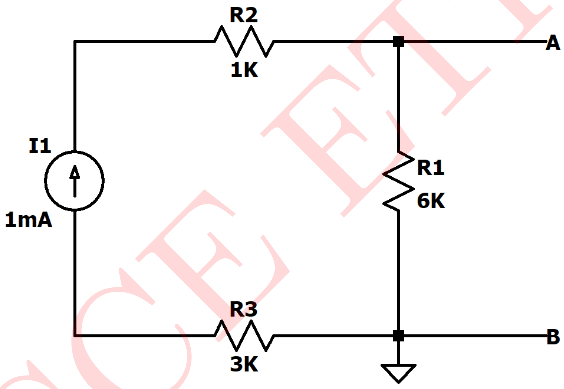

Figure 36: Circuit 9

Solution:

For Circuit 8,

Finding V_{Th},

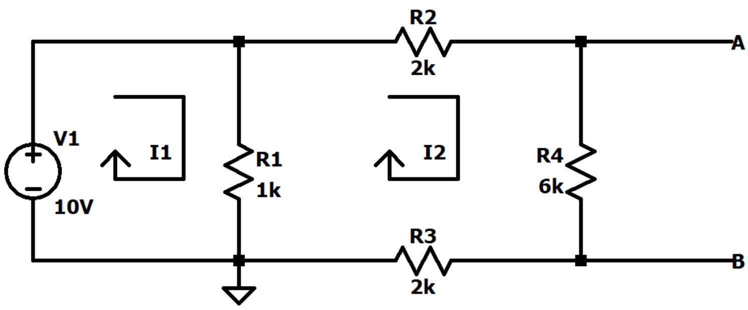

Figure 37: Considering Loops 1 and 2

Applying KVL to Loop 1,

$10 - (I_1 - I_2) = 0$

$I_1 - I_2 = 10$ ....(1)

Applying KVL to Loop 2,

$2I_2 + 6I_2 + 2I_2 + 1(I_2 - I_1) = 0$

$11I_2 - I_1 = 0$ ....(2)

From (1) and (2),

$I_1 = 11A$

$I_2 = 1A$

$V_{Th} = V_{6\Omega} = 6 \times I_2 = 6 \times 1$

$V_{Th} = 6V$

Finding R$_{Th}$,

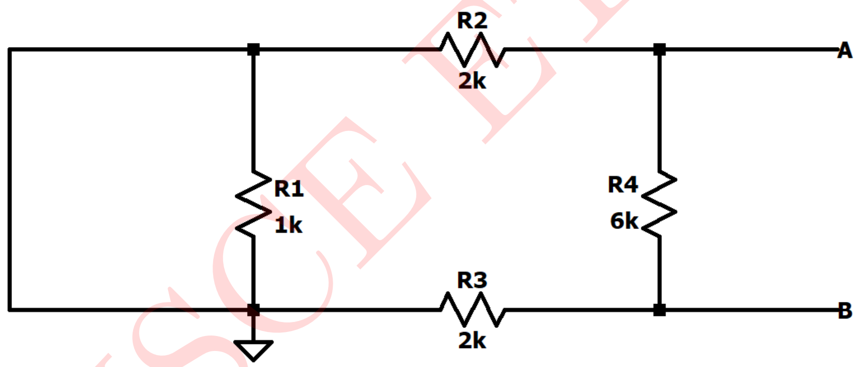

Figure 38: Modified Circuit 8a to find R$_{Th}$

$$\mathrm{R}_{Th} = \frac{(2k + 2k) \times 6k}{2k + 2k + 6k}$$

$\mathrm{R}_{Th} = 2.4k\Omega$

For Circuit 9,

Finding V_{Th},

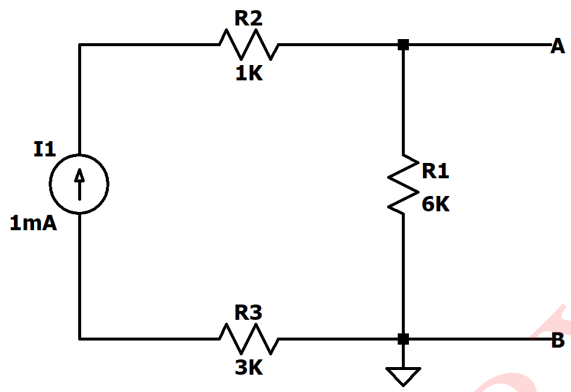

Figure 39: Circuit 2

$V_{Th} = I_1 \times R_1 = 1 \times 10^{-3} \times 6 \times 10^3$

$V_{Th} = 6V$

Finding R_{Th},

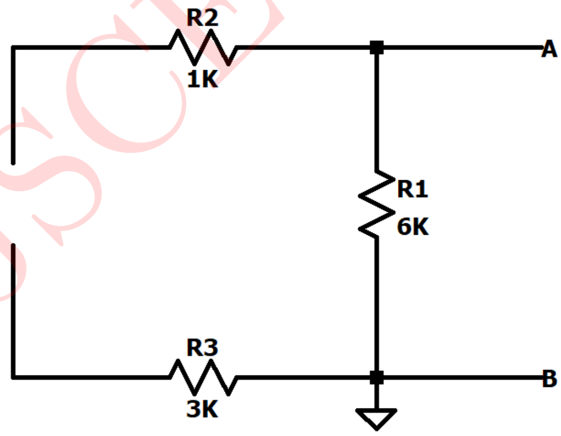

Figure 40: Modified Circuit 9a to find R_{Th}

$R_{Th} = 6k\Omega$

SIMULATED RESULTS for Circuit 8

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

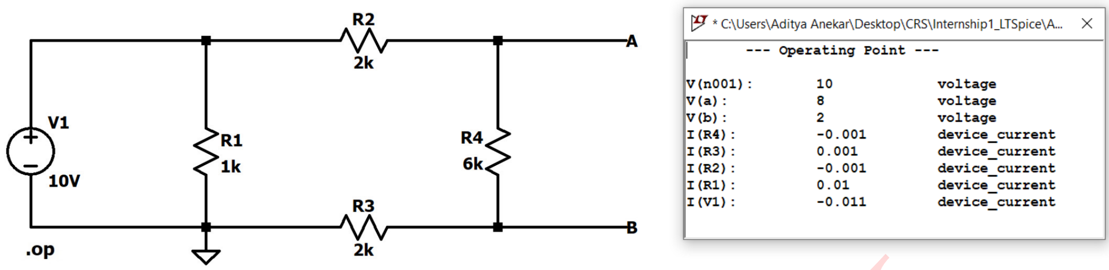

Figure 41: Circuit Schematic and Simulated Results

$V_{Th} = V_a - V_b$

$V_{Th} = 6V$

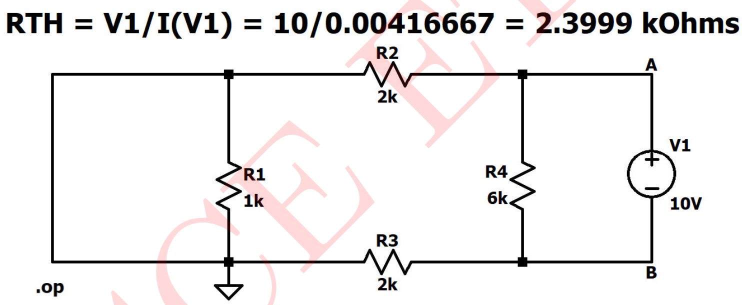

Figure 42: Finding R_{Th} by simulation

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_{Th}	6V	6V
R_{Th}	2.4kΩ	2.3999kΩ

Table 8: Numerical 8 Circuit 8

SIMULATED RESULTS for Circuit 9

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

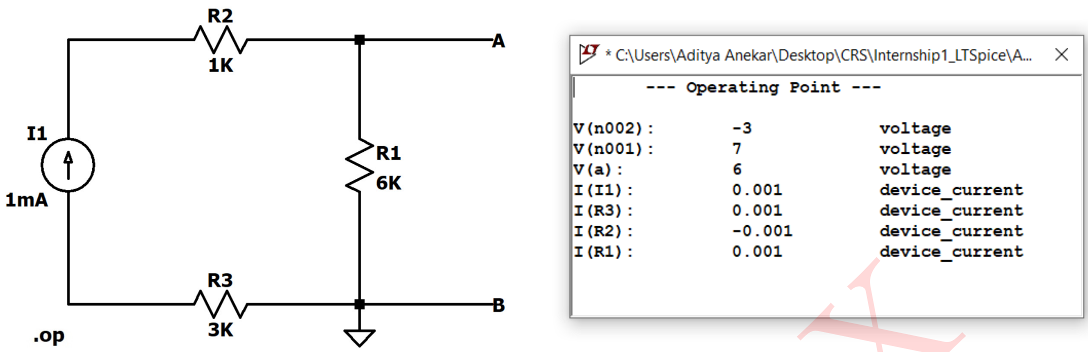

Figure 43: Circuit Schematic and Simulated Results

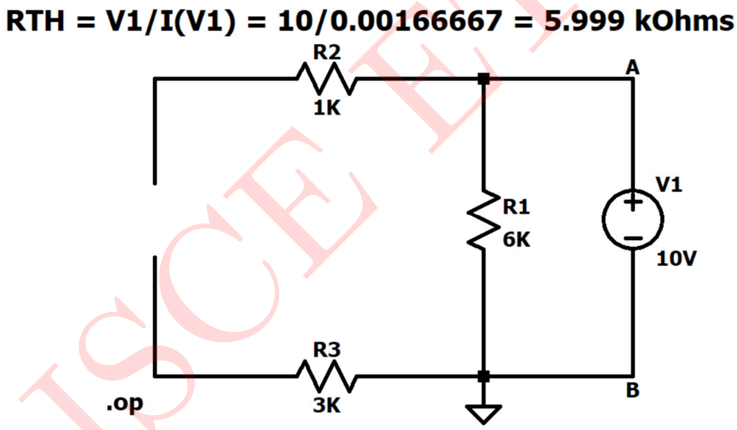

Figure 44: Finding R_{Th} by simulation

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_{Th}	6V	6V
R_{Th}	6kΩ	5.9999kΩ

Table 9: Numerical 8 Circuit 9

Numerical 9: Find Thevenin and Norton Equivalents at terminal $A - B$ of the circuit shown in Figure 45

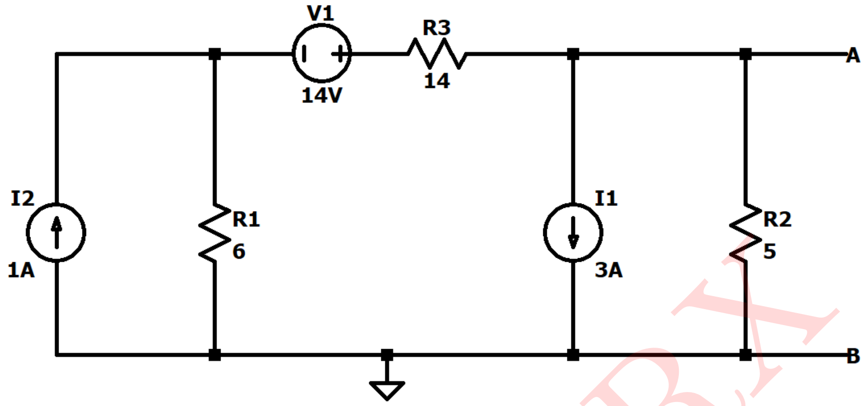

Figure 45: Circuit 10

Solution:

Finding R_{Th},

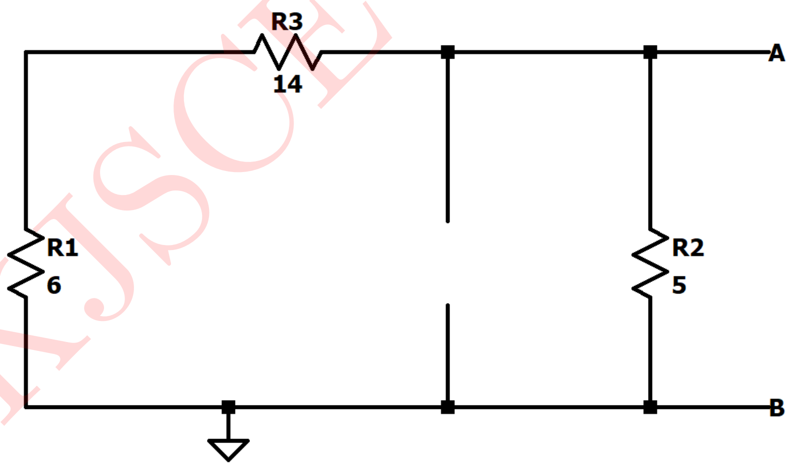

Figure 46: Modified Circuit 10a to find R_{Th}

$$R_{Th} = \frac{(14+6)\times 5}{14+6+5}$$

$$R_{Th} = 4\Omega$$

Finding V_{Th},

Applying Source Transformation,

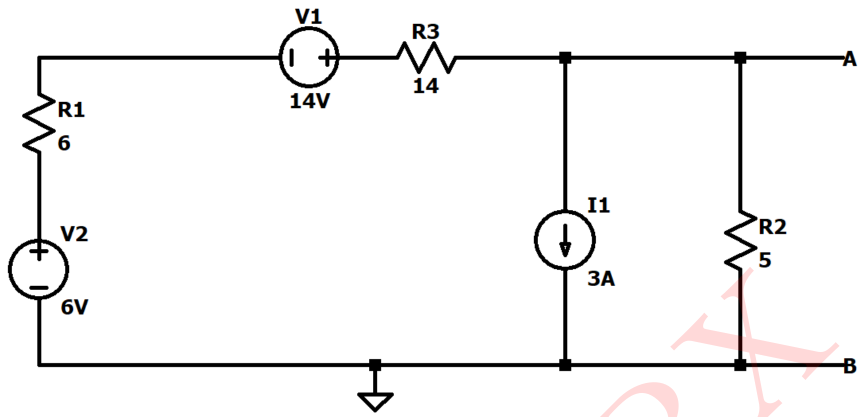

Figure 47: Modified Circuit 10b to find V_{Th}

Applying Nodal Analysis,

$$\frac{V_A - 14 - 6}{14 + 6} + 3 + \frac{V_A}{5} = 0$$

$$\frac{V_A - 20}{20} + \frac{V_A}{5} = -3$$

$V_A = -8V$

$\therefore V_{Th} = -8V$

Thevenin's Equivalent Circuit,

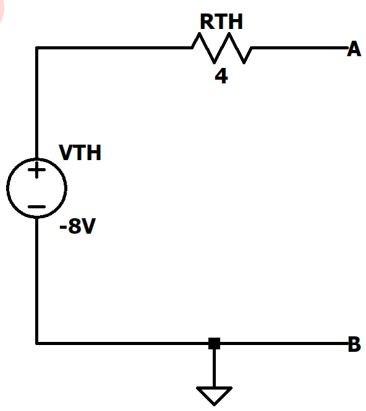

Figure 48: Thevenin's Equivalent Circuit

$$I_N = \frac{V_{Th}}{R_{Th}} = \frac{-8}{4}$$
$$\therefore I_N = -2A$$

Norton's Equivalent Circuit,

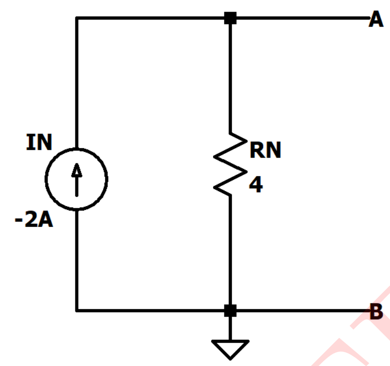

Figure 49: Norton's Equivalent Circuit

SIMULATED RESULTS

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

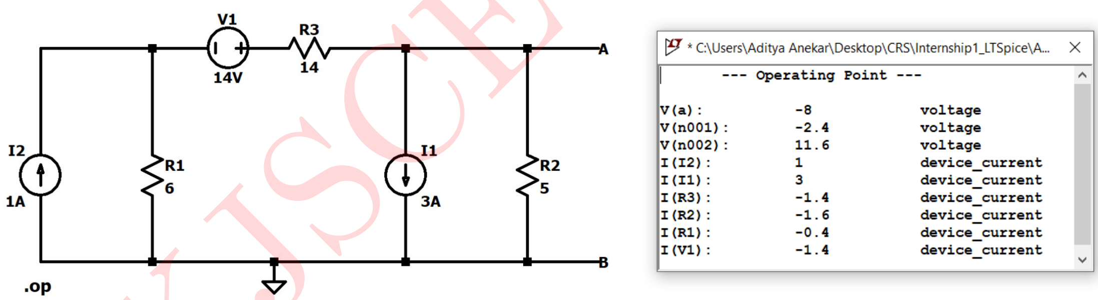

Figure 50: Circuit Schematic and Simulated Results

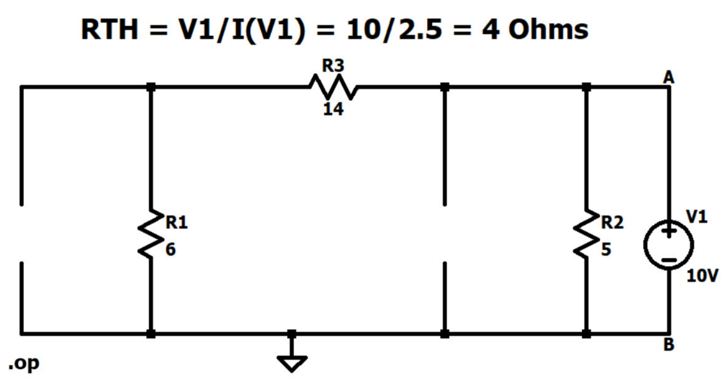

Figure 51: Finding R_{Th} by simulation

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_{Th}	$-8V$	$-8V$
I_N	$-2A$	$-2A$
R_{Th}	4Ω	4Ω

Table 10: Numerical 9

Numerical 10: Find the maximum power in R_L which is variable in the circuit shown below in Figure 52.

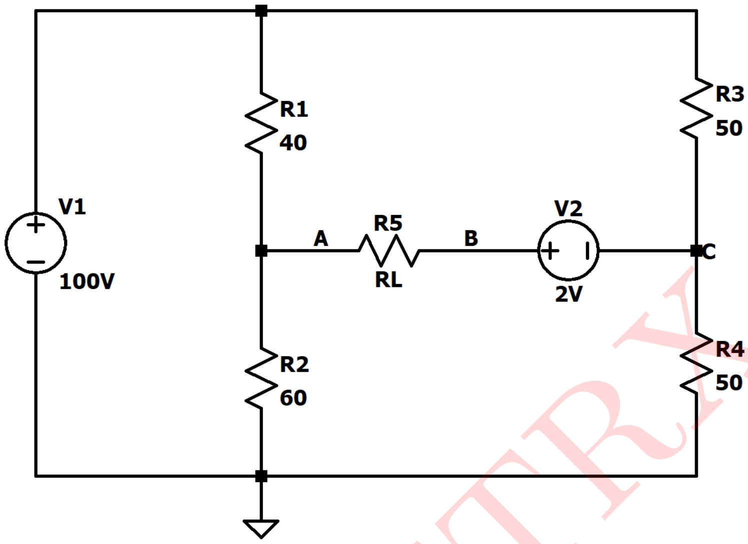

Figure 52: Circuit 11

Solution:

Finding R_{Th},

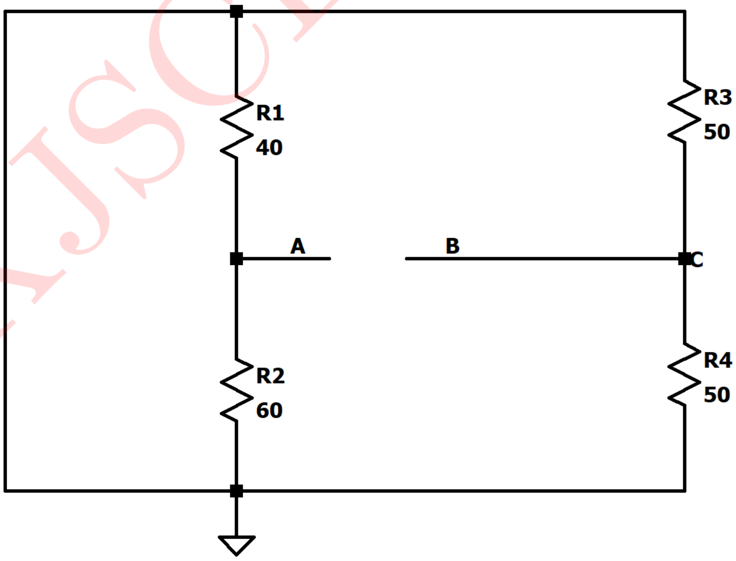

Figure 53: Modified Circuit 11a for finding R_{Th}

$$R_{Th} = \frac{40 \times 60}{40 + 60} + \frac{50 \times 50}{50 + 50}$$

$$R_{Th} = 49\Omega$$

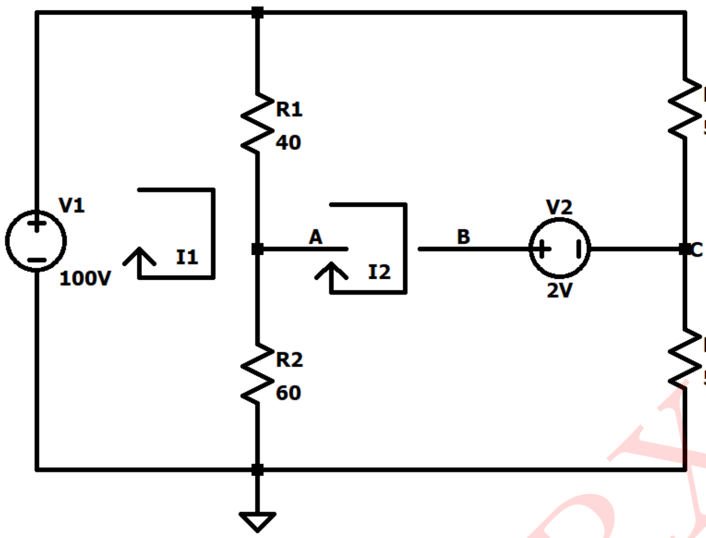

Figure 54: Considering Loops 1 and 2 in Circuit 11

Finding V_{Th},

Applying Kirchhoff's Voltage Law (KVL) to Loop 1,

$100 - 40(I_1 - I_2) - 60(I_1 - I_2) = 0$

$100 - 100(I_1 - I_2) = 0$

$I_1 - I_2 = 1$ ....(1)

Applying Kirchhoff's Voltage Law (KVL) to Loop 2,

$100(I_2 - I_1) + 50I_2 + 50I_2 = 0$

$200I_2 - 100I_1 = 0$

$I_1 = 2I_2$ ....(2)

From (1) and (2),

$I_1 = 2A$

$I_2 = 1A$

$V_A = 100 - 40(I_1 - I_2) = 100 - (40 \times 1)$

$\therefore V_A = 60V$

$V_B = 50(I_2) + 2 = (50 \times 1) + 2$

$\therefore V_B = 52V$

$V_{Th} = V_A - V_B = 60 - 52$

$\therefore V_{Th} = 8V$

Thevenin's Equivalent Circuit

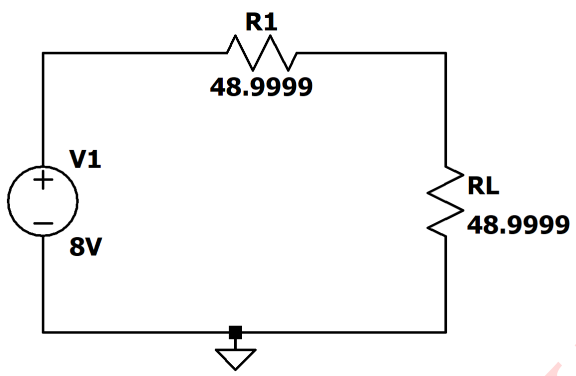

Figure 55: Thevenin's Equivalent Circuit

For Maximum Power Transfer,

$R_L = R_{Th} = 49\Omega$

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

$$P_{Max} = \frac{8^2}{4 \times 49}$$

$\therefore \text{P}_{Max} = 326.5306mW$

SIMULATED RESULTS

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

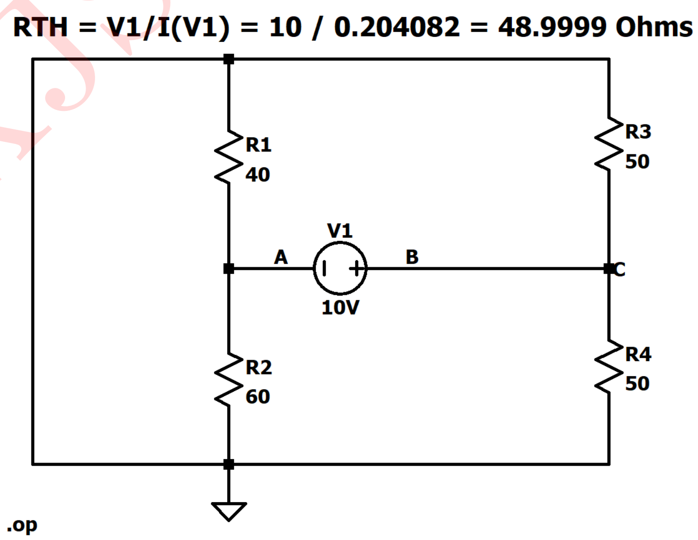

Figure 56: Modified Circuit 11b for finding R_{Th} by simulation

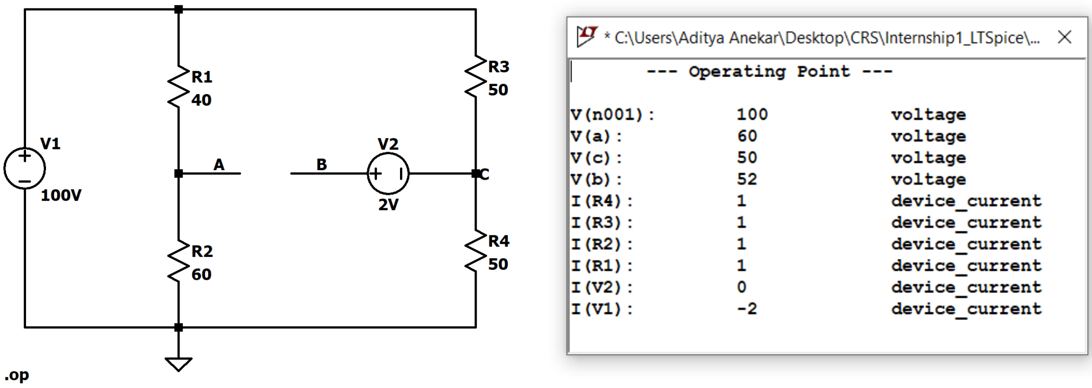

Figure 57: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
R_{Th}	49Ω	48.9999Ω
V_{Th}	8V	8V
P_{Max}	326.5306mW	326.53mW

Table 11: Numerical 10

Numerical 11: From Figure 58, find the value of R_L for Maximum Power transfer and calculate the Maximum Power.

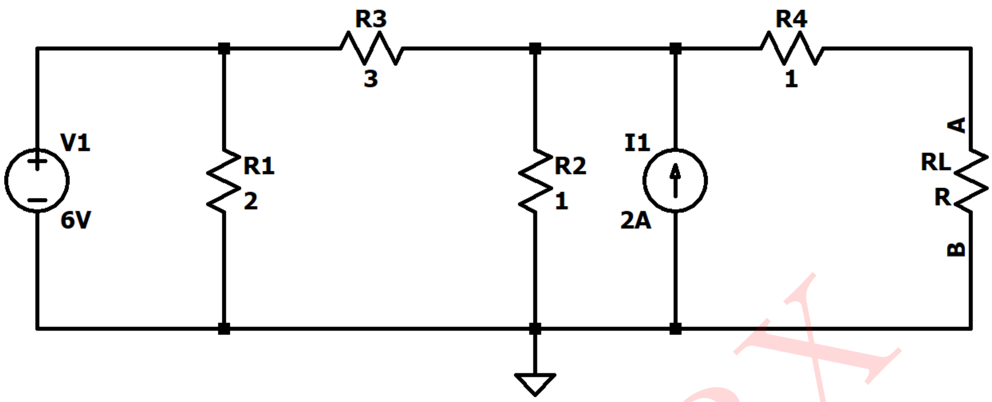

Figure 58: Circuit 12

Solution:

Considering Loops 1, 2 and 3,

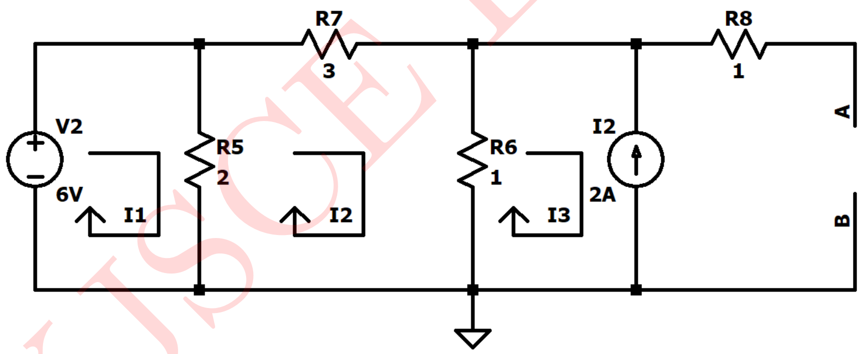

Figure 59: Loops 1, 2 and 3 in Circuit 12

Applying Kirchhoff's Voltage Law (KVL) to Loop 1,

$6 - 2(I_1 - I_2) = 0$

$I_1 - I_2 = 3$ ....(1)

Applying Kirchhoff's Voltage Law (KVL) to Loop 2,

$-2(I_2 - I_1) - 3I_2 - 1(I_2 - I_3) = 0$

$-6I_2 + 2I_1 + I_3 = 0$ ....(2)

From Loop 3,

$I_3 = -2A$ ....(3)

From (1), (2) and (3),

$I_1 = 4A$

$I_2 = 1A$

$I_3 = -2A$

Hence by Ohm's Law,

$V_{Th} = 1 \times (1 - (-2))$

$V_{Th} = 3V$

For finding R_{Th},

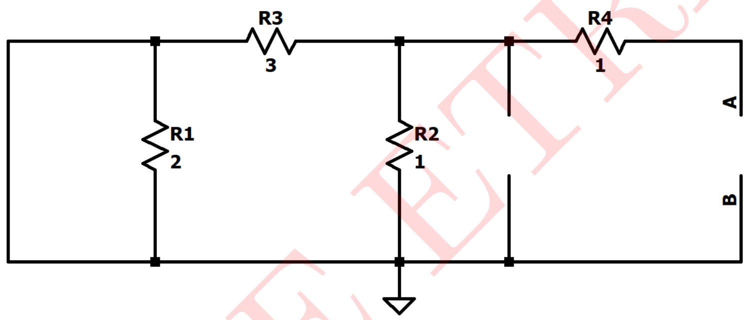

Figure 60: Modified Circuit 12a for finding R_{Th}

$R_{Th} = \dfrac{3 \times 1}{3 + 1} + 1$

$R_{Th} = 1.75\Omega$

Thevenin's Equivalent Circuit

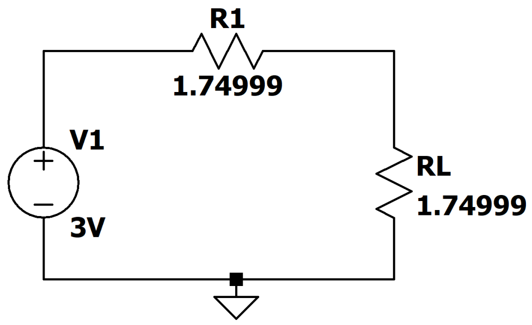

Figure 61: Thevenin's Equivalent Circuit

For Maximum Power Transfer,

$R_L = R_{Th} = 1.75\Omega$

$P_{Max} = \dfrac{{V_{Th}}^2}{4 \times R_{Th}} = \dfrac{3^2}{4 \times 1.75}$

$\therefore \mathrm{P}_{Max} = 1.2857W$

SIMULATED RESULTS

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

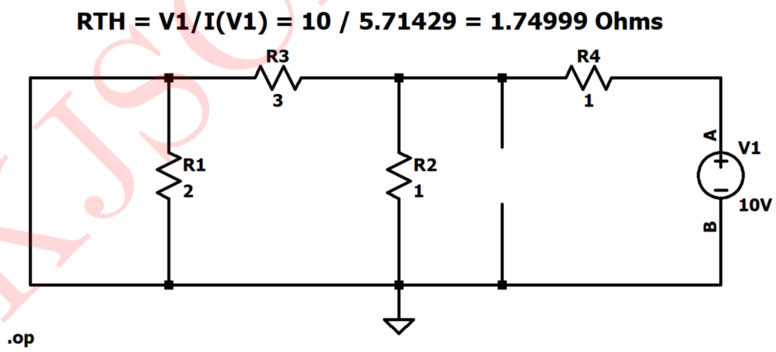

Figure 62: Modified Circuit 12b for finding R_{Th} by simulation

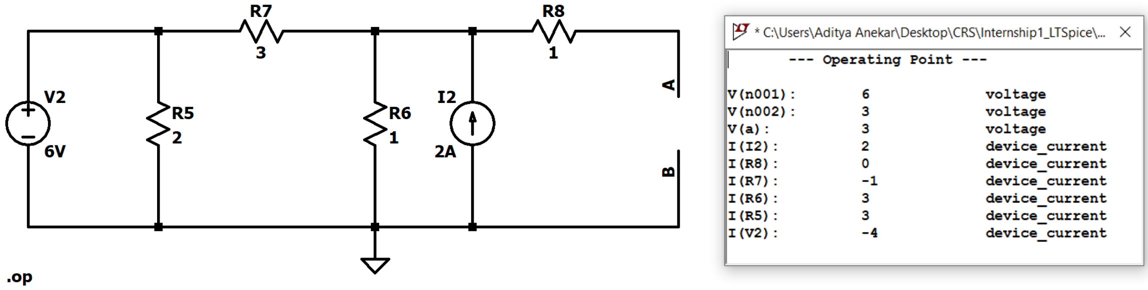

Figure 63: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
R_{Th}	1.75Ω	1.74999Ω
V_{Th}	3V	3V
P_{Max}	1.2857W	1.285W

Table 12: Numerical 11

****