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

Numerical 1: Compute the value of battery current I in the Figure 1:
All resistances are in ohms.

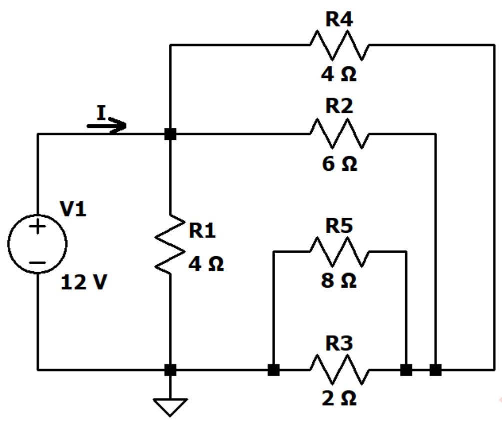

Figure 1: Circuit 1

Solution:

The given circuit can be reduced as:

The 4 Ω resistor and the 6 Ω resistor are connected in parallel.

The 8 Ω resistor and the 2 Ω resistor also are connected in parallel.

($8\Omega \;||\; 2\Omega = 2.4\Omega$ and $6\Omega \;||\; 4\Omega = 1.6\Omega$)

The circuit will be reduced to:

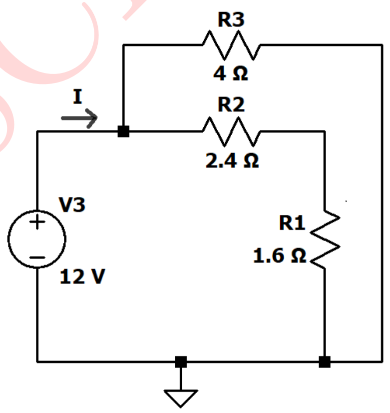

Figure 2: Modified Circuit for Figure 1

Now, the 2.4 Ω and 1.6 Ω resistors are in series.

$(2.4 + 1.6)\ \Omega\ = 4\Omega$

So, the circuit is reduced to:

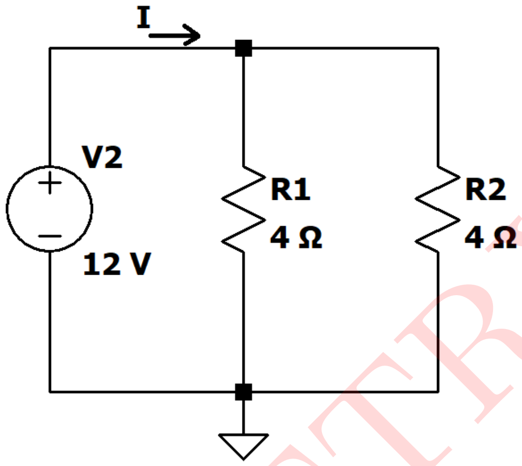

Figure 3: Modified Circuit for Figure 2

The two 4 Ω resistors form a parallel combination.

$(4 \mid\mid 4)\Omega\ = 2\ \Omega$

The circuit is further reduced to:

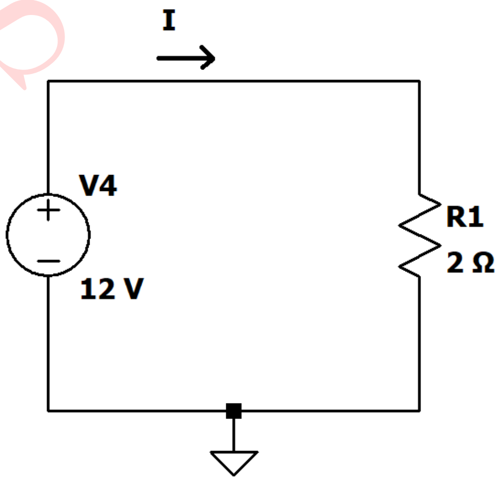

Figure 4: Modified Circuit for Figure 3

Applying Ohm's Law to the circuit,

$I = \dfrac{V}{R}\ = \dfrac{12}{2}\ = 6A$

The value of the battery current in the circuit is 6A

SIMULATED RESULTS:

Given circuit is simulated in LTspice. The results are presented below:

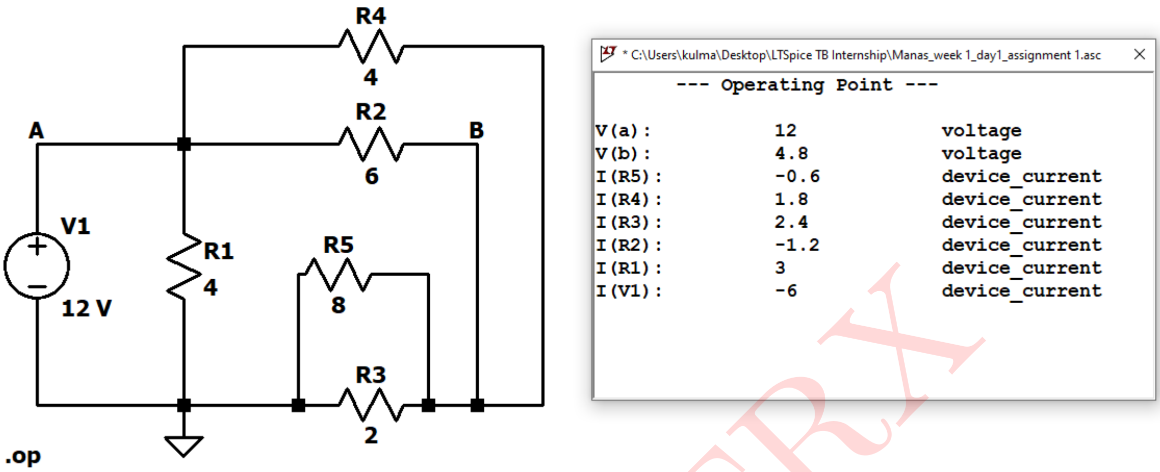

Figure 5: Circuit Schematic and Simulated Results

Comparison of calculated and simulated values:

Parameters	Theoretical Values	Simulated Values
Current (I)	$6A$	$6A$

Table 1: Numerical 1

Numerical 2: In the circuit of Figure 6, find the value of supply voltage V_1 so that 20 Ω resistor can dissipate 180 W.

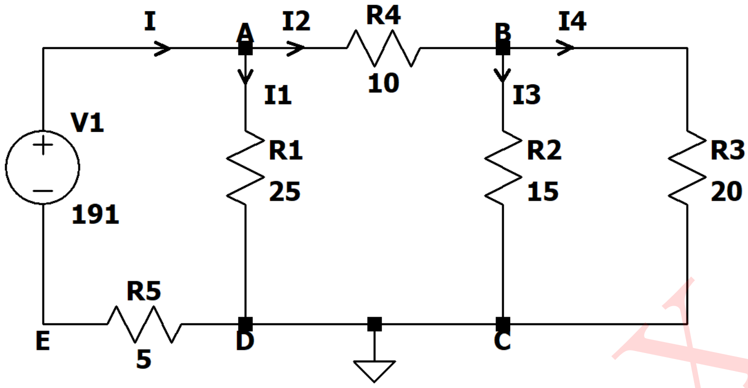

Figure 6: Circuit 2

Solution:

$I_4{}^2 \times\ 20 = 180W$
$I_4 = 3\ A$

Since 15 Ω and 20 Ω are in parallel,
$I_3 \times 15 = 3 \times 20$
$\therefore I_3 = 4\ A$
$I_2 = I_3 + I_4 = 4 + 3 = 7A$

Now, resistance of the circuit to the right of point A is

$$= 10 + \frac{15 \times 20}{35} = \frac{130}{7}\ \Omega$$

$$\therefore \mathrm{I}_1 \times 25 = 7 \times \frac{130}{7}$$

$$\therefore \mathrm{I}_1 = \frac{26}{5} A = 5.2A$$

$$\therefore \mathrm{I} = \mathrm{I}_1 + I_2 = 5.2 + 7 = 12.2A$$

Total circuit resistance $(R_{AE}) = (5\ +\ 25) \mid\mid \dfrac{130}{7} = \dfrac{955}{61}\ \Omega$

$\mathrm{V} = \mathrm{I} \times R_{AE} = 12.2 \times \dfrac{955}{61} = \mathbf{191V}$

The value of the supply voltage is 191V

SIMULATED RESULTS:

The given circuit is simulated in LT Spice. The results are presented below:

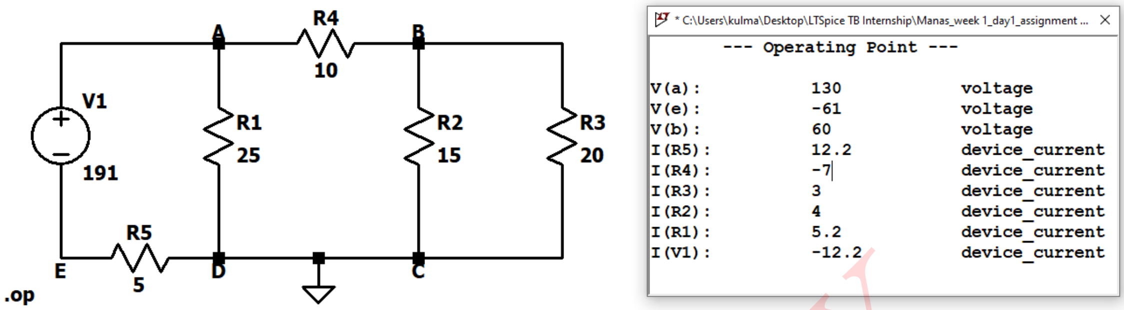

Figure 7: Circuit Schematic and Simulated Results

Comparison of calculated and simulated values:

Parameters	Calculated Values	Simulated Values
I	$12.2A$	$12.2A$
I_1	$5.2A$	$5.2A$
I_2	$7A$	$7A$
I_3	$4A$	$4A$
I_4	$3A$	$3A$
Supply Voltage (V)	$191V$	$191V$

Table 2: Numerical 2

Numerical 3: Find V_0 and the power absorbed by each element in Circuit 3.

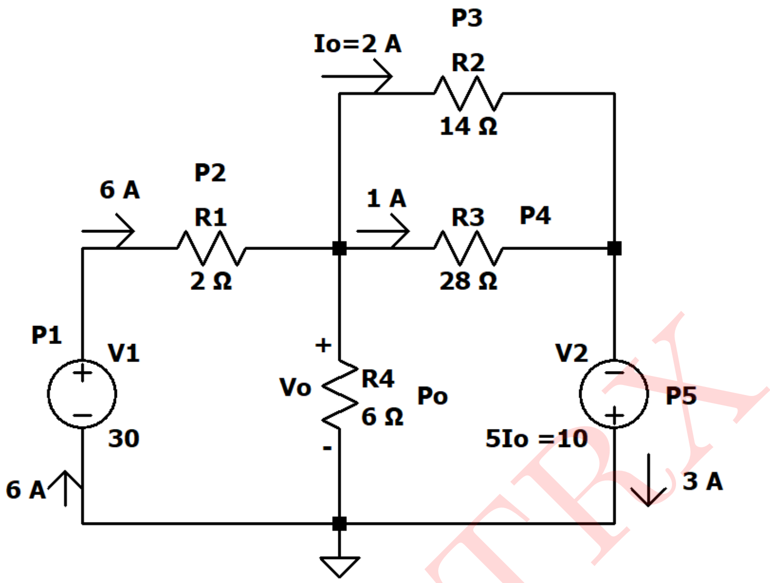

Figure 8: Circuit 3

Solution:

We consider all the elements to be resistors.

Let the power absorbed/dissipated by the elements be $P_1,\ P_2,\ P_3,\ P_4,\ P_5,\ P_0$ respectively.

Power across any element is given by the formula $P = V \times I$

$\therefore P_1 = 30 \times -6 = -180W$
$\therefore P_2 = 12 \times 6 = 72W$
$\therefore P_3 = 28 \times 2 = 56W$
$\therefore P_4 = 28 \times 1 = 28W$
$\therefore P_5 = (5 \times 2) \times -3 = -30W$

We know that, the total of the values of power absorbed/dissipated by all the elements must be equal to zero. i.e $P_{Total} \ = 0$

But, $P_{Total} = P_1 + P_2 + P_3 + P_4 + P_5 + P_0$

$\therefore \mathrm{P}_0 = -180 + 72 + 56 + 28 - 30$
$\therefore \mathrm{P}_0 = 54W$

We know that, $P = V \times I$
$\therefore \mathrm{P}_0 = V_0 \times 3$

$\therefore \mathbf{V}_0 = \mathbf{18V}$

SIMULATED RESULTS:

Given circuit is simulated in LTspice. The results are presented below:

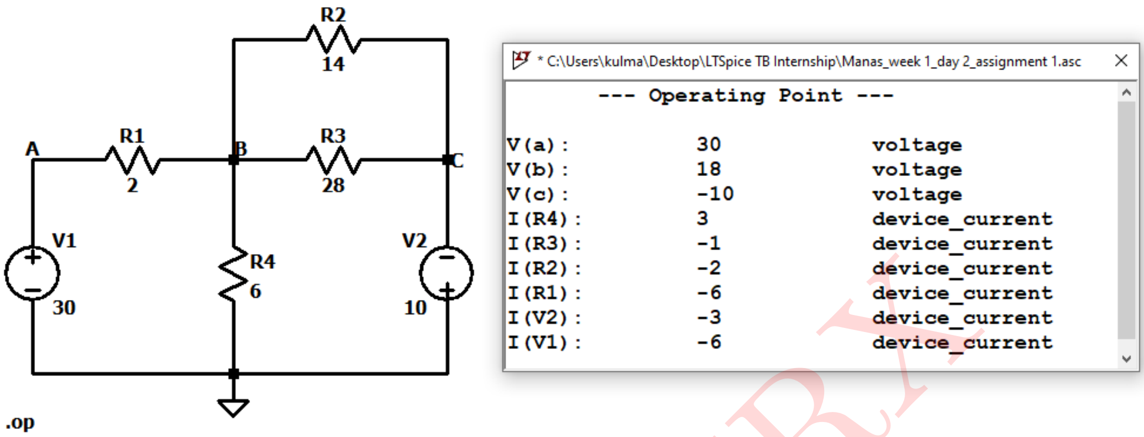

Figure 9: Circuit Schematic and Simulated Results

Comparison of given and simulated values:

Parameters	Calculated Value	Simulated Value
P_1	$-180W$	$-180W$
P_2	$72W$	$72W$
P_3	$56W$	$56W$
P_4	$28W$	$28W$
P_5	$-30W$	$-30W$
P_0	$54W$	$54W$
V_0	$18V$	$18V$

Table 3: Numerical 3

Numerical 4: For the Circuit 4, find the branch currents and using mesh analysis.

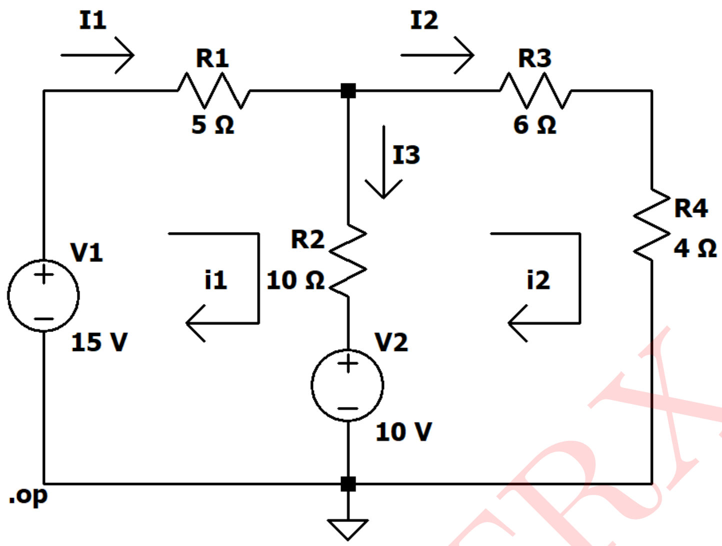

Figure 10: Circuit 4

Solution:

We first obtain the mesh currents using K.V.L

Applying K.V.L to mesh 1,

$-15 + 5i_1 + 10(i_1 - i_2) + 10 = 0$
$\therefore 3\text{i}_1 + 2i_2 = 1$ .... (1)

Applying K.V.L to mesh 2,

$6i_2 + 4i_2 + 10(i_2 - i_1) - 10 = 0$
$\therefore \text{i}_1 = 2i_2 - 1$ .... (2)

Substituting the value of i_1 from equation (2) to equation (1), we get

$6i_2 - 3 - 2i_2 = 1$
$\therefore \text{i}_2 = 1\ A$
$\therefore \text{i}_1 = 2i_2 - 1 = 2 - 1 = 1\ A$
$\therefore \text{i}_1 = 1\ A$

$I_1 = i_1 = 1A, I_2 = i_2 = 1A, I_3 = i_1 - i_2 = 0A$

The three branch currents I_1, I_2 and I_3 are 1A, 1A and 0A respectively.

SIMULATED RESULTS:

The given circuit is simulated in LT Spice. The results are presented below:

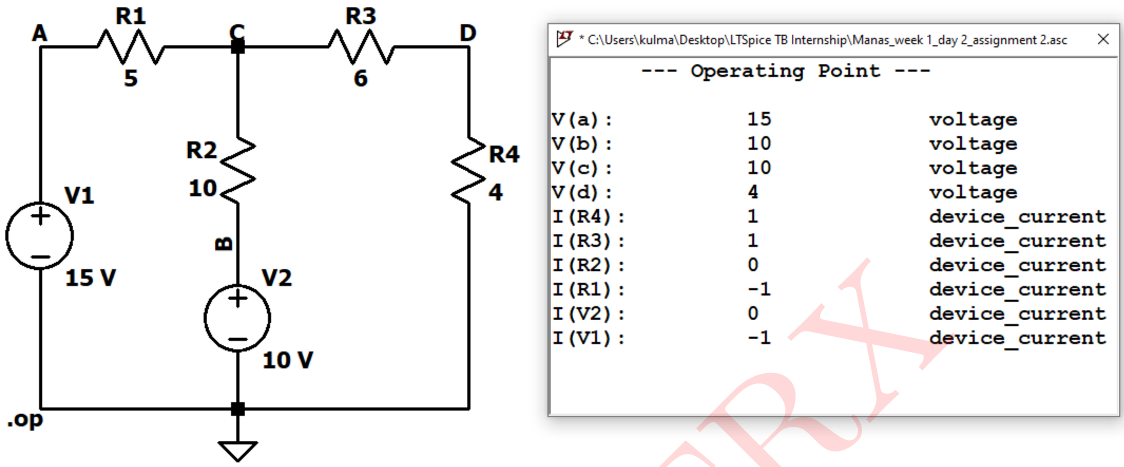

Figure 11: Circuit Schematic and Simulated Results

Comparison of calculated and simulated values:

Parameters	Calculated Values	Simulated Values
I_1	$1A$	$1A$
I_2	$1A$	$1A$
I_3	$0A$	$0A$

Table 4: Numerical 4

Numerical 5: Apply Superposition theorem to the circuit of Figure 12 for finding the voltage drop V across the 5Ω resistor.

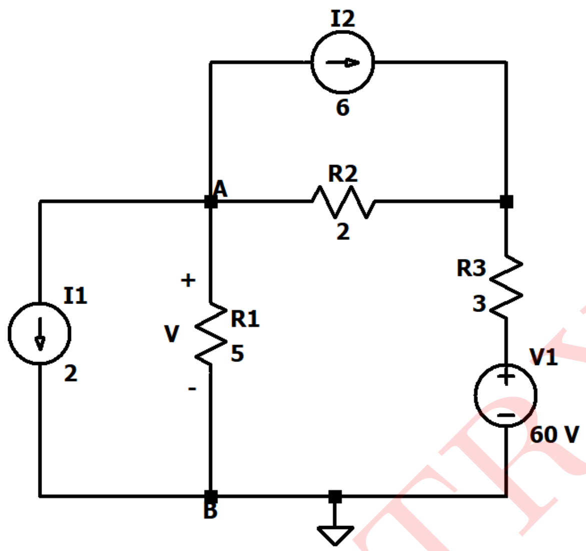

Figure 12: Circuit 5

Solution:

CASE I:
Figure 13 shows the redrawn circuit with the voltage source acting alone while the two current sources have been replaced by open circuits.

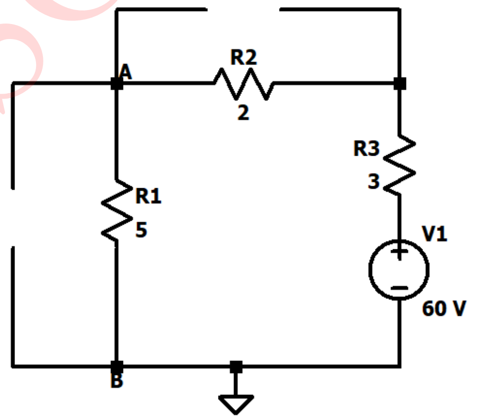

Figure 13: Modified Circuit when 60V source is active

Using voltage-divider principle, we get

$$V_1 = 60 \times \frac{5}{(5+2+3)} = 30V$$

It would be taken as positive, because current through the 5Ω resistances flows from A to B, thereby making the upper end of the resistor positive and the lower end negative.

$\therefore V_1 = 30V$

CASE II:

Figure 14 shows the same circuit with the 6A source acting alone while the two other sources have been replaced by open or short circuit respectively. It will be seen that 6A source has to parallel circuits across it, one having a resistance of 2Ω and the other $(3 + 5) = 8\Omega$.

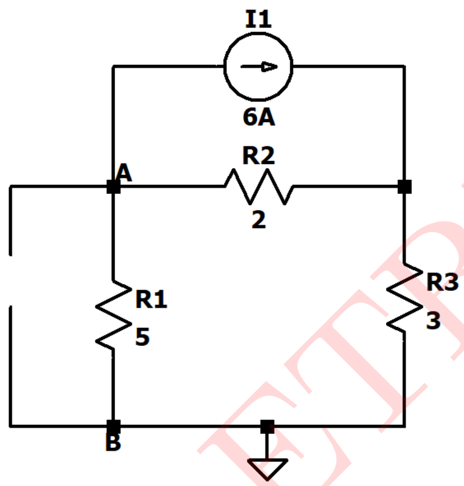

Figure 14: Modified Circuit when 6A source is active

Using the current-divider rule,

The current through the 5Ω resistor $= 6 \times \dfrac{2}{(2+3+5)} = 1.2A$

$\therefore$ $V_2 = 1.2 \times 5 = 6V$

It would be taken negative because current is flowing from B to A. i.e.point B is at a higher potential as compared to point A.

$\therefore V_2 = -6V$

CASE III:

Figure 15 shows the case when 2A source acts alone, while the other two sources are dead.As seen, this current divides equally at point B, because the two parallel paths have equal resistances of 5Ω each.

So, the circuit is reduced to:

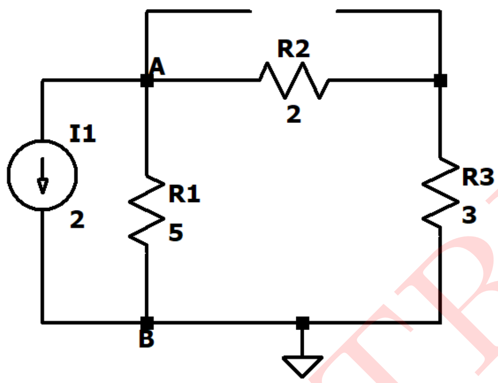

Figure 15: Modified Circuit when 2A source is active

Hence, $V_3 = 5 \times 1 = 5V$
It would be taken as negative because current flows from B to A.

Hence, $V_3 = -5V$

Using Superposition principle, we get

$V = V_1 + V_2 + V_3 = 30 - 6 - 5 = 19V$

$\therefore$ $\mathbf{V = 19V}$

SIMULATED RESULTS:

Given circuit is simulated in LTspice. The results are presented below:

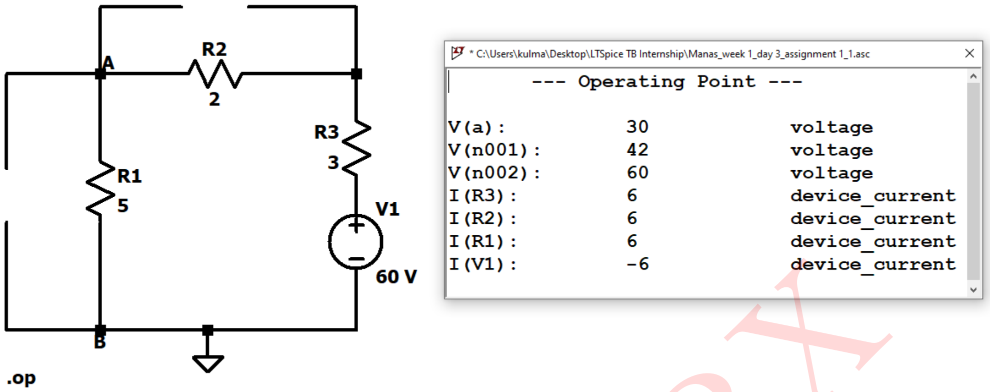

Figure 16: Circuit Schematic and Simulated Results when 60V source is active

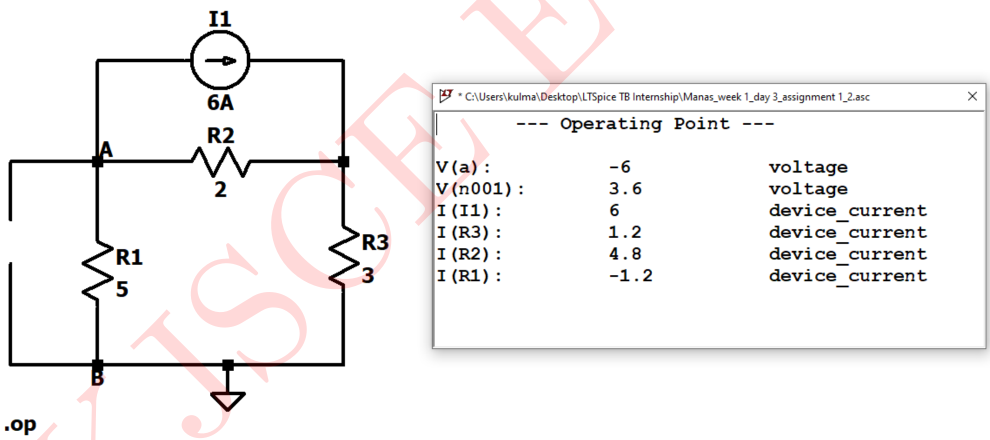

Figure 17: Circuit Schematic and Simulated Results when 6A source is active

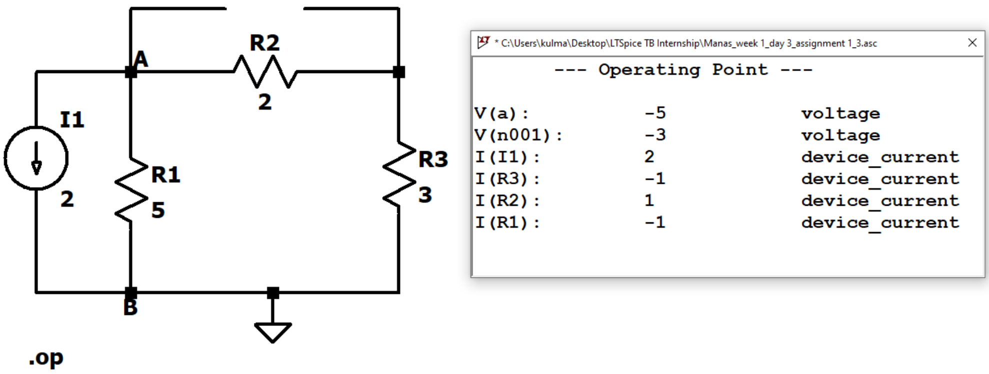

Figure 18: Circuit Schematic and Simulated Results when 2A source is active

Comparison of calculated and simulated values:

Parameters	Calculated Values	Simulated Values
V_1	$30V$	$30V$
V_2	$-6V$	$-6V$
V_3	$-5V$	$-5V$

Table 5: Numerical 5

Numerical 6 : Using Thevenin's theorem, find the equivalent circuit to the left of the terminals in the Circuit 6. Then find current I flowing through the resistor R_4.

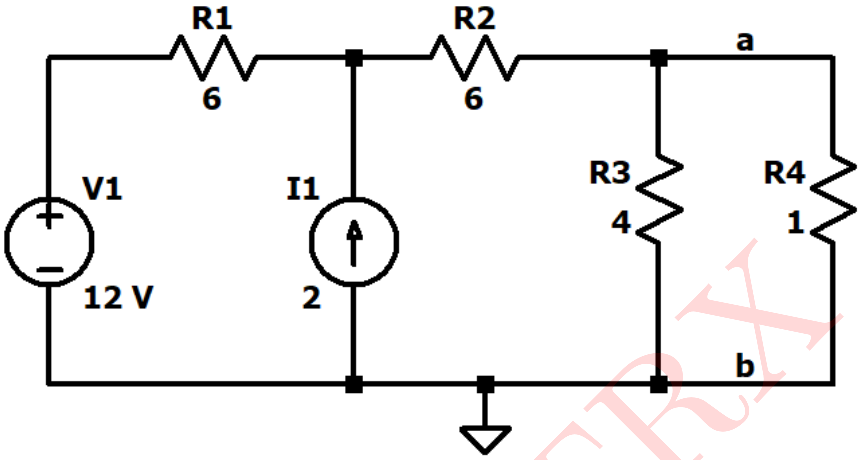

Figure 19: Circuit 6

Solution:

STEP I: Calculation of V_{TH}

To find V_{TH}, we replace the 1Ω resistor with open circuit.

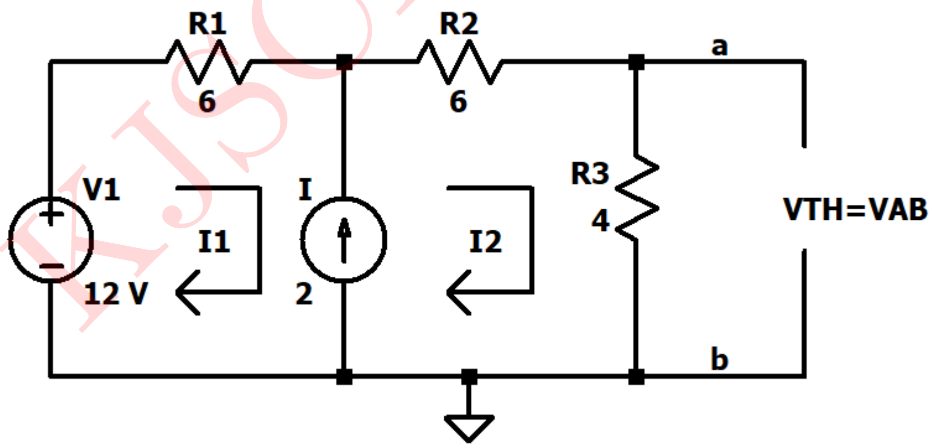

Figure 20: Modified circuit to find V_{TH}

Let I_1 and I_2 be the currents through mesh 1 and mesh 2 respectively.
The two meshes 1 and 2 form a super-mesh.

$\therefore \mathrm{I}_2 - I_1 = 2$ ... (1)

Applying KVL to the entire loop,

$+12 - 6I_1 - 6I_2 - 4I_2 = 0$

$6I_1 + 10I_2 = 0$ ... (2)

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

$\therefore$ $I_1 = -0.5A \;\; = 0.5A(\downarrow)$

Now, $V_{TH} = I_2 \times 4$

$\therefore$ $V_{TH} = 1.5 \times 4$

$\therefore$ $V_{TH} = 6V$

STEP II: Calculation of R_{TH}

To find R_{TH}, we replace the voltage source with short circuit and the current source with open circuit.

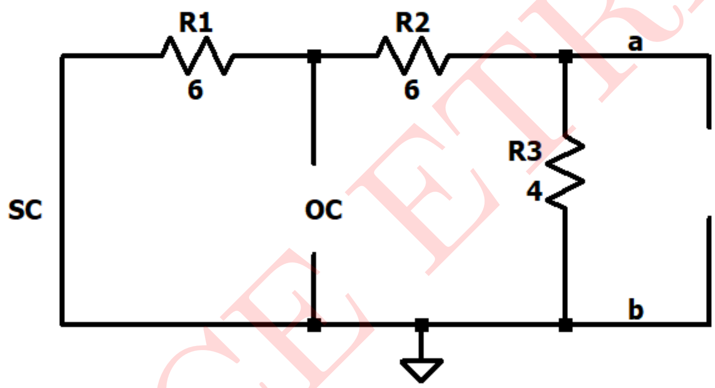

Figure 21: Modified circuit to find R_{TH}

$\therefore$ $R_{TH} = (6+6)||4$

$\therefore$ $R_{TH} = \frac{12 \times 4}{12+4}$

$\therefore$ $R_{TH} = 3\Omega$

Thevenin's Equivalent Circuit:

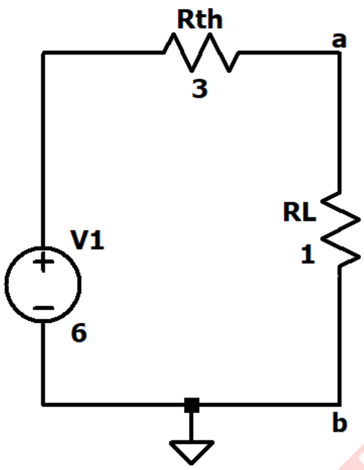

Figure 22: Thevenin's Equivalent Circuit

$$I = \frac{V_{TH}}{R_{TH} + R_L} = \frac{6}{3+1} = 1.5A$$

$\therefore$ $\mathbf{I = 1.5A}$

The value of current I is 1.5A

SIMULATED RESULTS:

The given circuit is simulated in LT Spice. The results are presented below:

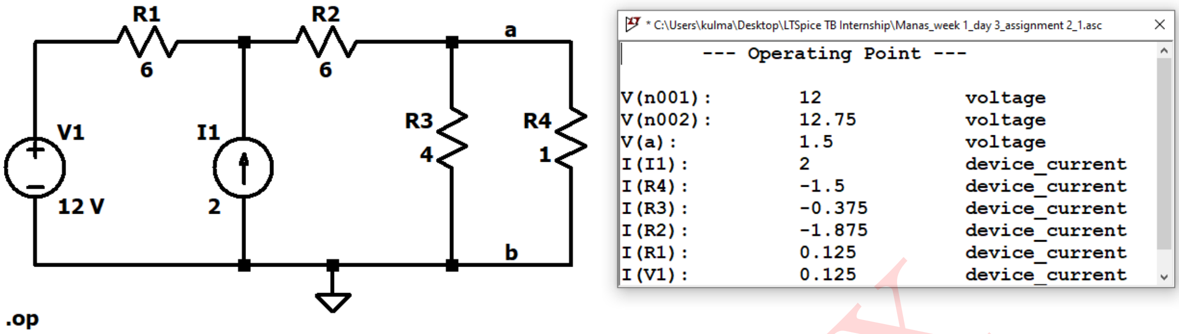

Figure 23: Circuit Schematic and Simulated Results for directly finding current I

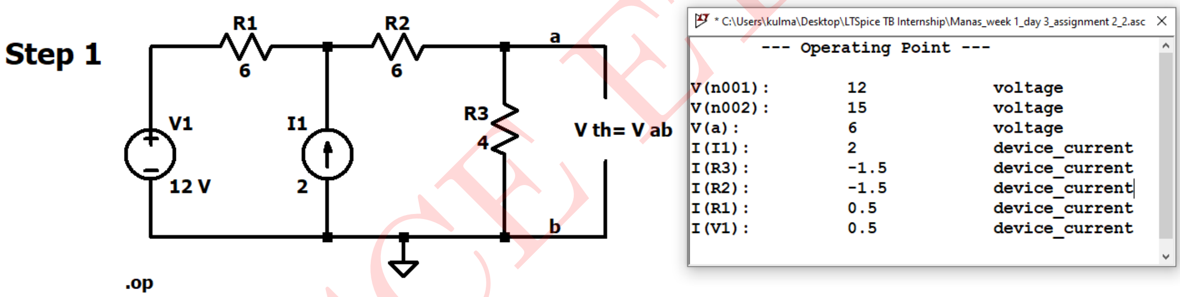

Figure 24: Circuit Schematic and Simulated Results for finding V_{TH}

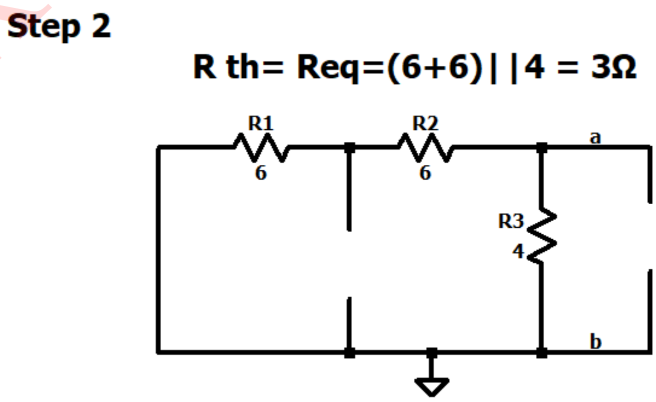

Figure 25: Circuit Schematic finding R_{TH}

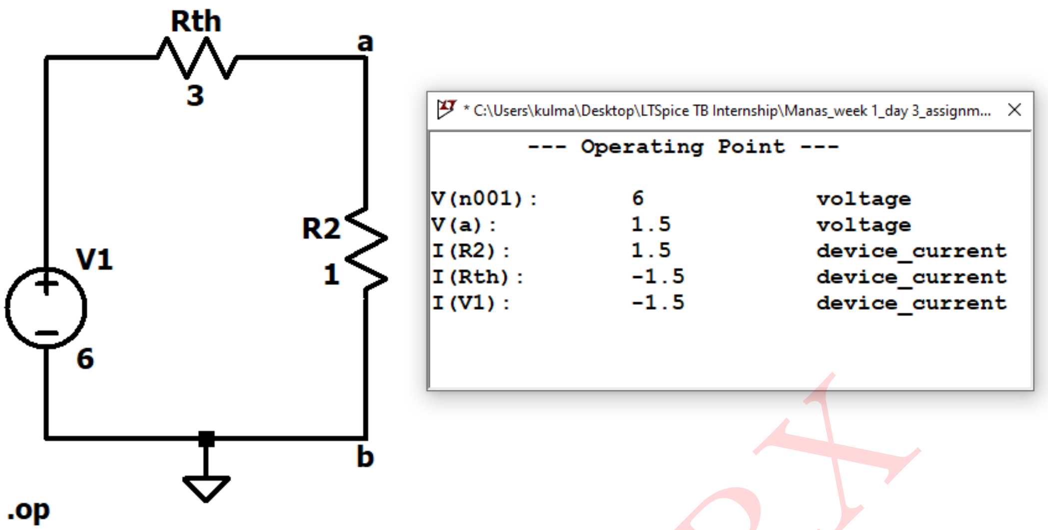

Figure 26: Circuit Schematic and Simulated Results for Thevenin's Equivalent circuit

Comparison of calculated and simulated values:

Parameters	Calculated Value	Simulated Value
V_{TH}	$6V$	$6V$
R_{TH}	3Ω	3Ω
I	$1.5A$	$1.5A$

Table 6: Numerical 6

Numerical 7: Using Norton's theorem, find the current which would flow in a 25Ω resistor connected between points N and O in Circuit 7. All resistance values are in ohms.

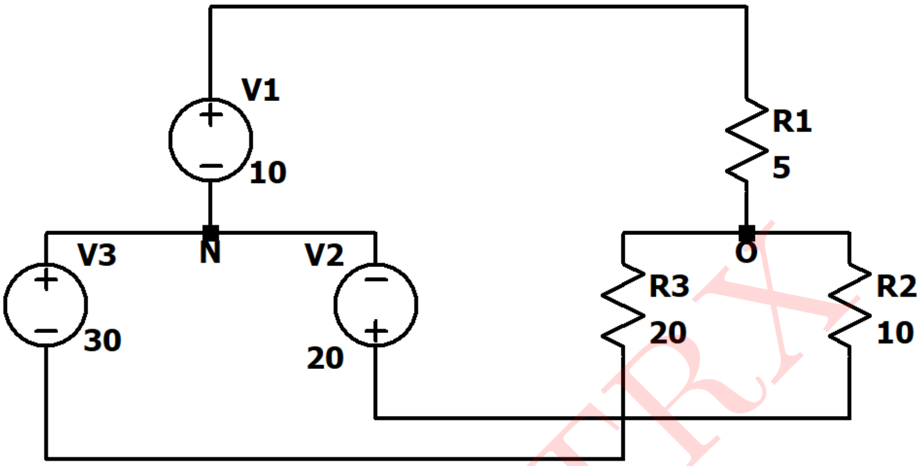

Figure 27: Circuit 7

Solution:

For case of understanding, the given circuit may be redrawn as shown in Figure 28.

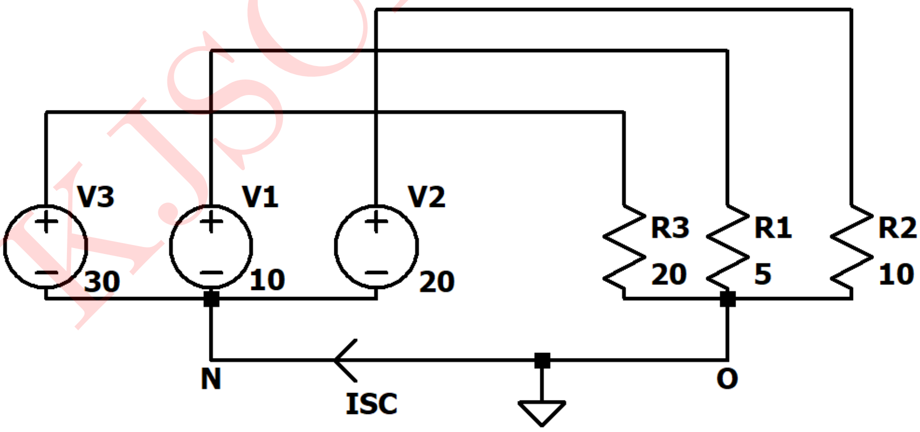

Figure 28: Modified Circuit for Figure 1

Total current in short-circuit across ON is equal to the sum of currents driven by different batteries through their respective resistances.

$I_{SC} = \frac{10}{5} + \frac{20}{10} + \frac{30}{20} = 5.5A$

The resistance R_L of the circuit when looked into from point N and O is

$\frac{1}{R_L} = \frac{1}{5} + \frac{1}{10} + \frac{1}{20} = \frac{7}{20}\Omega$

$\therefore \mathrm{R}_L = \frac{20}{7} = 2.86\Omega$

Hence, given circuit reduces to that shown in Figure 3.

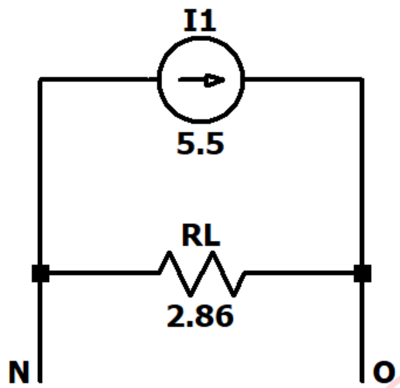

Figure 29: Modified Circuit for Figure 2

Open-circuit voltage across NO is $= I_{SC} \times R_L = 5.5 \times 2.86 = 15.73V$

Now, we connect the 25Ω resistor across N and O.

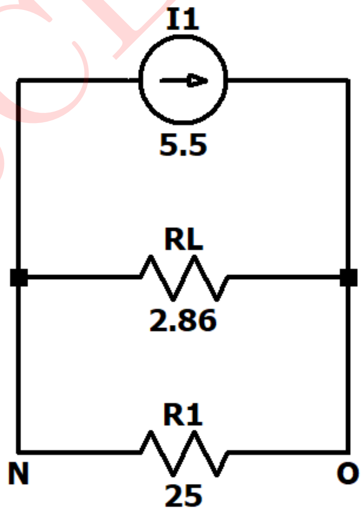

Figure 30: Modified Circuit after connecting 25Ω resistor

Hence, current through 25Ω resistor connected across NO is
$I = 5.5 \times \dfrac{2.86}{2.86 + 25} = 0.565A$

The current flowing through the 25Ω resistor is 0.565A

SIMULATED RESULTS:

Given circuit is simulated in LTspice. The results are presented below:

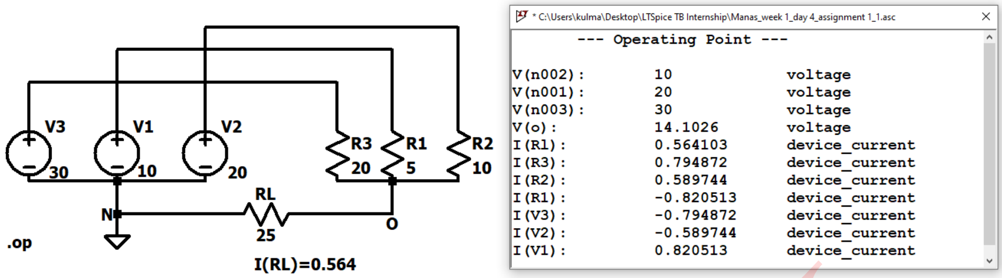

Figure 31: Circuit Schematic and Simulated Results to directly find I_{RL}

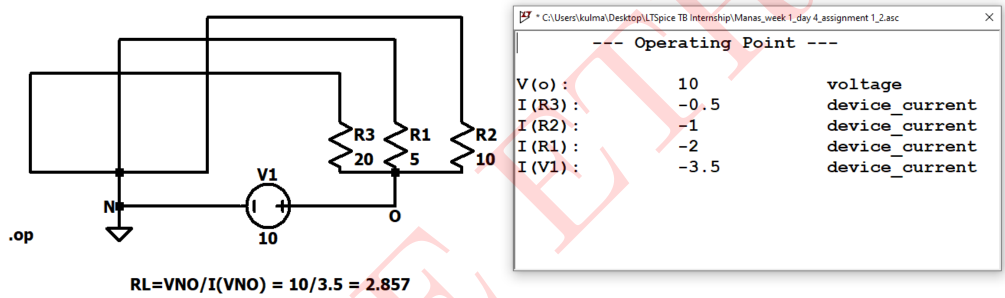

Figure 32: Circuit Schematic and Simulated Result to find R_L

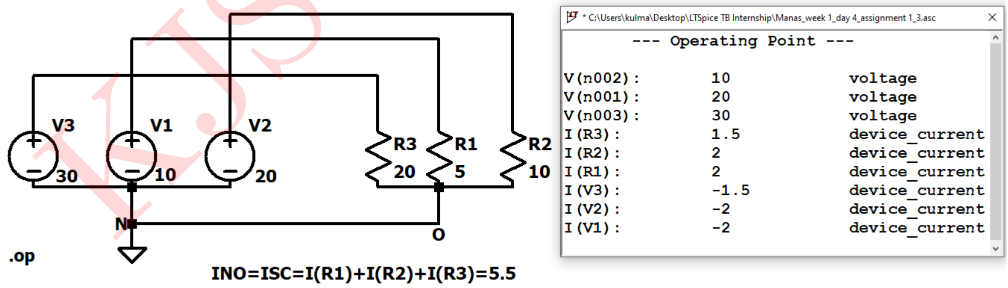

Figure 33: Circuit Schematic and Simulated Results to find I_{NO}

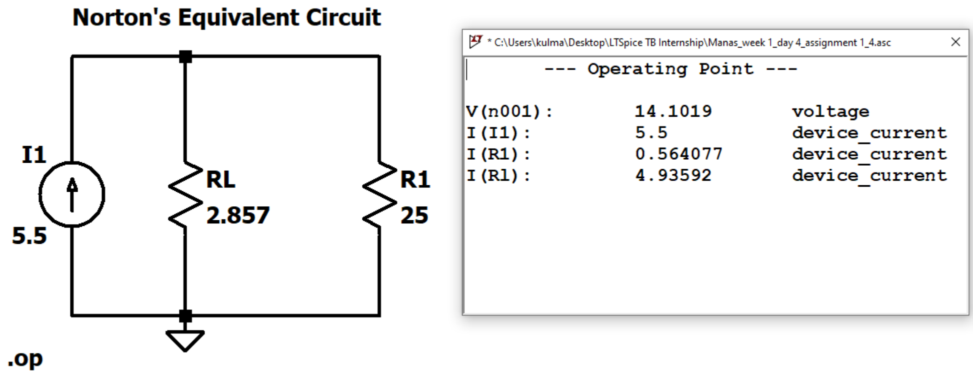

Figure 34: Circuit Schematic and Simulated Results for Norton's Equivalent Circuit

Comparison of calculated and simulated values:

Parameters	Calculated Values	Simulated Values
I_{SC}	$5.5A$	$5.5A$
R_L	2.86Ω	2.857Ω
I	$0.565A$	$0.56077A$

Table 7: Numerical 7

Numerical 8 : In the network shown in Circuit 8, determine the maximum power delivered to R_L

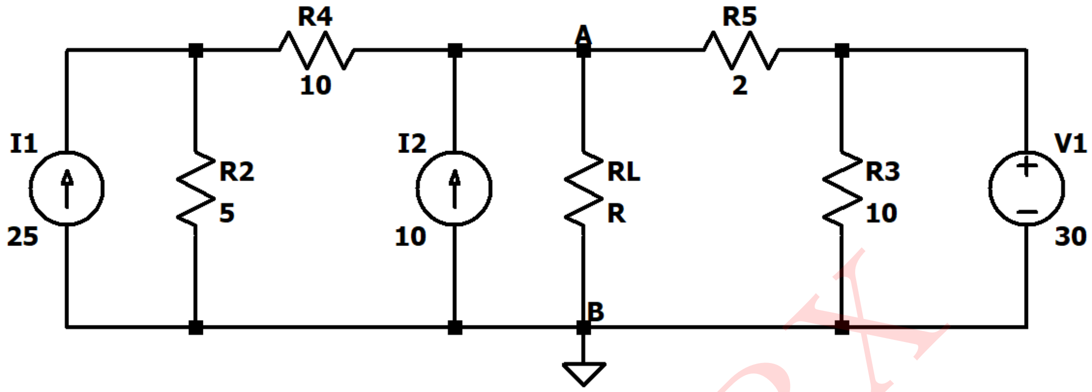

Figure 35: Circuit 8

Solution:

STEP I: Calculation of V_{TH}

To find V_{TH}, we replace R_L with open circuit.

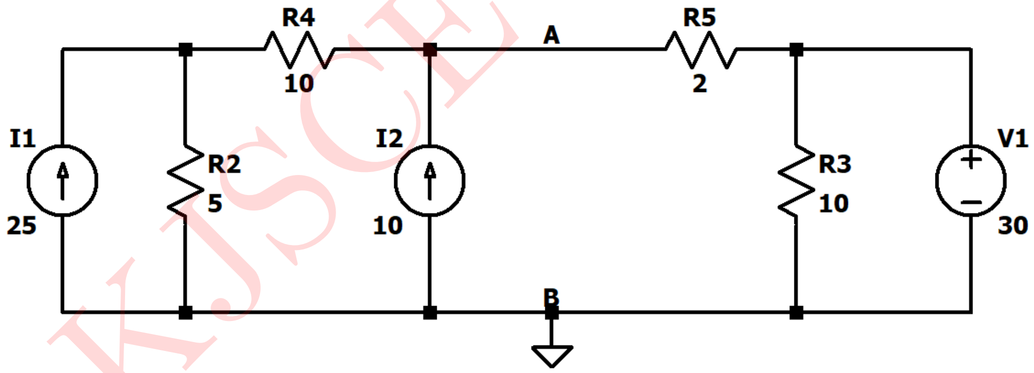

Figure 36: Modified circuit to find V_{TH}

Using source transformation, we convert the 25A source to a voltage source.
The circuit is reduced to:

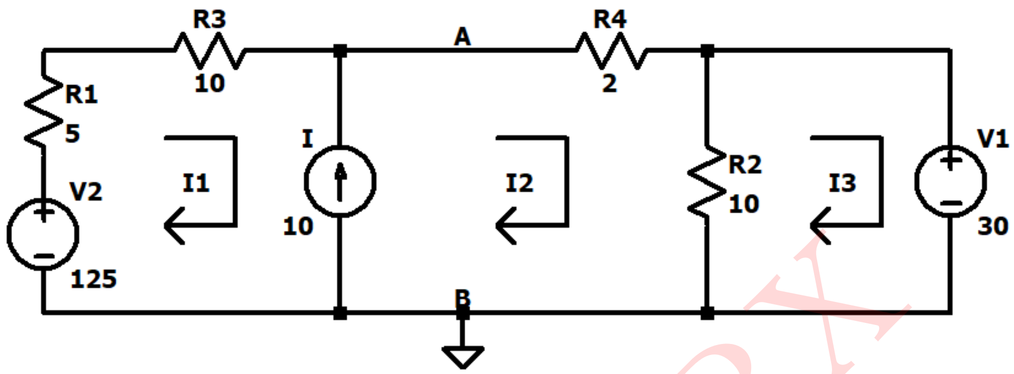

Figure 37: Simplified circuit of Figure 36

Let I_1, I_2 and I_3 be the currents through mesh 1, mesh 2 and mesh 3 respectively.
Mesh 1 and mesh 2 form a super-mesh.
Expressing the current in the common branch,we get the current equation as:

$\therefore \mathrm{I}_2 - I_1 = 10$ ... (1)

Applying KVL in the super mesh,

$-10I_1 - 2I_2 - 106(I_2 - I_3) + 125 - 5I_1 = 0$

$\therefore 15\mathrm{I}_1 + 12I_2 - 10I_3 = 125$ ... (2)

Applying K.V.L to mesh 3,

$-10(I_3 - I_2) - 30 = 0$

$\therefore 10\mathrm{I}_2 - 10I_3 = 30$ ... (3)

Solving equations (1), (2) and (3) simultaneously,

$\therefore \mathrm{I}_2 = 14.41A$

Hence, $I_{2\Omega} = 14.41A$ $(\rightarrow)$

Further, we get $V_{TH} = V_{AB}$

$\therefore \mathrm{V}_{TH} = 30 + (2 \times 14.41)$

$\therefore \mathrm{V}_{TH} = 58.82V$

STEP II: Calculation of R_{TH}

To find R_{TH}, we replace the voltage sources with short circuit and the current source with open circuit.

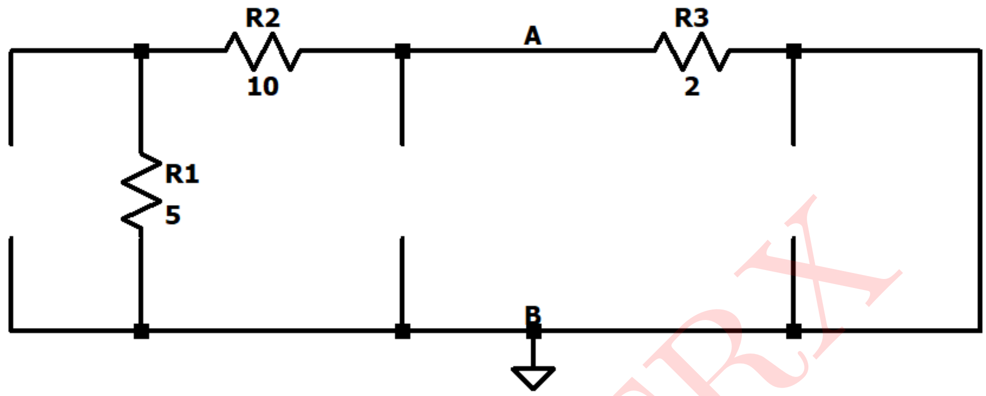

Figure 38: Modified circuit to find R_{TH}

Since the 10Ω and 5Ω resistor are in series,
$(10 + 5) = 15\Omega$

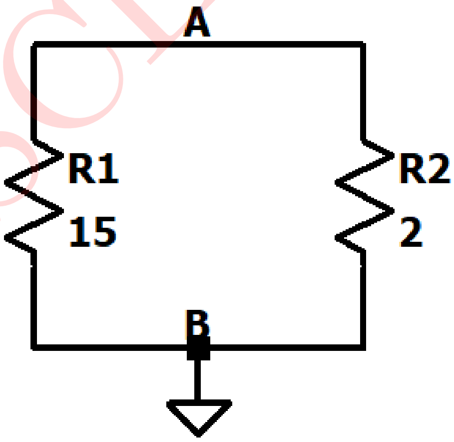

Figure 39: Simplified circuit of Figure 38

$\therefore \mathrm{R}_{TH} = (15||2)\Omega$

$\therefore \mathrm{R}_{TH} = \dfrac{15 \times 2}{15 + 2}$

$\therefore \mathrm{R}_{TH} = 1.76\Omega$

THEVENIN'S EQUIVALENT CIRCUIT:

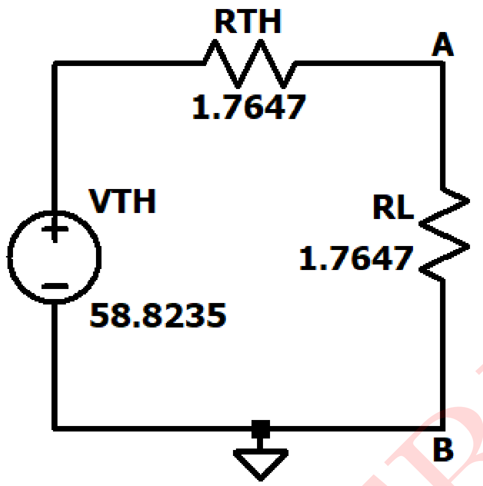

Figure 40: Thevenin's Equivalent Circuit

P_{max} can be calculated as:

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

$$\therefore \mathrm{P}_{max} = \frac{58.82^2}{4 \times 1.76}$$

$$\therefore \mathrm{P}_{max} = 491.45W$$

The maximum power transferred in the circuit through R_L is 491.45W

SIMULATED RESULTS:

The given circuit is simulated in LT Spice. The results are presented below:

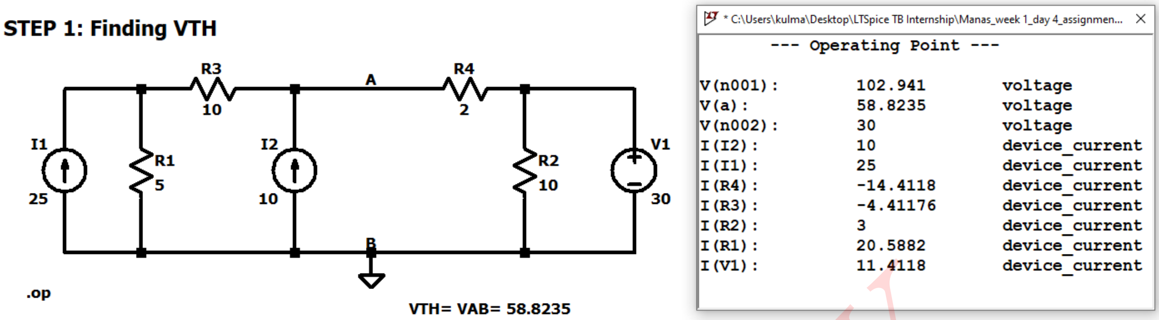

Figure 41: Circuit Schematic and Simulated Results to find V_{TH}

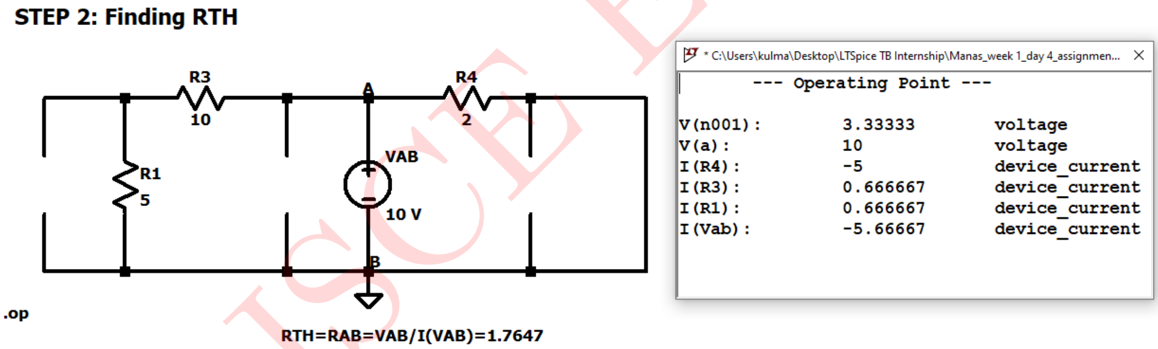

Figure 42: Circuit Schematic and Simulated Results to find R_{TH}

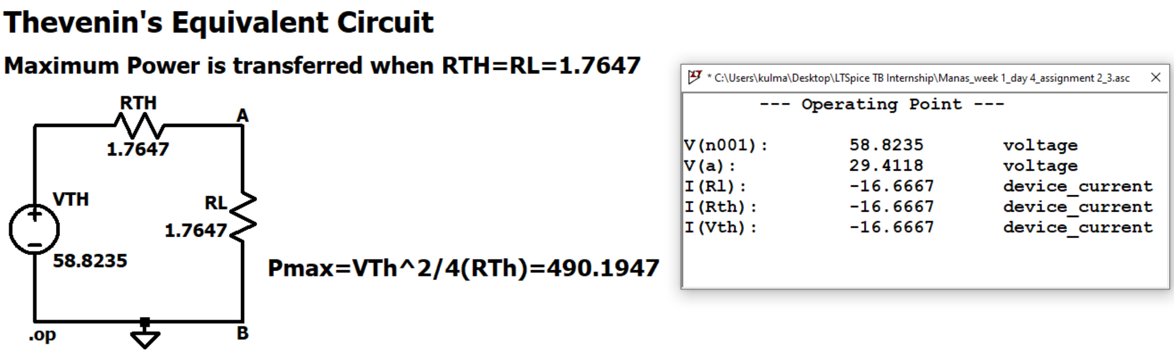

Figure 43: Circuit Schematic and Simulated Results for Thevenin's Equivalent Circuit

Comparison of calculated and simulated values:

Parameters	Calculated Value	Simulated Value
V_{TH}	$58.82V$	$58.8235V$
R_{TH}	1.76Ω	1.7647Ω
P_{max}	$491.45W$	$490.1947W$

Table 8: Numerical 8

Numerical 9: For the network given in circuit 9, determine the value of R_L for maximum power at the load. Also determine the maximum power.

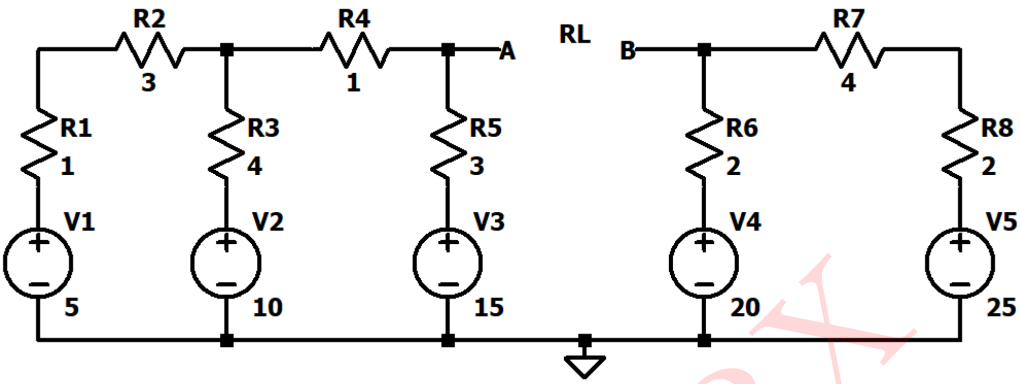

Figure 44: Circuit 9

Solution:

STEP I: Calculation of V_{TH}

In the circuit, with terminals A and B kept open, from the right hand side, V_B (w.r.t reference node 0) can be calculated V_4 and V_5 will have a net voltage of 10V circulating a current of $\left(\frac{5}{8}\right) = 0.625A$ in clockwise direction.

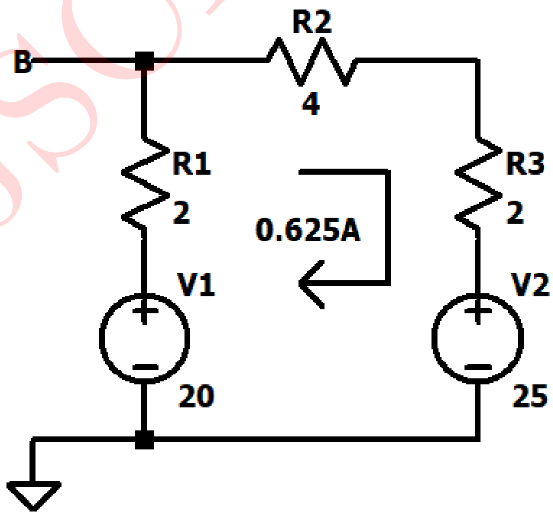

Figure 45: Modified circuit to find V_{TH}

$\therefore$ V$_B = 20 + (0.625 \times 2) = 21.25V$

On the Left-hand part of the circuit, there are two loops. V_A (w.r.t 0) has to be evaluated. Let the first loop (with V_1 and V_2 as the sources) carry a clockwise current of i_1 and the second loop (with V_2 and V_3 as the sources), a clockwise current of i_2.

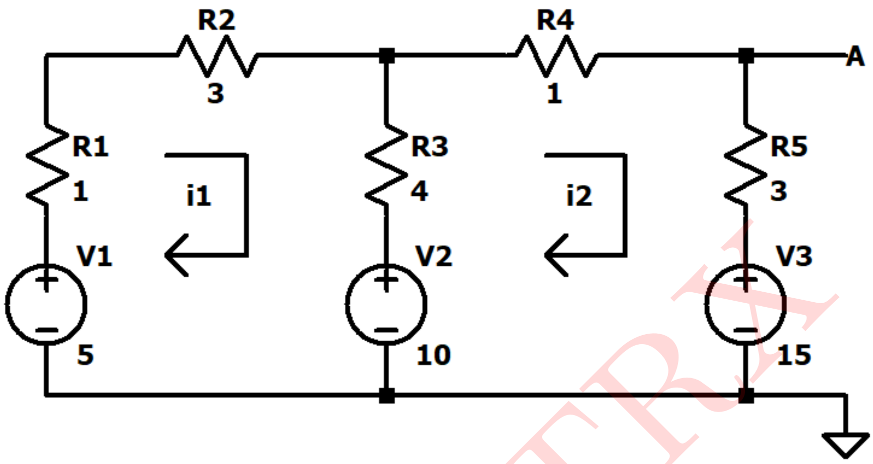

Figure 46: Simplified circuit for Figure 45

Writing the circuit equations:

$\therefore$ $8\mathrm{i}_1 - 4i_2 = -5$ ......(1)

$\therefore$ $-4\mathrm{i}_1 + 8i_2 = -5$ ......(2)

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

$i_1 = 1.25A, \ i_2 = 1.25A$

$\therefore$ $\mathrm{V}_A = 10 + (1.25 \times 1) = 11.25V$

The Thevenin's equivalent voltage can be calculated as:

$V_{TH} = V_A - V_B = 11.25 - 21.25 = -10V$

$\therefore$ $\mathrm{V}_{TH} = 10V$

STEP II: Calculation of R_{TH}

To find R_{TH}, we replace the voltage source with short circuit.

The circuit reduces to:

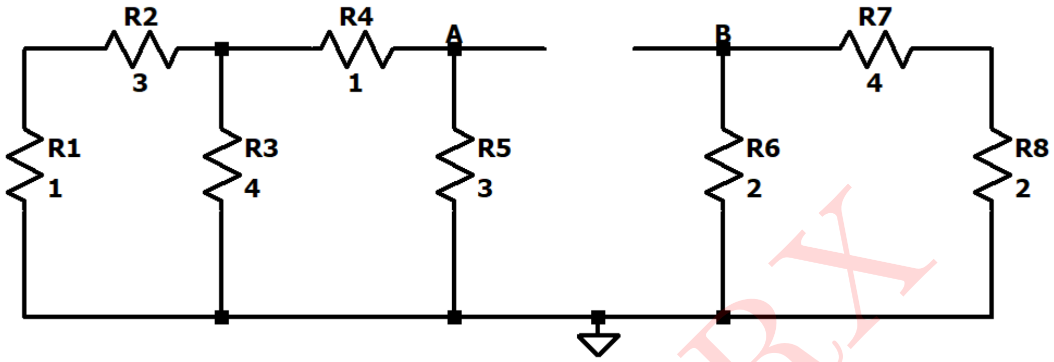

Figure 47: Modified circuit to find R_{TH}

On the left hand side, the equivalent resistance is calculated as $[\ (4||4) + 1\ ]\ ||\ 3 = 1.5\Omega$

Similarly, on the right hand side, the equivalent resistance is calculated as

$(4 + 2)||2 = 1.5\Omega$

The circuit further reduces to:

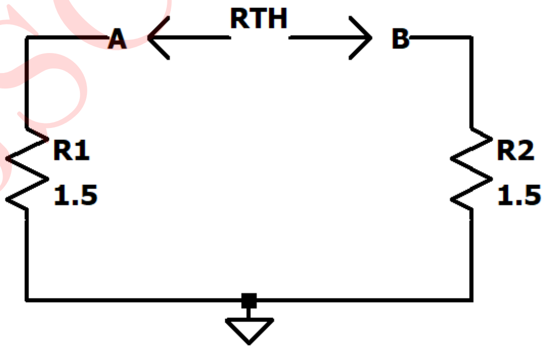

Figure 48: Simplified circuit for Figure 47

$\therefore \mathrm{R}_{TH} = 1.5 + 1.5 = 3\Omega$

$\therefore \mathrm{R}_{TH} = 3\Omega$

Thevenin's Equivalent Circuit:

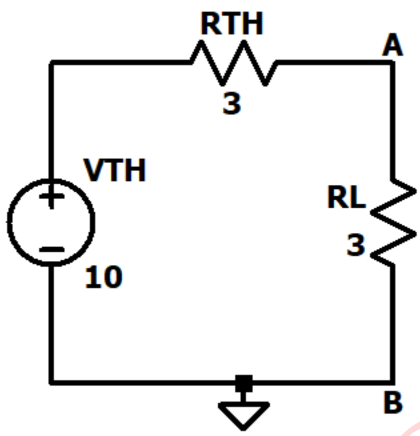

Figure 49: Thevenin's Equivalent Circuit

For maximum power to be transferred, $R_L = R_{TH} = 3\Omega$

Current(I) flowing through the circuit is given by:

$$I = \frac{V_{TH}}{R_{TH} + R_L} = \frac{10}{3+3} = 1.67A$$

The maximum power transferred can be calculated as:

$P_{max} = I^2 \times R_{TH} = 1.67^2 \times 3 = 8.3667W$

$\therefore$ **The maximum power transferred to the load is 8.3667W**

SIMULATED RESULTS:

The given circuit is simulated in LT Spice. The results are presented below:

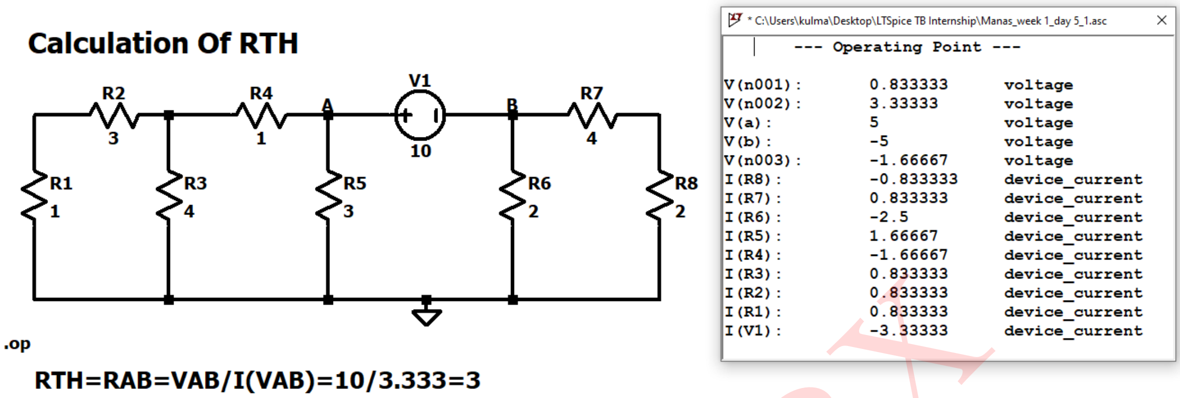

Figure 50: Circuit Schematic and Simulated Results for finding V_{TH}

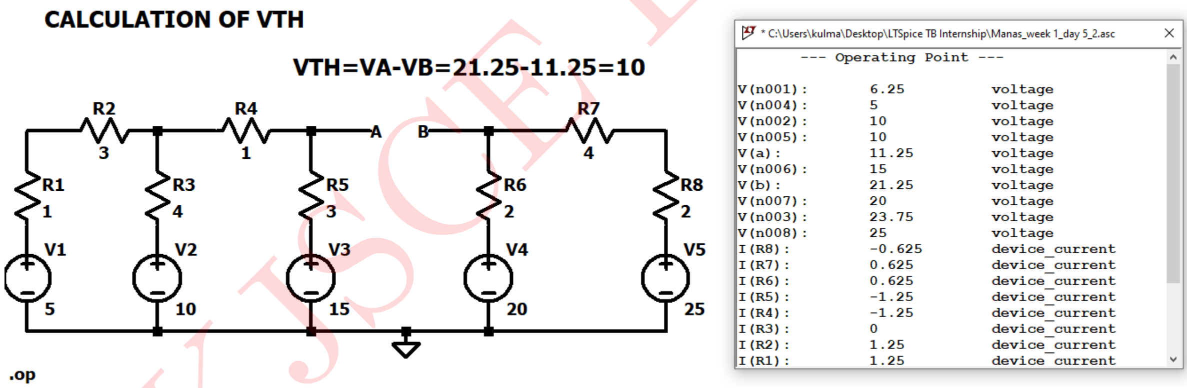

Figure 51: Circuit Schematic finding R_{TH}

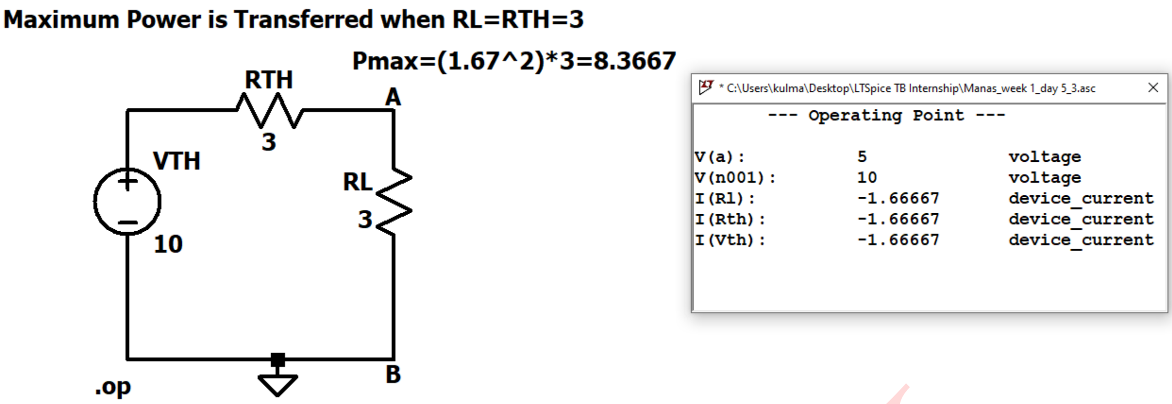

Figure 52: Circuit Schematic and Simulated Results for Thevenin's Equivalent circuit

Comparison of calculated and simulated values:

Parameters	Calculated Value	Simulated Value
V_{TH}	$10V$	$10V$
R_{TH}	3Ω	3Ω
P_{max}	$8.3667W$	$8.3667W$

Table 9: Numerical 9