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

Numerical 1:

a) Using the nodal analysis, determine the total circuit current I for the circuit shown in the Figure 1.
b) Show the current directions for every resistance in the circuit.

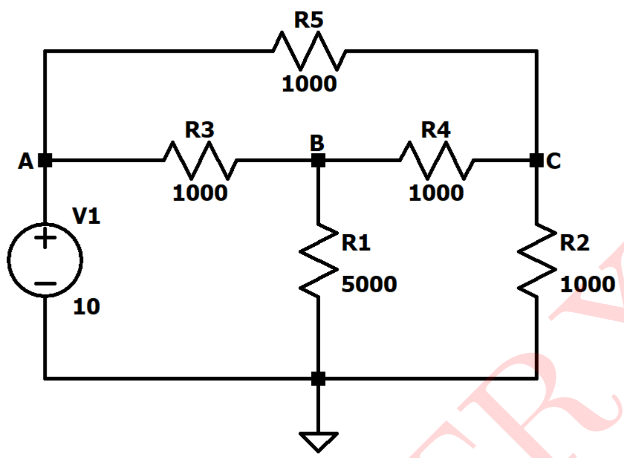


Figure 1: Circuit 1

Solution:
Using Nodal analysis:

Applying KCL at node A:

$\mathbf{V_B = 10V}$

As voltage source is directly connected between node A and reference node (ref)

Applying KCL at node B:

$$\frac{V_B - V_A}{1000} + \frac{V_B - V_C}{1000} + \frac{V_B}{5000} = 0$$

$$\frac{V_B - 10}{1000} + \frac{V_B - V_C}{1000} + \frac{V_B}{5000} = 0$$

$$11V_B - 5V_C = 50 \qquad ......(i)$$

Applying KCL at node C:

$$\frac{V_C - V_A}{1000} + \frac{V_C - V_B}{1000} + \frac{V_C}{1000} = 0$$

$$V_C - 10 + V_C - V_B + V_C = 0$$

$$3V_C - V_2 = 10 \qquad ......(ii)$$

Solving equation(i) and equation(ii),We have

$\mathbf{V_B = 7.142857V}$

$\mathbf{V_C = 5.71429V}$

Hence,

$$I(R_5) = \frac{V_C - V_A}{1000} = \frac{5.71429 - 10}{1000} = -0.00428571\text{A}$$

$$I(R_4) = \frac{V_\text{C} - V_\text{B}}{1000} = \frac{5.71429 - 7.142857}{1000} = -0.00142857\text{A}$$

$$I(R_3) = \frac{V_\text{B} - V_\text{A}}{1000} = \frac{7.142857 - 10}{1000} = -0.00285714\text{A}$$

$$I(R_2) = \frac{V_\text{C}}{1000} = \frac{5.71429}{1000} = -0.00571429\text{A}$$

$$I(R_1) = \frac{V_\text{B}}{5000} = \frac{7.1428571}{5000} = -0.00142857\text{A}$$

$$\begin{aligned} \text{I(V}_1) &= I(R_5) + I(R_3) \\ &= -0.00428571 - 0.0028571 \\ &= -0.00714286 \end{aligned}$$

SIMULATED RESULTS:

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

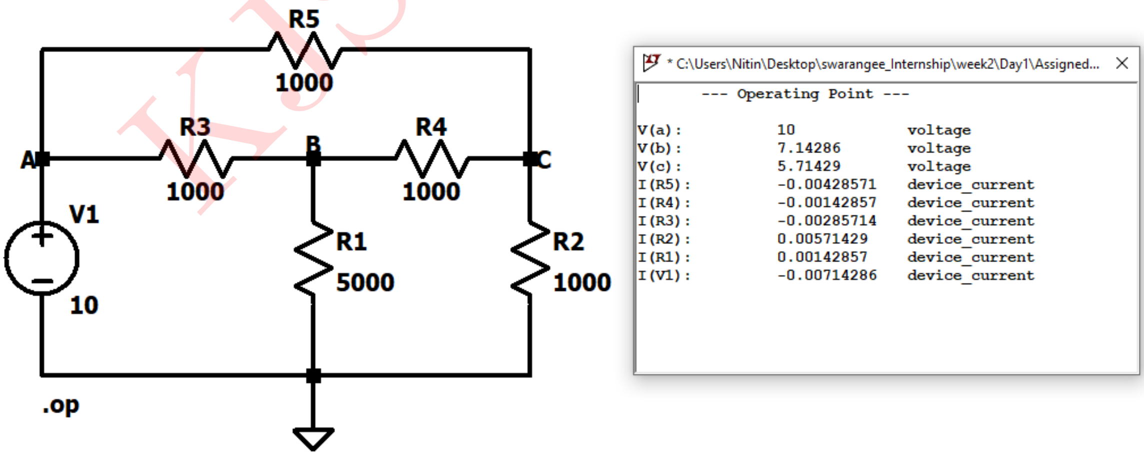


Figure 2: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V(A)	10V	10V
V(B)	7.14286V	7.1428V
V(C)	5.71429V	5.71429V
$I(R_5)$	−0.00428571A	−0.00428571A
$I(R_4)$	−0.00142857A	−0.00142557A
$I(R_3)$	−0.00285714A	−0.00285714A
$I(R_2)$	0.00571429A	0.00571429A
$I(R_1)$	0.00142857A	0.00142857A
$I(R_I)$	−0.00714286A	−0.00741286A

Table 1: Numerical 1

Numerical 2: Using Maxwell's loop current method, calculate the output V_o for the circuit shown in the Figure 3

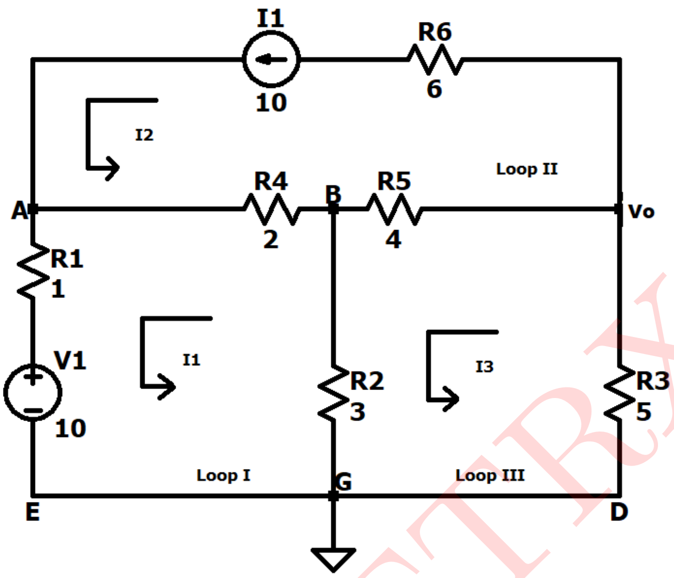


Figure 3: Circuit 2

Solution:
Using Maxwell's loop current method:

In loop II:
$\mathbf{I_2 = 10A}$

*Current source in present in a mesh not common to any other loop.Hence, KVL cannot be applied as voltage is drop is unknown.

Applying KVL in loop I:

$-10 - I_1 - 2(I_1 - I_2) - 3(I_1 - I_3) = 0$

$-10 - I_1 - 2(I_1 - 10) - 3(I_1 - I_2) = 0$

$6I_1 - 3I_3 = 10$ ....(i)

Applying KVL in loop III,

$-5I_3 - 4(I_3 - I_2) - 3(I_3 - I_1) = 0$

$-5I_3 - 4(I_3 - 10) - 3(I_3 - I_1) = 0$

$12I_3 - 3I_1 = 40$ ....(ii)

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

$\mathbf{I_1 = 3.80952A}$

$\mathbf{I_3 = 4.28571A}$

Hence,

$I(V_1) = I_1 = 3.80592A$

$I(R_1) = I_1 = 3.80592A$

$I(R_2) = I_3 - I_1 = 0.49619A$

$I(R_3) = -I_3 = -4.28571A$

$I(R_4) = I_1 - 10 = -6.19048A$

$I(R_5) = I_3 - 10 = -5.71429A$

$I(R_6) = I_2 = 10A$

$I(I_1) = I_2 = 10A$

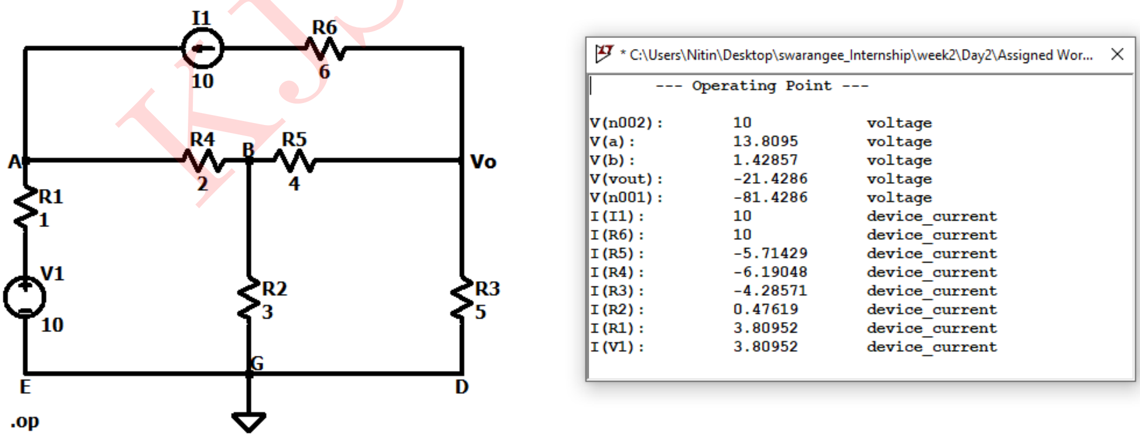
$$\begin{aligned} V_A &= V_B + (I(R_4) \times R_4) \\ &= 1.42857 + (-6.19048 \times 2) \\ &= 13.8095V \end{aligned}$$

$$\begin{aligned} V_B &= I(R_2) \times R_2 \\ &= 0.47619 \times 3 \\ &= 1.42857V \end{aligned}$$

$$\begin{aligned} V_o = V_C &= I(R_3) \times R_3 \\ &= -4.28571 \times 5 \\ &= -21.42855V \end{aligned}$$

SIMULATED RESULTS:

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



V(n002):	10	voltage
V(a):	13.8095	voltage
V(b):	1.42857	voltage
V(vout):	-21.4286	voltage
V(n001):	-81.4286	voltage
I(I1):	10	device_current
I(R6):	10	device_current
I(R5):	-5.71429	device_current
I(R4):	-6.19048	device_current
I(R3):	-4.28571	device_current
I(R2):	0.47619	device_current
I(R1):	3.80952	device_current
I(V1):	3.80952	device_current

Figure 4: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$I(R_1)$	3.80952A	3.80952A
$I(R_2)$	6.47619A	6.47619A
$I(R_3)$	−4.28571A	−4.28571A
$I(R_4)$	−6.10948A	−6.10948A
$I(R_5)$	−5.71429A	−5.71429A
V_o	−21.42855V	−21.42855V

Table 2: Numerical 2

Numerical 3: Using Maxwell's loop current method, calculate the output V_o for the circuit shown in the Figure 5.

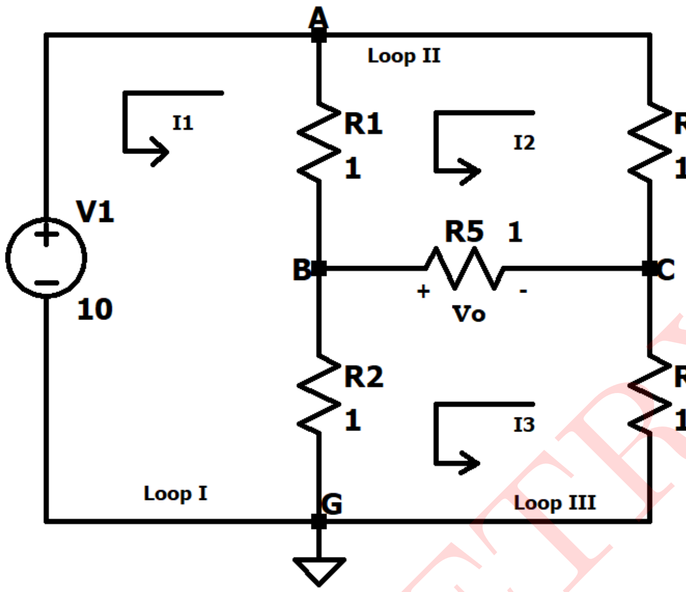


Figure 5: Circuit 3

Solution:

Using Maxewll's loop current method:

Let us assume in this case V = 10V

*Although the final value of V_o remains same irrespective of the value of the V assumed

Applying KVL in Loop I:

$-10 - (I_1 - I_2) - (I_1 - I_3) = 0$

$-2I_1 + I_2 + I_3 = 10$ ....(i)

Applying KVL in Loop II:

$-I_2 - (I_2 - I_3) - (I_2 - I_1 = 0$

$I_1 - 3I_2 + I_3 = 0$ ....(ii)

Applying KVL in Loop III:

$-I_3 - (I_3 - I_2) - (I_3 - I_1 = 0$

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

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

$\mathbf{I_1 = 10A}$

$\mathbf{I_2 = 5A}$

$\mathbf{I_3 = 5A}$

Hence,

$$V_A = V_{assume} = 10V$$
$$V_B = I(R_1) \times R_1 = 1 \times 5 = 5V$$
$$V_C = I(R_3) \times R_3 = 1 \times 5 = 5V$$
$$I(R_5) = I_3 - I_2 = 5 - 5 = 0A$$
$$I(R_4) = I_3 = 5A$$
$$I(R_3) = I_2 = 5A$$
$$I(R_2) = I_1 - I_3 = 10 - 5 = 5A$$
$$I(R_1) = I_1 - I_2 = 10 - 5 = 5A$$
$$I(V_1) = -I_1 = -10A$$
$$\begin{aligned} V_o &= I(R_5) \times R_5 \\ &= 0 \times 1 \\ &= 0V \end{aligned}$$

SIMULATED RESULTS:

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

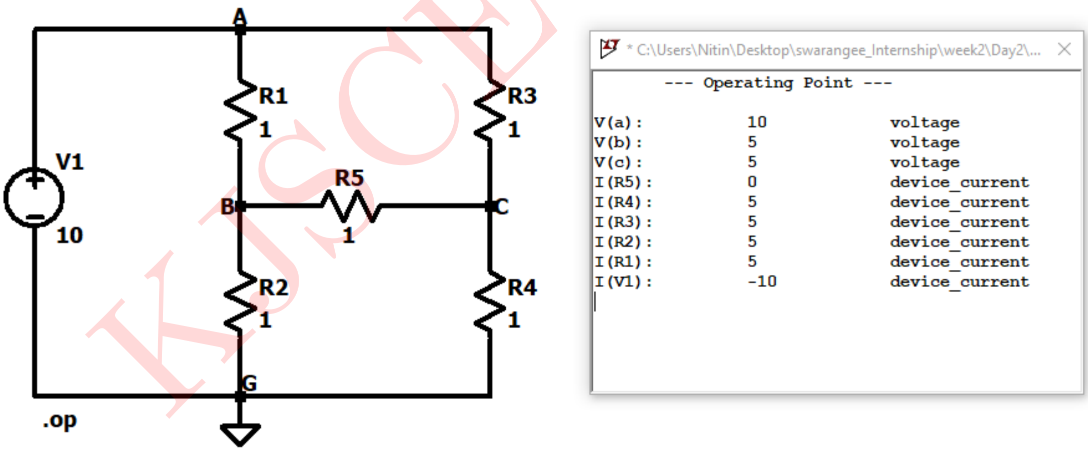


Figure 6: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	**Theoretical Values**	**Simulated Values**
V_A	10V	10V
V_B	5V	5V
V_C	5V	5V
$I(R_5)$	0A	0A
$I(R_4)$	5A	5A
$I(R_3)$	5A	5A
$I(R_2)$	5A	5A
$I(R_1)$	5A	5A
V_o	0V	0V

Table 3: Numerical 3

Numerical 4: For the circuit shown in figure 7, find the equivalent resistance.

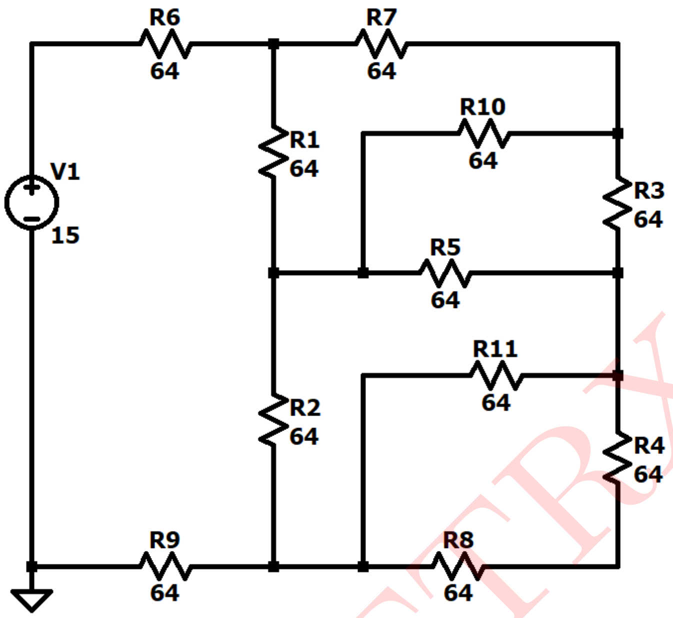


Figure 7: Circuit 4

Solution:

In Figure 8:

Converting the series circuit
$R_S = 64 + 64 = 128\Omega$

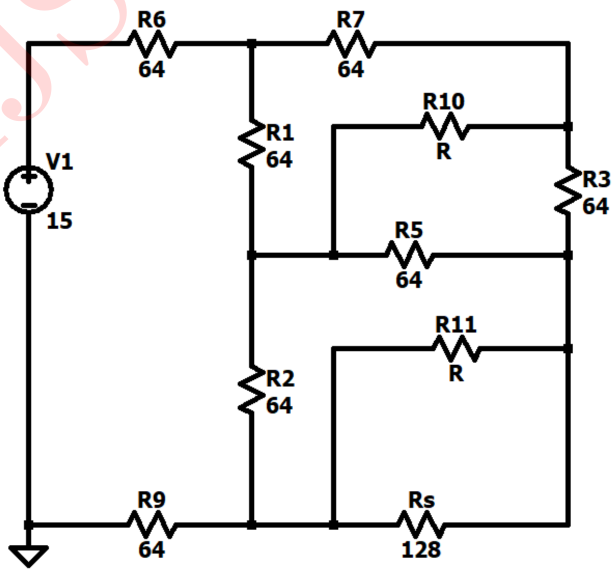


Figure 8: Modified Circuit after adding series resistances

In Figure 9:
Converting the parallel circuit
$$\frac{1}{R_P} = \frac{1}{128} + \frac{1}{64} = 42.67\Omega$$

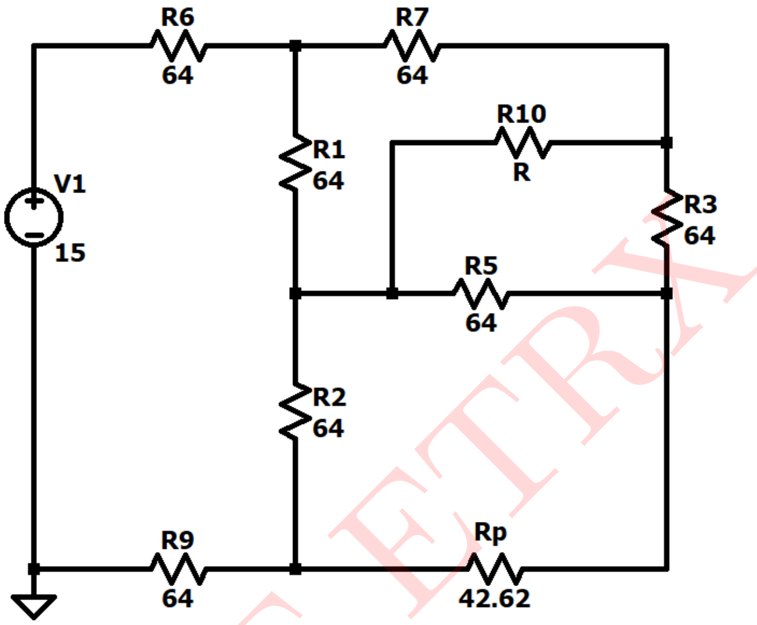


Figure 9: Modified Circuit after adding parellel resistance

In Figure 10:
Converting delta to star
$$R_1 = R_2 = R_3 = \frac{64 \times 64}{64 + 64 + 64} = 21.33\Omega$$

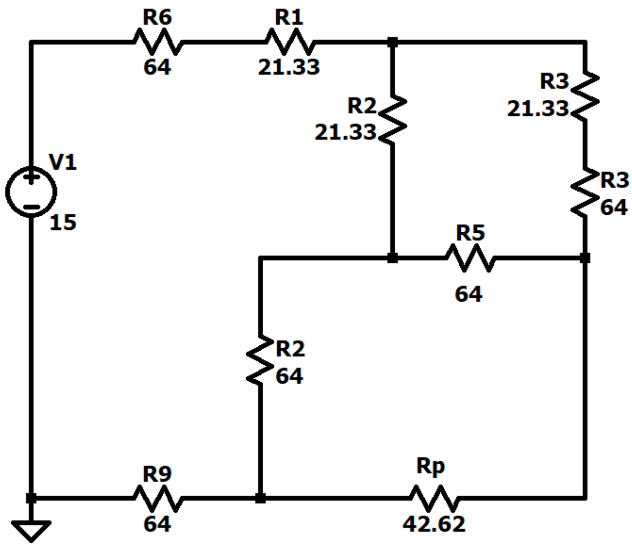


Figure 10: Modified Circuit after coversion of delta to star

In Figure 11:
Converting to delta to star
$$R_2 = R_3 = \frac{42.67 \times 64}{64 + 64 + 42.67} = 16.001\Omega$$
$$R_1 = \frac{64 \times 64}{64 + 64 + 42.67} = 23.995\Omega$$

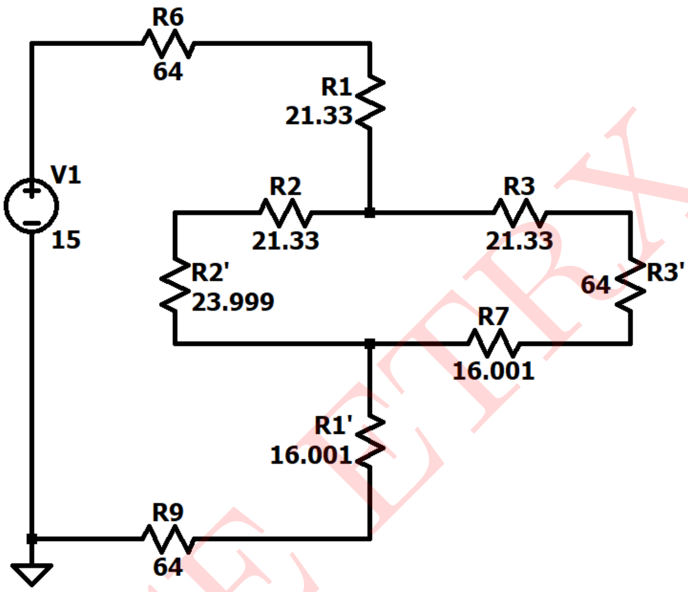


Figure 11: Modified Circuit after coversion of delta to star

In Figure 12:
Converting the series circuit
$R_{S_1} = 64 + 21.33 + 16.001 = 101.331\Omega$

$R_{S_2} = 21.33 + 23.9995 = 45.3295\Omega$

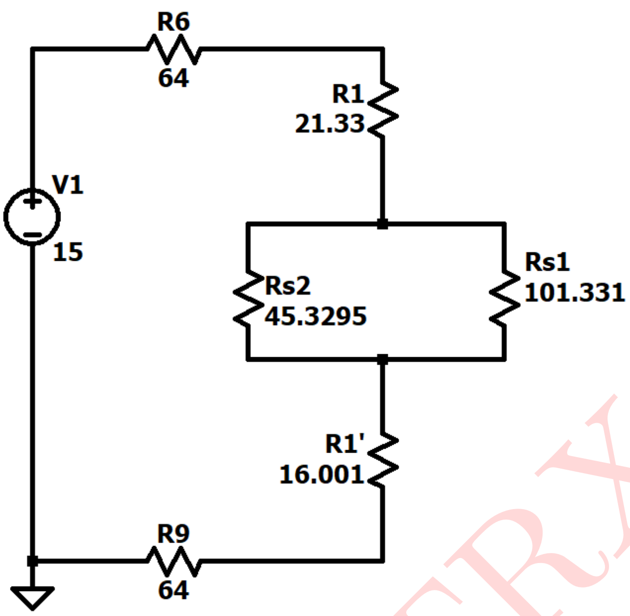


Figure 12: Modified Circuit after adding series resistances

In Figure 13:
Converting the parallel circuit

$$\frac{1}{R_P} = \frac{1}{101.331} + \frac{1}{45.3295} = 31.28\Omega$$

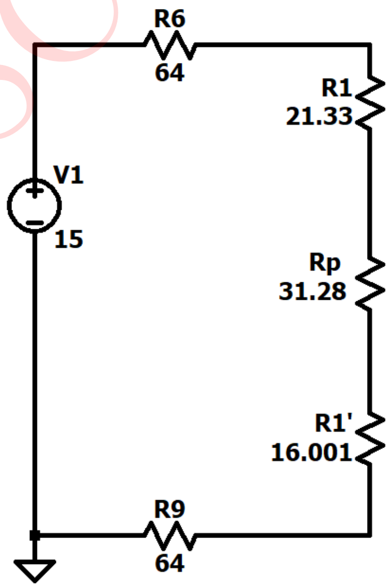


Figure 13: Modified Circuit after adding parellel resistances

$$
\begin{aligned}
R_{\text{eq}} &= 64 + 21.33 + 31.28 + 16.001 + 64 \\
&= 196.611\Omega
\end{aligned}
$$

SIMULATED RESULTS:

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

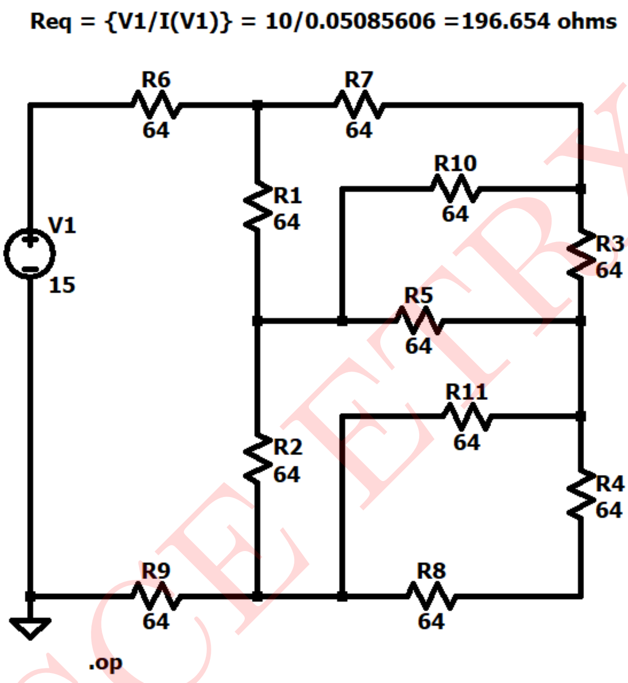


Figure 14: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_1	10V	10V
$I(V_1)$	0.0508506A	0.0508506A
R_{eq}	196.661Ω	196.654Ω

Table 4: Numerical 4

Numerical 5: Obtain the Thevenin and Norton equivalent circuits for the circuit shown in Figure 15. All the resistance values are in ohms.

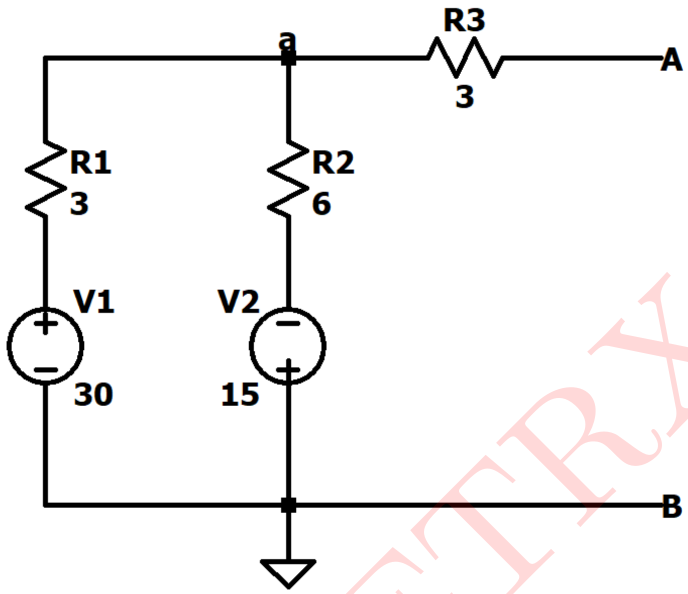


Figure 15: Circuit 5

Solution:

Solution for Thevenin's equivalent circuit:

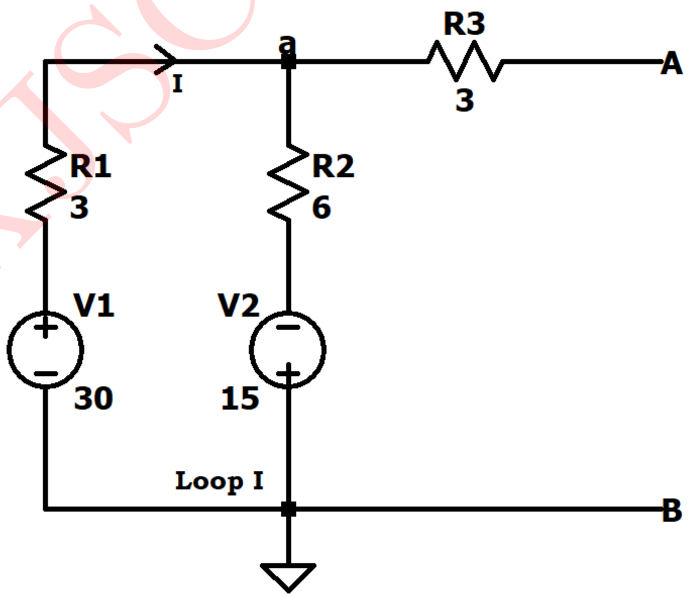


Figure 16: Circuit

Applying KVL to loop I:

$-30 + 3I + 6I - 15 = 0$

9I $= 45$

$\therefore I = 5A$

$$\begin{aligned} V_{Th} &= I \times R_3 \\ &= 5 \times 3 \end{aligned}$$

$\mathbf{V_{Th} = 15V}$

To calculate R_{Th}, we replace voltage sources with a short circuit equivalent:

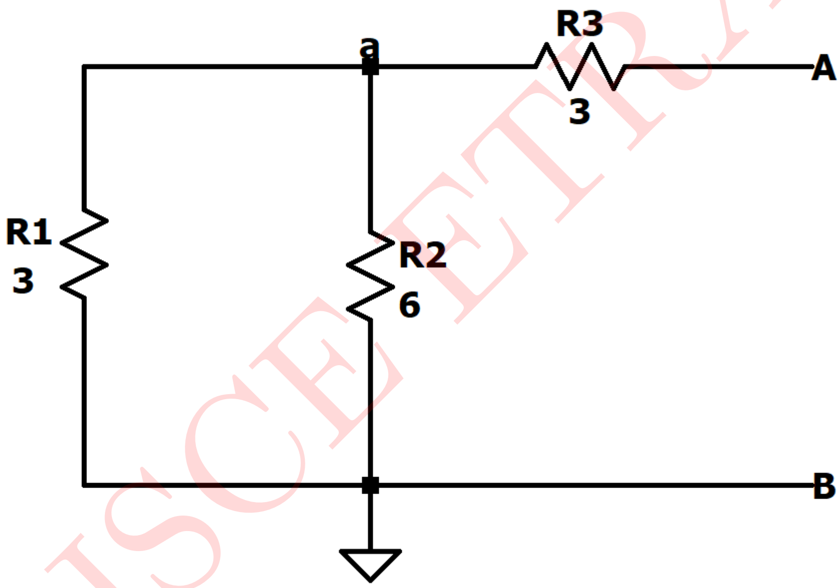


Figure 17: Modified circuit after short circuiting voltage sources

From Figure 18:

Parallel Circuit

$\frac{1}{R_P} = \frac{1}{3} + \frac{1}{6}$

$R_P = 2\Omega$

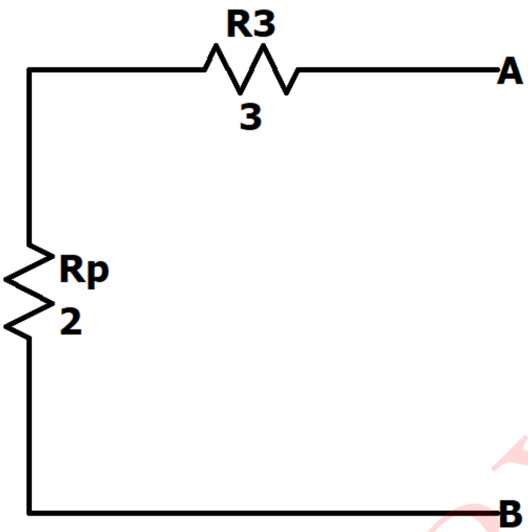


Figure 18: Modified circuit after calculating Parallel resitors

From Figure 19:

Series circuit

$R_s = 3 + 2 = 5\Omega$

$R_s = 5\Omega$

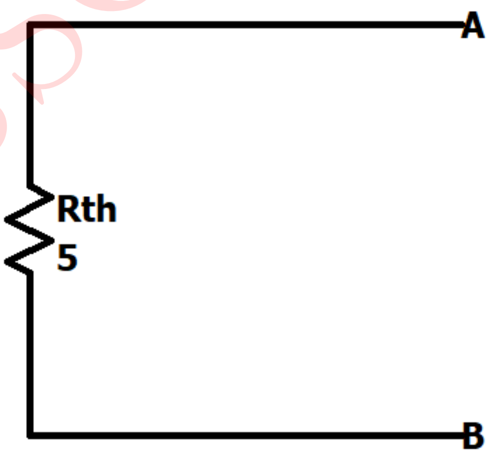


Figure 19: Modified circuit after calculating series resistances

$\mathbf{R_{Th}} = 5\Omega$

Hence, the equivalent circuit for Thevenin's Theorem is

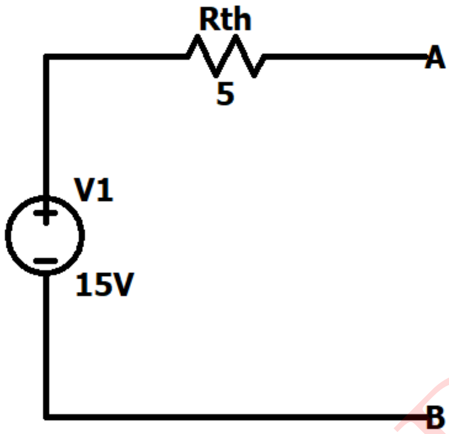


Figure 20: Thevenin's equivalent circuit

Solution forNorrton's equivalent cirucit:

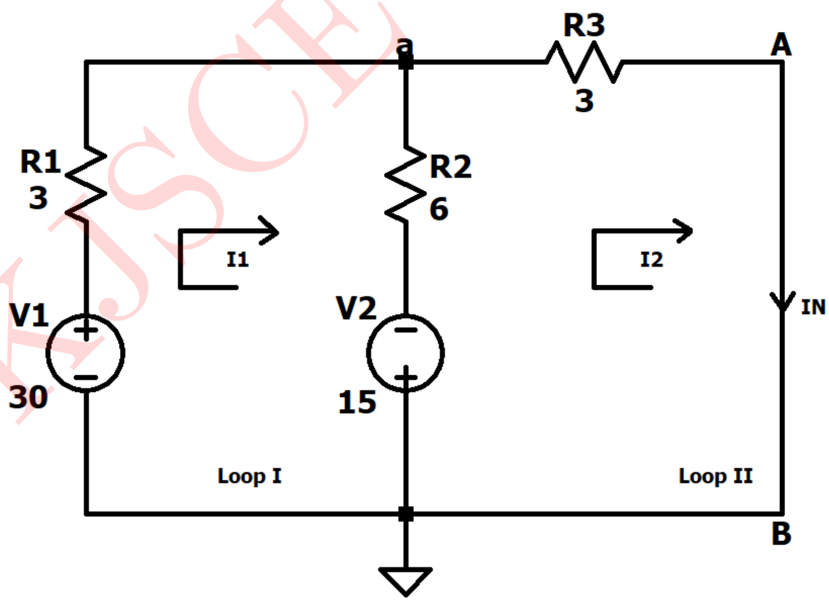


Figure 21: Circuit

Applying KVL to loop I:

$$30 + 3I_1 + 6(I_1 - I_2) - 15 = 0$$
$$9I_1 + 6I_2 = 45$$
$$3I_1 + 2I_2 = 15$$

Applying KVL to loop II:

$-15 - 6(I_2 - I_1) - 3I_2 = 0$

$$6I_1 - 9I_2 = 15$$

$$2I_1 - 3I_2 = 15$$

Solving equation(i) and equation(ii), we get

$\mathbf{I_1 = 7A}$

$\mathbf{I_2 = I_N = 3A}$

To calculate R_N:

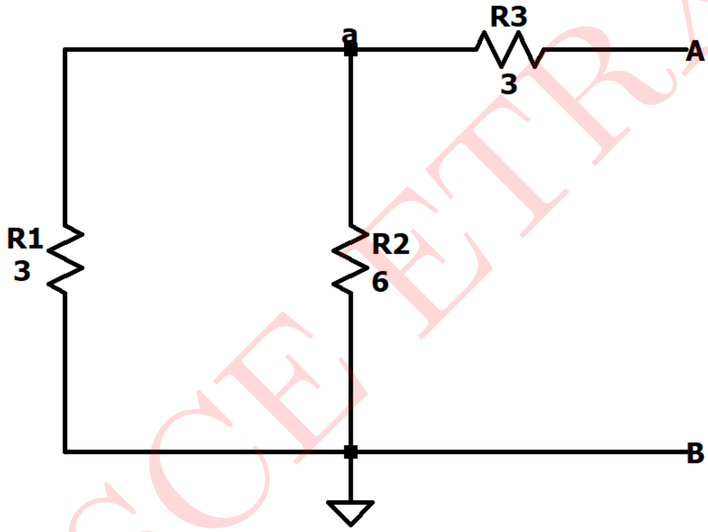


Figure 22: Circuit after short circuiting Voltage sources

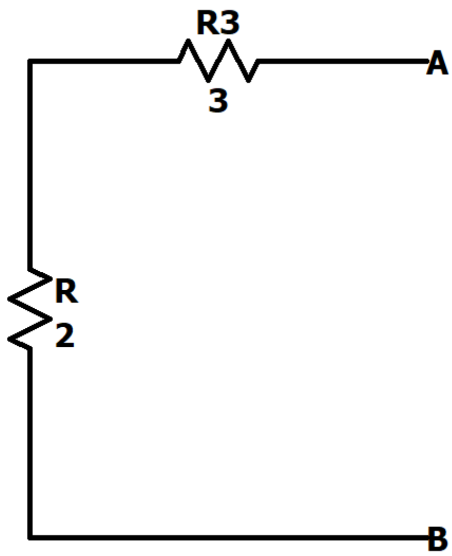


Figure 23: Modified Circuit after solving parallel circuits

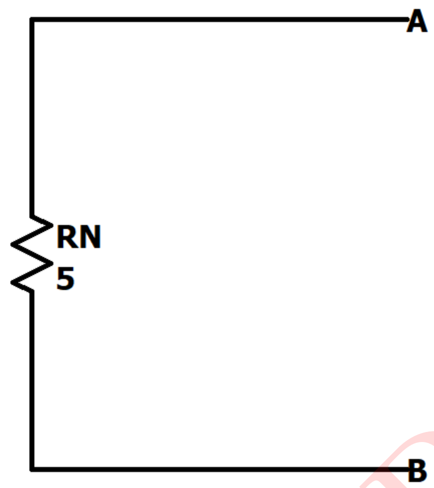


Figure 24: Modified circuit after adding series resistances

$\mathbf{R_N} = 5\Omega$

Nortons equivalent circuit:

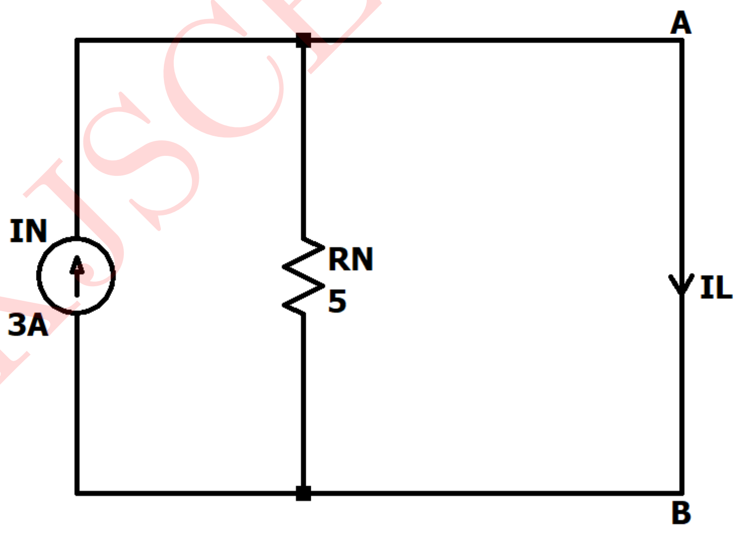


Figure 25: Norton's equivalent circuit

SIMULATED RESULTS:

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

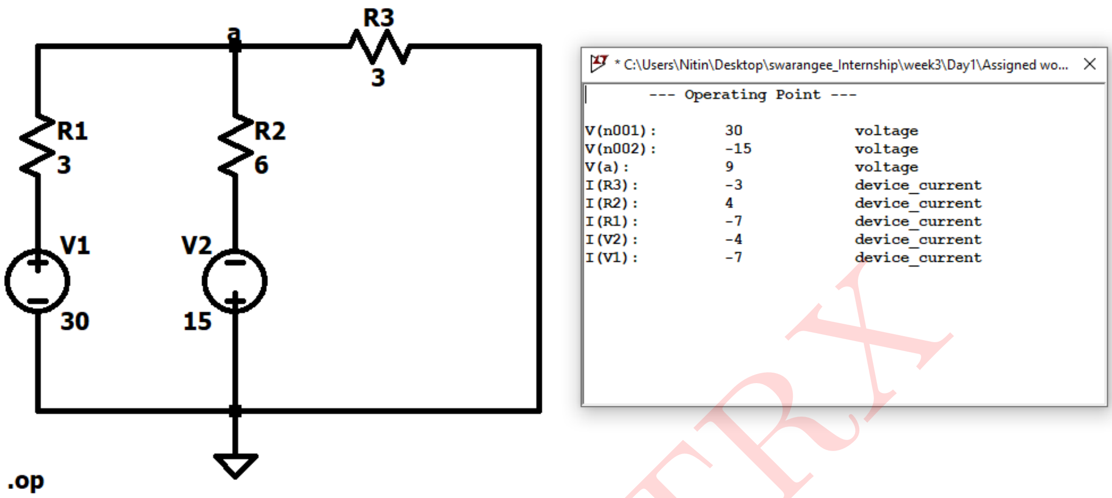


Figure 26: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I(R_1)	-7A	-7A
I(R_2)	4A	4A
I(R_3)	-3A	-3A
I(V_2)	-4A	-4A
I(V_1)	-7A	-7A

Table 5: Numerical 5

Sample Calculations:

$I(R_1) = I_1 = -7A$

$I(R_2) = (I_1 - I_2) = 4A$

$I(R_3) = -I_N = -3A$

$I(V_1) = -I_1 = -7A$

$I(V_2) = -(I_1 - I_2) = -4A$

Numerical 6: Find the currents and voltages in the circuit shown in Figure 27.

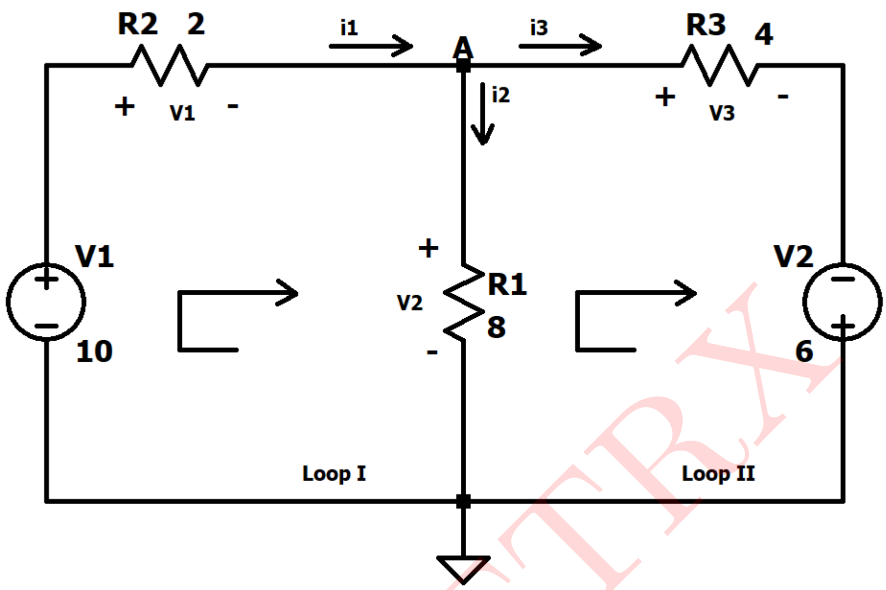


Figure 27: Circuit 6

Solution:

By Ohm's law:

$V_1 = 2i_1$; $V_2 = 8i_2$; $V_3 = 4i_3$

Now we apply KCL at NodeA,

$i_1 - i_1 - i_1 = 0$ ....(i)

Applying KVL to lopp I, we get

$-10 + V_1 + V_2 = 0$

Substituting values of V_1 and V_2, we get

$-10 + 2i_1 + 8i_2 = 0 = 0$

$i_1 = \dfrac{10 - 8i_2}{2}$ .....(a)

Applying KVL in Loop II, we get

$-6 - V_2 + V_3 = 0 = 0$

Substituting values of V_2 and V_3, we get

$-6 - 8i_2 + 4i_3 = 0 = 0$

$i_3 = \dfrac{4i_2 + 3}{2}$ .....(b)

Substituting (a) and (b) in (i)

$$\frac{10 - 8i_2}{2} - i_2 - \frac{4i_2 - 3}{2} = 0$$

i_2 = 0.5A 0R 500mA

$i_1 = 3A;\ i_3 = 2.5A;\ V_1 = 6V;\ V_2 = 4V;\ V_3 = 10V$

SIMULATED RESULTS:

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

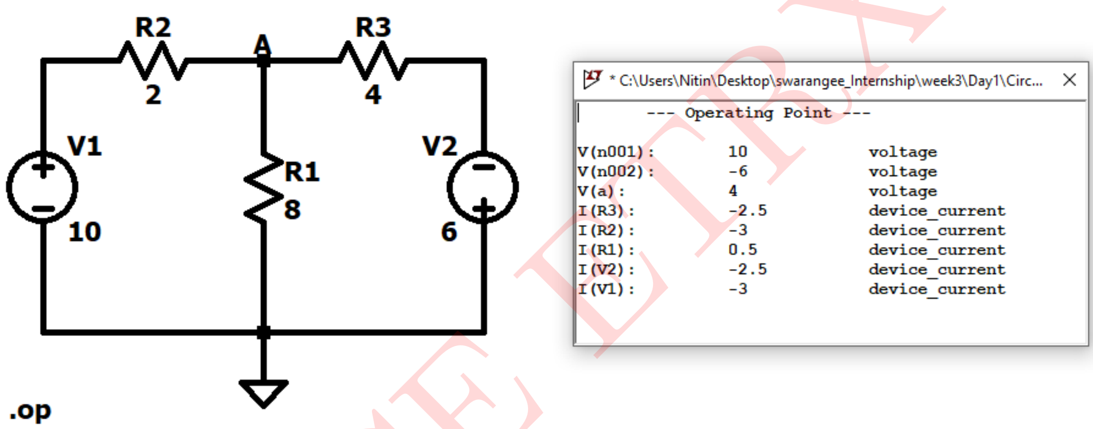


Figure 28: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
i_1	3A	3A
i_2	500mA	500mA
i_3	2.5A	2.5A
V_1	6V	6V
V_2	4V	4V
V_3	10V	10V

Table 6: Numerical 6

Numerical 7: Find currents and voltages in the circuit shown in Figure 29.

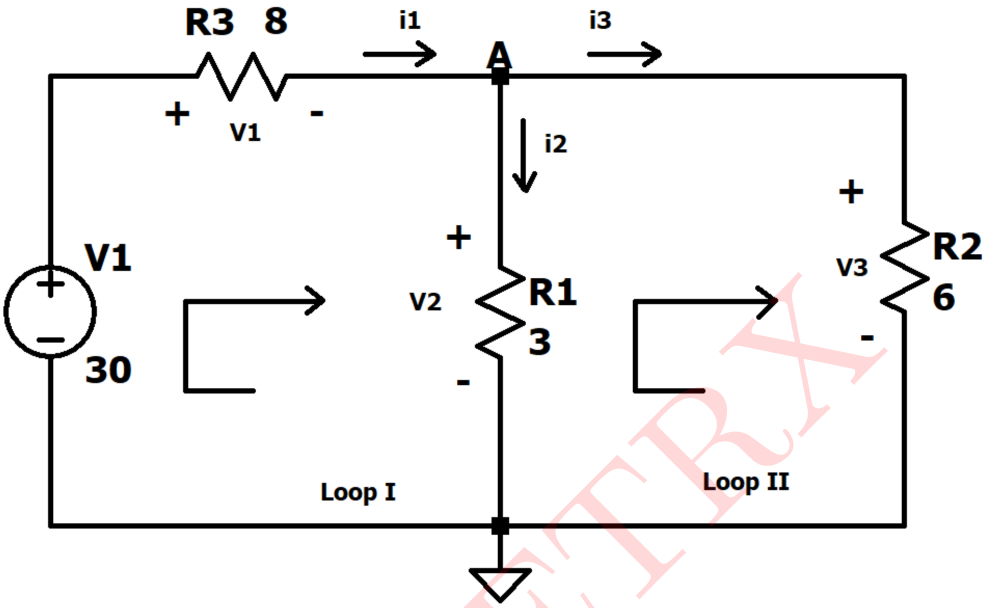


Figure 29: Circuit 7

Solution:

We apply Ohm's law and Kirchoff's law.

By Ohm's law,

$V_1 = 8i_1$; $V_2 = 3i_2$; $V_3 = 6i_3$

Since the voltage and current of each resistors are related by ohm's law as shown, we are really looking for three things: (V_1, V_2, V_3) OR (i_1, i_2, i_3)

At node A, KCL gives,

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

Applying KVL to loop I:

$-30 + V_1 + V_2 = 0$

expressing equation in terms of i we get

$-30 + 8_{i1} + 3i_2 = 0$

$$i_1 = \frac{30 - 3i_2}{8}$$

Applying KVl to loop II:

$-V_2 + V_3 = 0$

As expected the two resistors are in parallel

$V_3 = V_2$

expressing V_3 and V_2 in terms of i_3 and i_2

$6i_3 = 3i_2$

$i_3 = \dfrac{i_2}{2}$ $\qquad\qquad\qquad\qquad .....(ii)$

Substituting equation (ii) in equation (i)

$\dfrac{30 - 3i_2}{8} - i_2 - \dfrac{i_2}{2} = 0$

$i_2 = 2A$

$i_1 = 3A;\ i_3 = 1A;\ V_1 = 24V;\ V_2 = 6V;\ V_3 = 6V$

SIMULATED RESULTS:

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

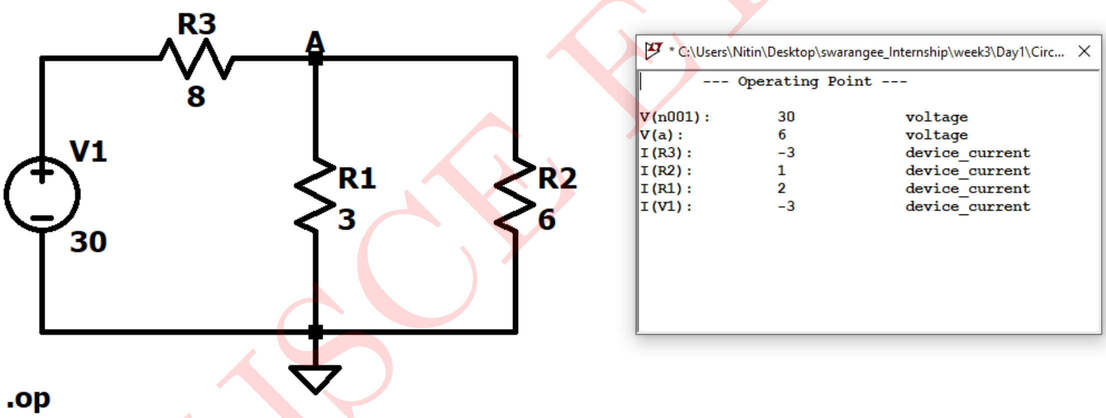


Figure 30: Circuit Schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
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 7: Numerical 7

Numerical 8: Find:
a)Thevenin (or equivalent) voltage:

b)Thevenin (or equivalent) resistance:

for the two-terminal networks shown in figure 31.

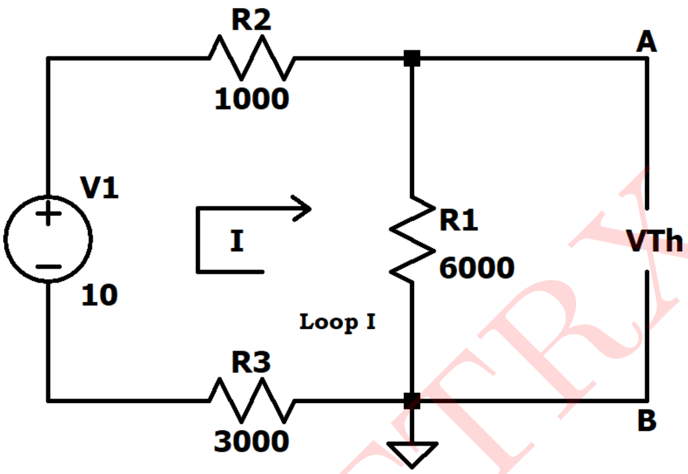


Figure 31: Circuit 8

Solution:

To calculate V_{Th}:

Applying KVL in loop I:

$10 - 1000I - 6000I - 3000I = 0$

$$I = \frac{10}{10000}$$

$$I = \frac{1}{1000}$$

$$I = 0.001A$$

$$V_{Th} = I \times R_1$$
$$= 0.001 \times 6000$$

$\mathbf{V_{Th} = 6V}$

To calculate R_{Th}:
we replace voltage sources wiith a short circuit equivalent for finding R_{Th}.

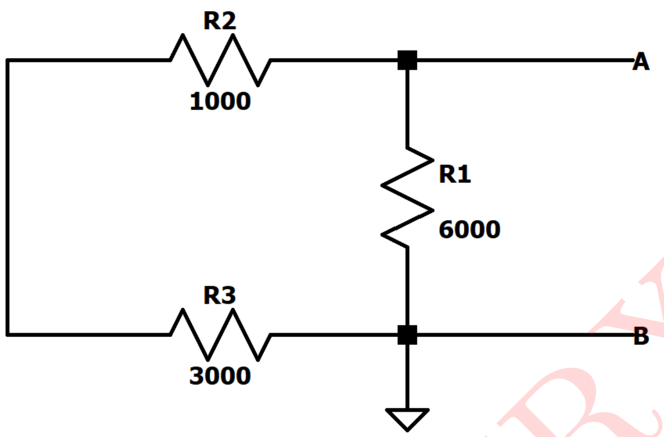


Figure 32: Modified circuit after shorting the voltage sources

From Figure 33:
For series Circuit
$R_s = R_2 + R_3 = 4k\Omega$

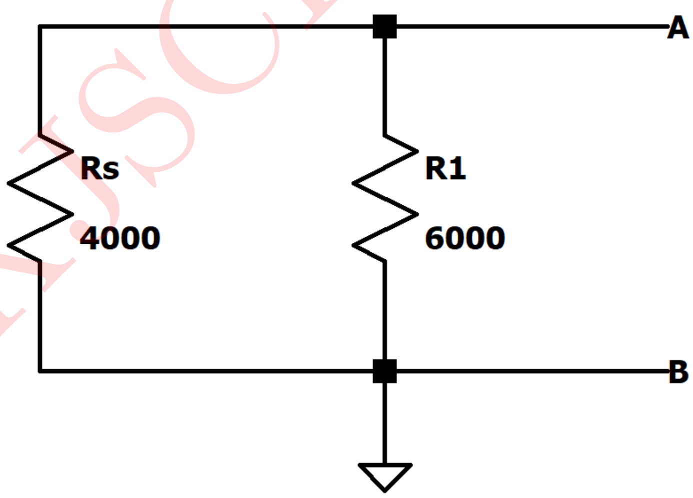


Figure 33: Modified circuit after adding series resistances

From Figure 34:

For parallel circuit

$$\frac{1}{R_P} = \frac{1}{64k} + \frac{1}{4k} = 2.4k\Omega$$

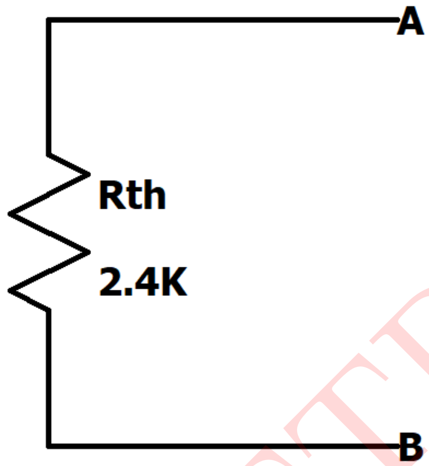


Figure 34: Modified circuit after solving parallel resistance

SIMULATED RESULTS:

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

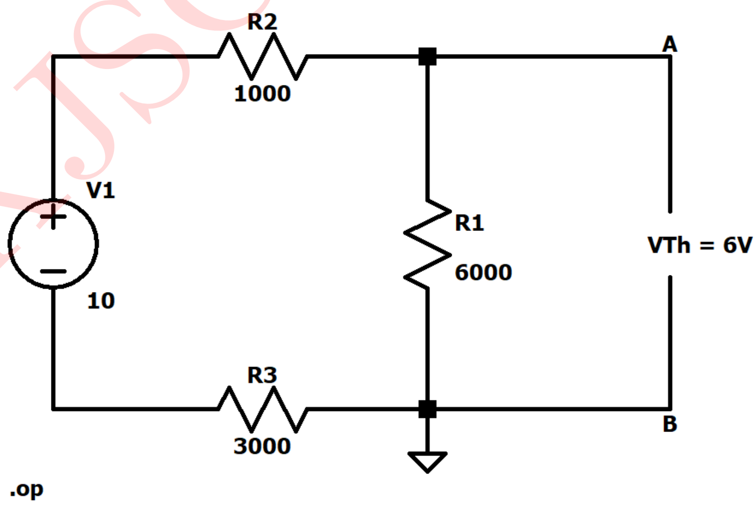


Figure 35: Circuit Schematic and simulated results for V_{Th}

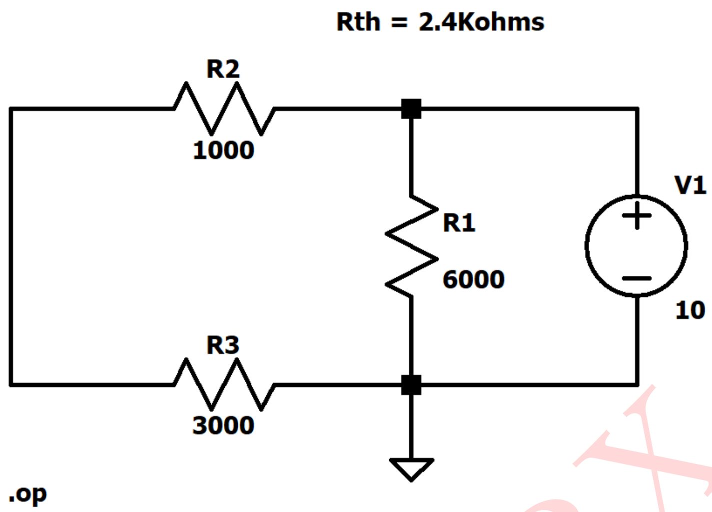


Figure 36: Circuit Schematic and simulated results for R_{Th}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{Th}	6V	6V
R_{Th}	2.4kΩ	2.4kΩ
$I(R_1), I(R_2), I(R_3)$	0.001A	0.001A

Table 8: Numerical 8

Calculations from simulations:

$$I(R_{Th}) = \frac{V_1}{I(V_1)} = \frac{10}{0.00416667} = 2.4K\Omega$$

Numerical 9: Find:
a)Thevenin (or equivalent) voltage:

b)Thevenin (or equivalent) resistance:

for the two-terminal networks shown in Figure 37.

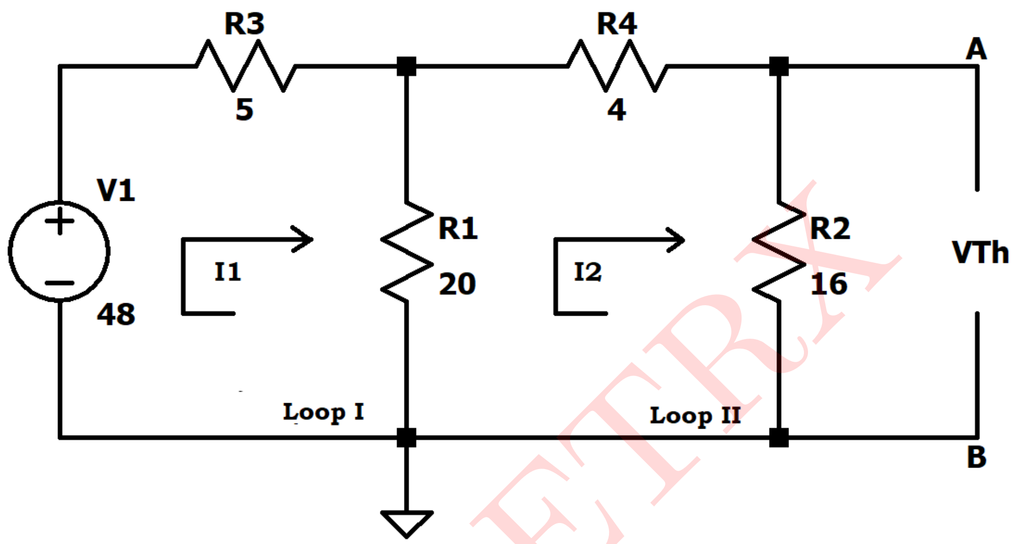


Figure 37: Circuit 9

Solution:

To calculate V_{Th} :

Applying KVL in loop I:

$48 - 5I_1 - 20(I_1 - I_2) = 0$

$25I_1 - 20I_2 = 48$ .....(i)

Applying KVL in loop II:

$-20(I_2 - I_1) - 4I_2 - 16I_2 = 0$

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

Solving equation(i) and equation(ii), we get

$$I_2 = \frac{8}{5} = 1.6A$$
$$I_1 = \frac{6}{5} = 1.2A$$

$$V_{Th} = I_2 \times R_2$$
$$= \frac{8}{5} \times 16$$

$\mathbf{V_{Th} = 25.6V}$

To calculate R_{Th}:

we replace voltage sources with a short circuit equivalent to find R_{Th}.

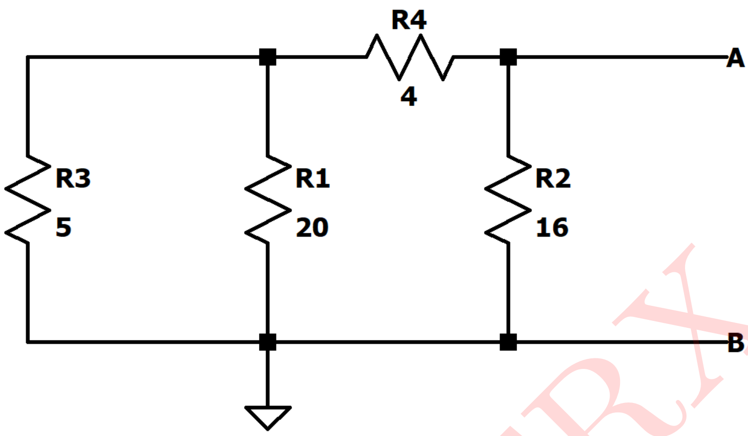


Figure 38: Modified circuit after shorting voltage sorces

From Figure 39:

For parallel circuit

$$\frac{1}{R_P} = \frac{1}{5} + \frac{1}{20}$$

$$R_P = \frac{20}{5} = 4\Omega$$

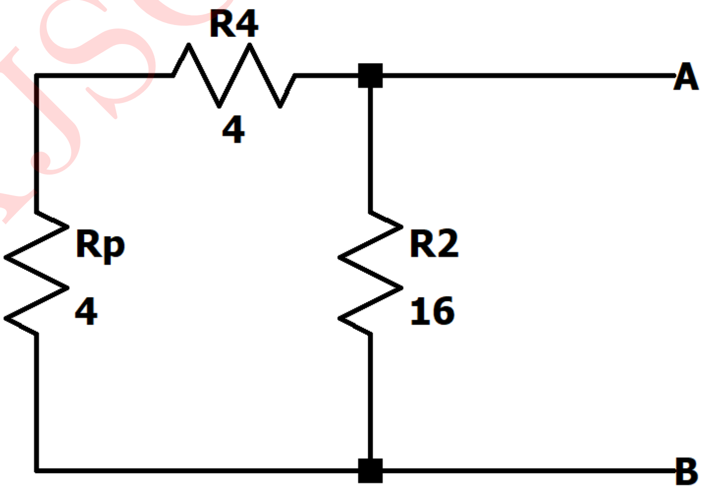


Figure 39: Modified circuit after solving parallel combination

From Figure 40:

For series Circuit
$R_s = 4 + 4 = 8\Omega$

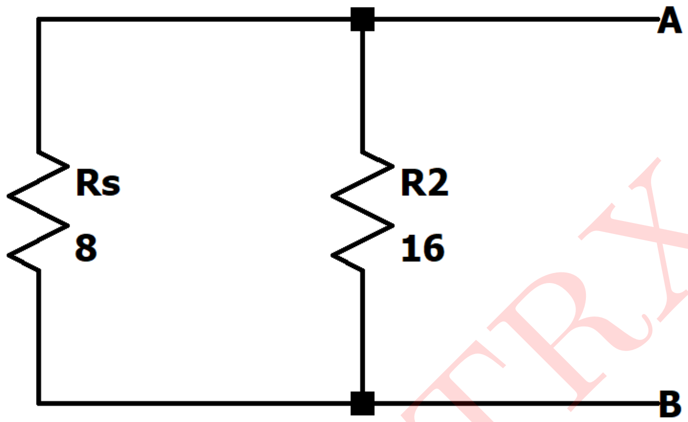


Figure 40: Modified circuit after adding series resistances

From Figure 41:

For parallel circuit
$\frac{1}{R_P} = \frac{1}{16} + \frac{1}{8}$

$R_P = R_{Th} = \frac{16}{3} = 5.33\Omega$

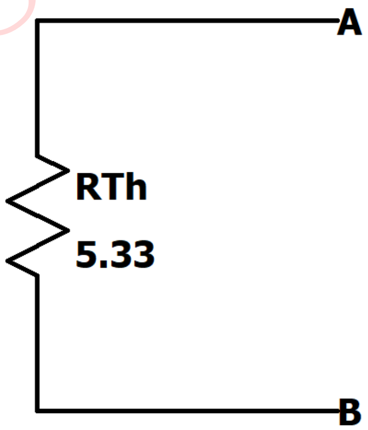


Figure 41: Modified circuit after solving parallel resistances

SIMULATED RESULTS:

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

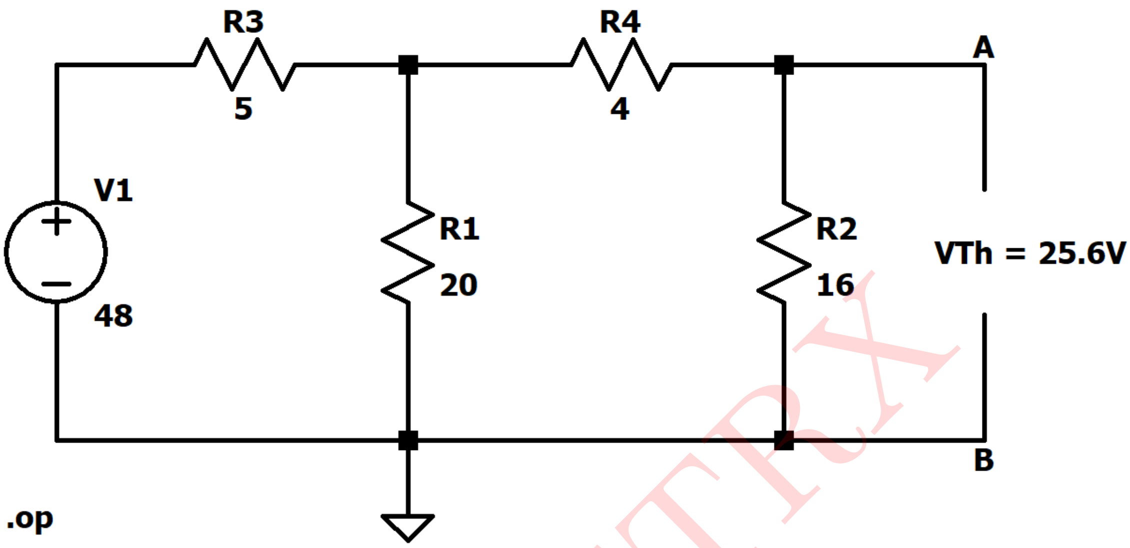


Figure 42: Circuit Schematic and simulated results for V_{Th}

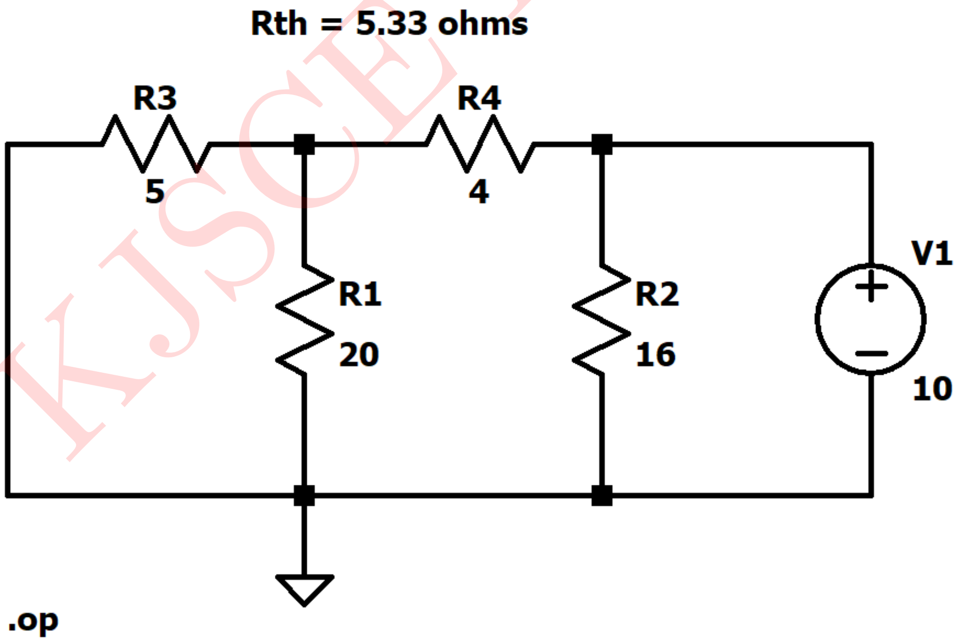


Figure 43: Circuit Schematic and simulated results for R_{Th}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{Th}	25.6V	25.6V
R_{Th}	5.33Ω	5.33Ω
$I(R_1), I(R_2), I(R_4)$	1.6A	1.6A
$I(R_3)$	3.2A	3.2A

Table 9: Numerical 9

Calculations from simulations:

$$I(R_{Th}) = \frac{V_1}{I(V_1)} = \frac{10}{1.875} = 5.33\Omega$$

Numerical 10: Obtain the Norton equivalent of the circuit 10 in Figure 44 to the left of terminals a-b. Use the result to find current i.

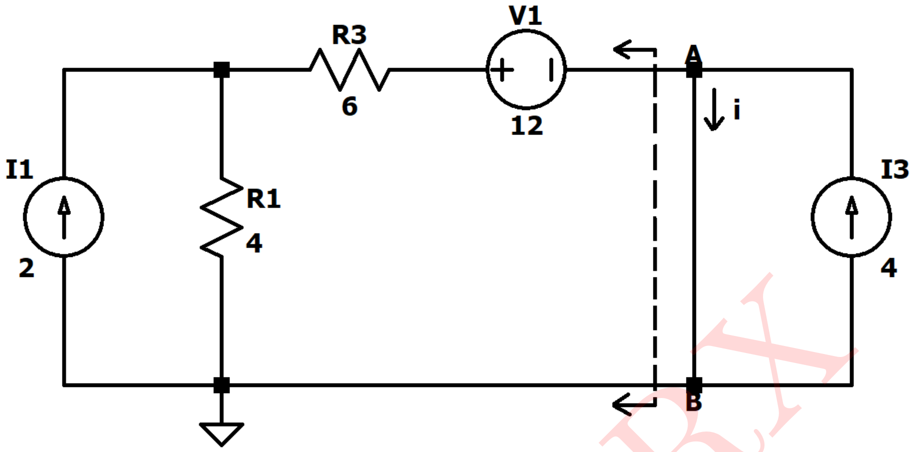


Figure 44: Circuit 10

Solution:

To calculate the Norton's equivalent to the left of terminals a and b

To calculate I_N :

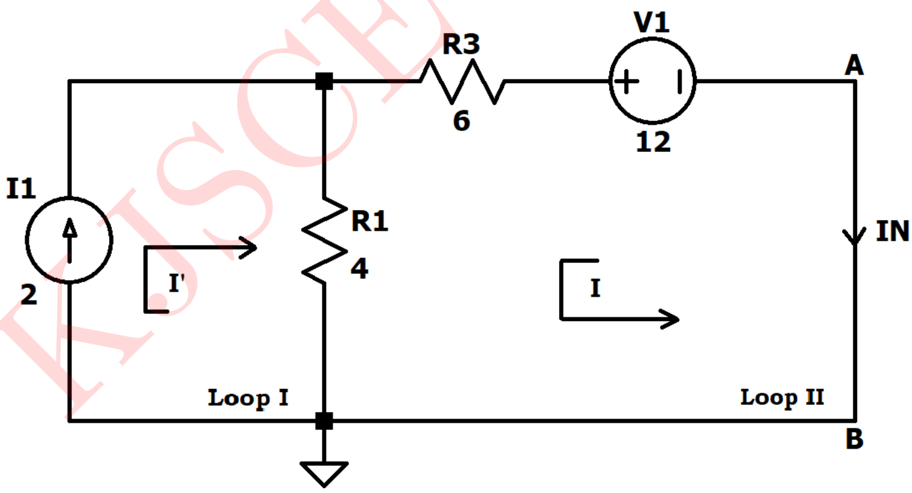


Figure 45: Circuit to the left of a-b terminals

In loop I:

I' = 2A

Applying KVL to loop II

$12 - 6I - 4(I - (-I')) = 0$

$12 - 6I - 4(I + I') = 0$

$I = 0.4A$

$I_{4\Omega} = (I + I')$

$= 2 + 0.4$

$\mathbf{I_N = 2.4A}$

To calculate R_N :

From Figure 46:

For series circuit

$R_N = R_s = 6 + 4 = 10\Omega$

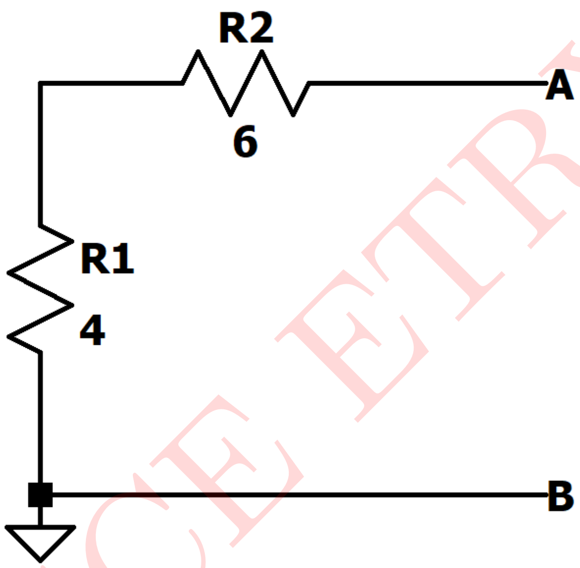


Figure 46: To calculate R_N

Norton's equivalent circuit and the remaining circuit

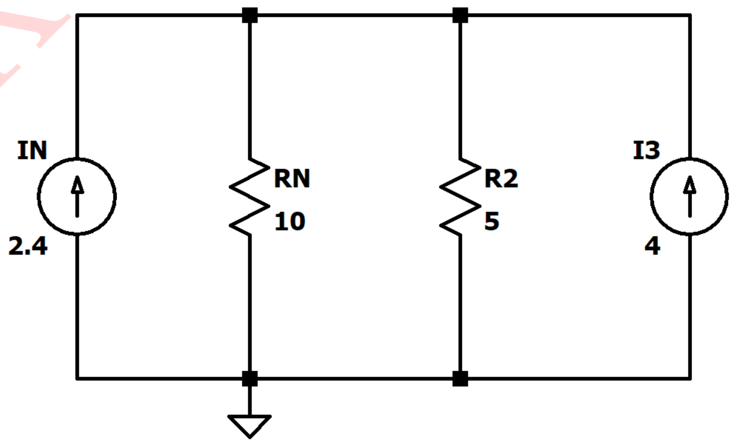


Figure 47: Norton's equivalent circuit

From Figure 48:

Adding parallel current sources

$$I_{5\Omega} = i = 6.4 \times \frac{10}{5+10} = 4.2667A$$

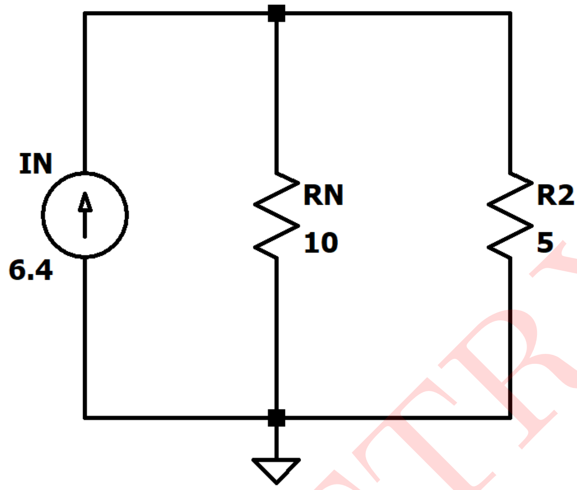


Figure 48: Modified circuit after solving parallel sources

SIMULATED RESULTS:

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

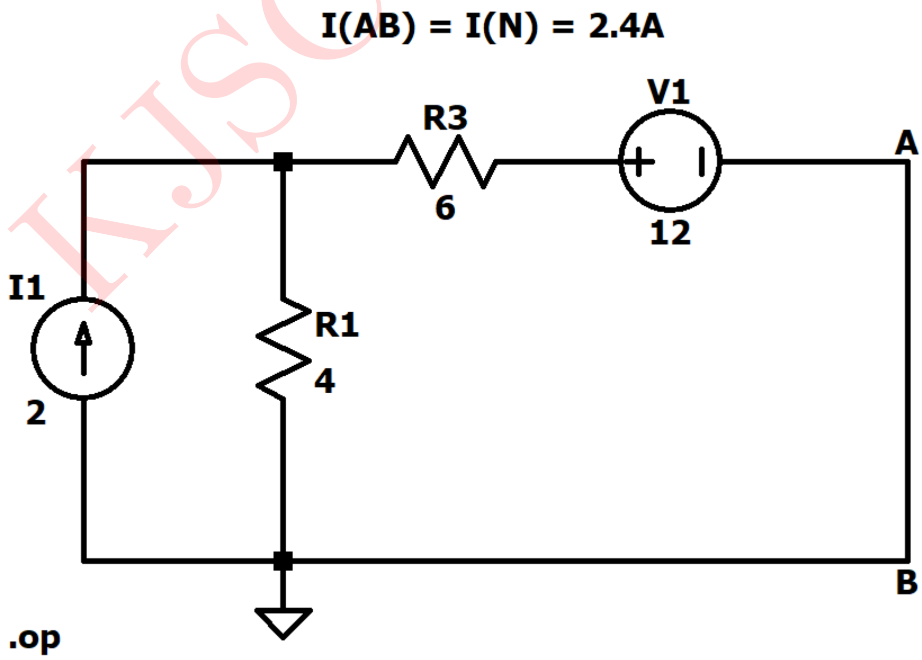


Figure 49: Circuit Schematic and simulated results for I_N

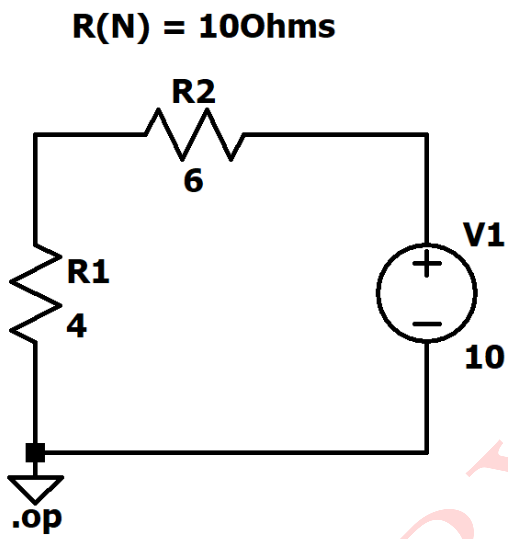


Figure 50: Circuit Schematic and simulated results for R_N

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$I_N/I_{4\omega}$	2.4A	2.4A
R_N	10Ω	10Ω
$I(R_{5\Omega})$	4.2667A	4.2667A

Table 10: Numerical 10

Calculations from simulations:

$$I(R_{Th}) = \frac{V_1}{I(V_1)} = \frac{10}{1} = 10\Omega$$

Numerical 11: Calculate the value of R_L for it to absorb the maximum power and find out the maximum power in the circuit of Figure 51.

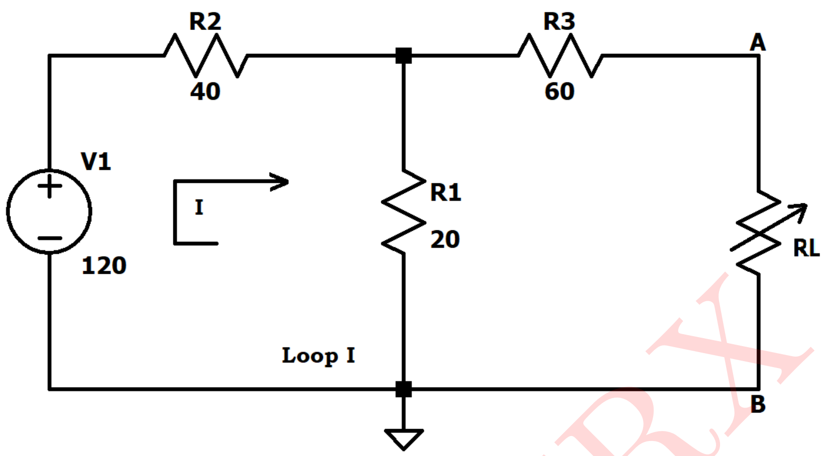


Figure 51: Circuit 11

Solution:
Applying Thevenin's theorem:

To calculate V_{Th}:

Applying KVL to loop:

$120 - 40I - 20I = 0$
$\therefore$ I = 2A

$V_{Th} = I \times R_1$
$\quad = 2A \times 20\Omega$

$\mathbf{V_{Th} = 40V}$

To calculate R_{Th}:

We replace voltage sources with a short circuit equivalent

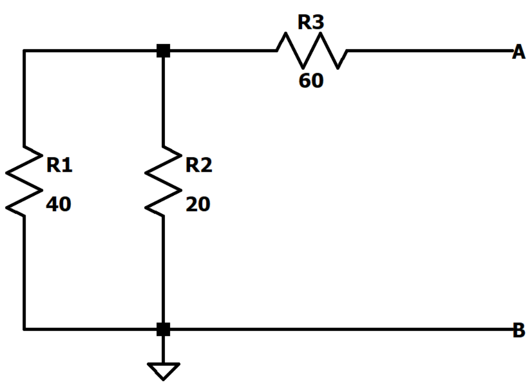


Figure 52: Modified circuit after short circuiting voltage source

From Figure 53:

For parallel circuit

$$\frac{1}{R_P} = \frac{1}{20} + \frac{1}{40}$$

$$R_P = \frac{40}{3} = 13.333\Omega$$

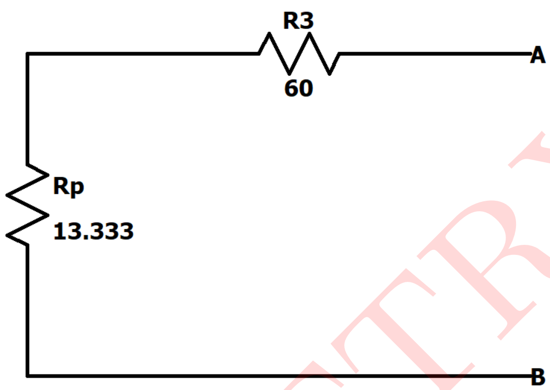


Figure 53: Modified circuit after calculating parallel resistances

From Figure 54:

$$R_{Th} = \frac{40}{3} + 60$$

$$\mathbf{R_{Th} = 73.33\Omega}$$

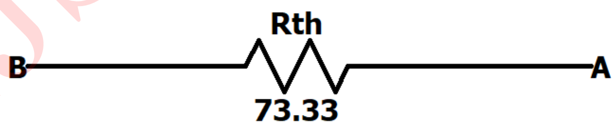


Figure 54: Modified circuit after calculating series resistances

Thevenin's equivalent circuit:

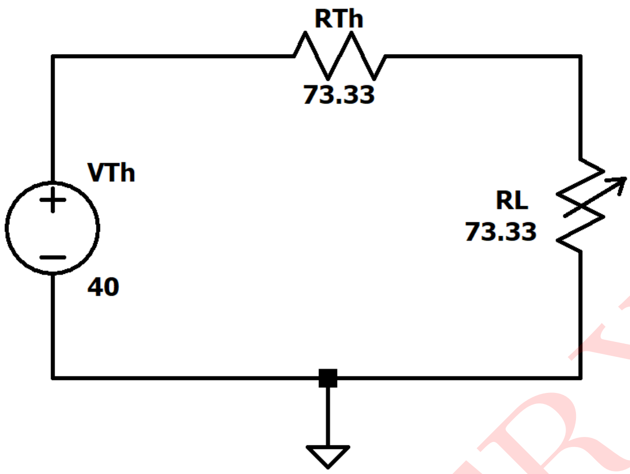


Figure 55: Thevenin's equivalent circuit

For maximum power

$\mathbf{R_L = R_{Th} = 73.33\Omega}$

$$\mathbf{P_{max} = \frac{{V_{Th}}^2}{4R_{Th}} = 5.4548W}$$

SIMULATED RESULTS:

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

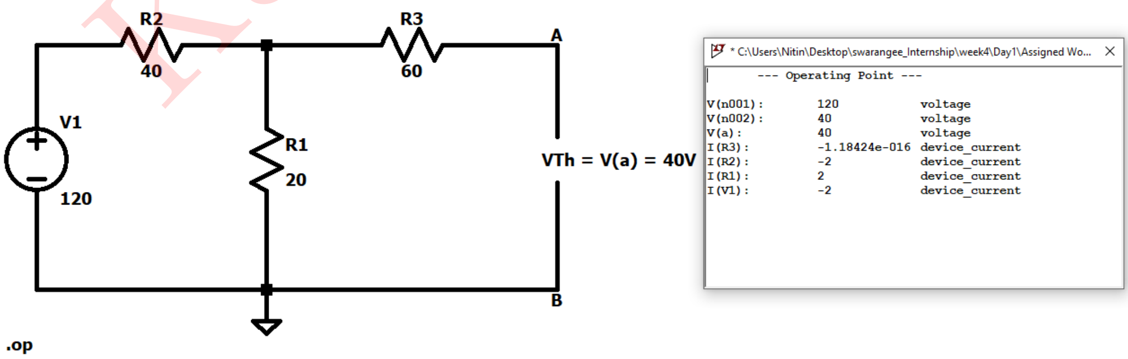


Figure 56: Circuit schematic and simulated results for V_{Th}

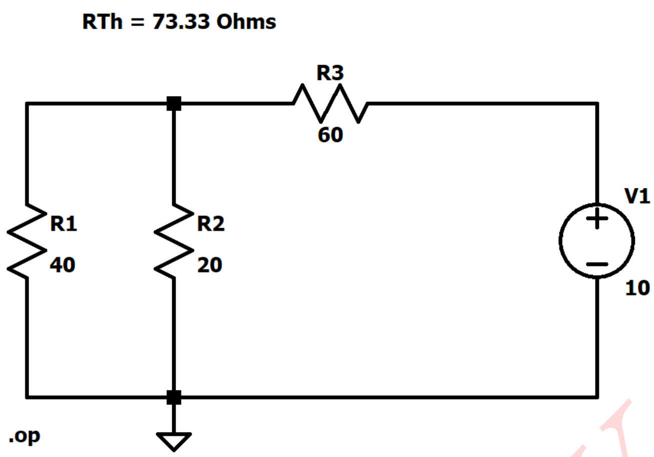


Figure 57: Circuit schematic and simulated results for R_{Th}

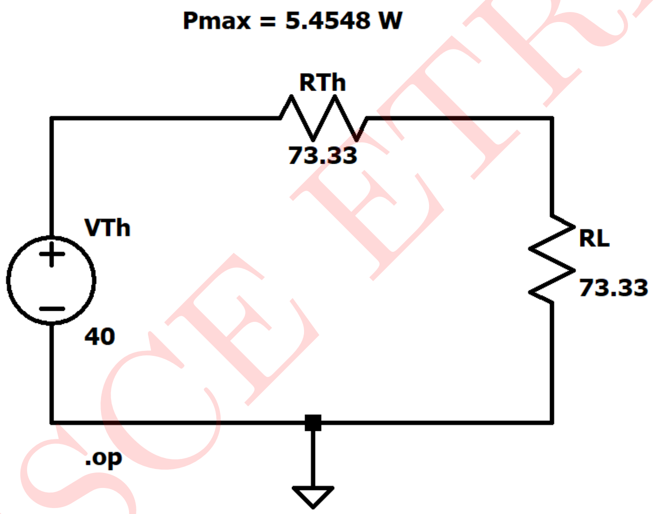


Figure 58: Circuit schematic and simulated results for P_{max}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{Th}	40V	40V
R_{Th}	73.33Ω	73.33Ω
P_{max}	5.4548W	5.4548W

Table 11: Numerical 11

Numerical 12: For the circuit shown below, what will be the value of R_L to get the maximum power? What is the maximum power delivered to the load?

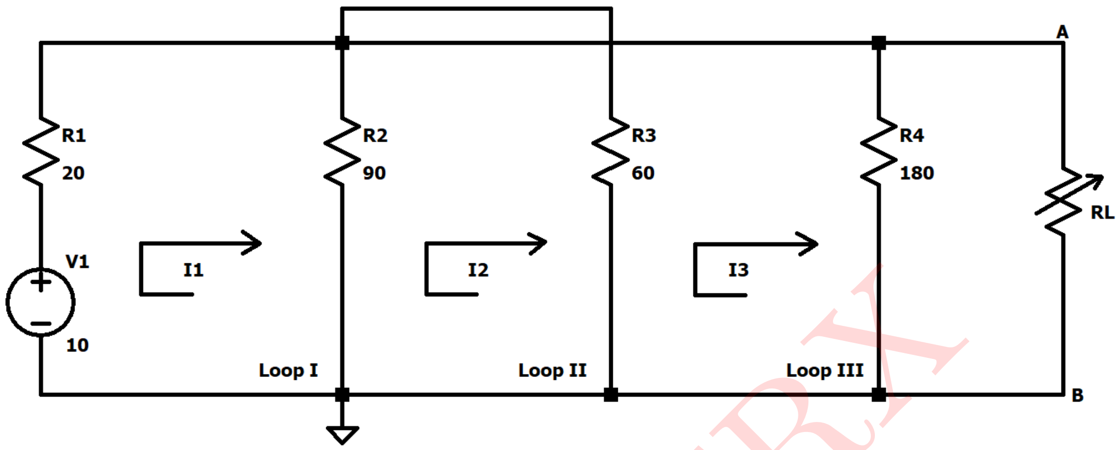


Figure 59: Circuit 12

Solution:
Applying Thevenin's theorem:

To calculate V_{Th}:

Applying KVL to loop I:

$10 - 20I_1 - 90(I_1 - I_2) = 0$

$11I_1 - 9I_2 = 1$ ....(i)

Applying KVL to loop II:

$-90(I_2 - I_1) - 60(I_2 - I_3) = 0$

$3I_1 - 5I_2 + 2I_3 = 1$ ....(ii)

Applying KVL to loop III:

$-60(I_3 - I_2) - 180I_3 = 0$

$I_2 = 4I_3$ ....(iii)

Solving equation(i),equation(ii) and equation(iii), we get

$I_1 = 0.2A$; $I_2 = 0.133A$; $I_3 = 0.0333A$

$$V_{Th} = I_3 \times R_4$$
$$= 180 \times 0.0333$$

$\mathbf{V_{Th} = 5.999V}$

To calculate R_{Th}:

We short circuit voltage sources

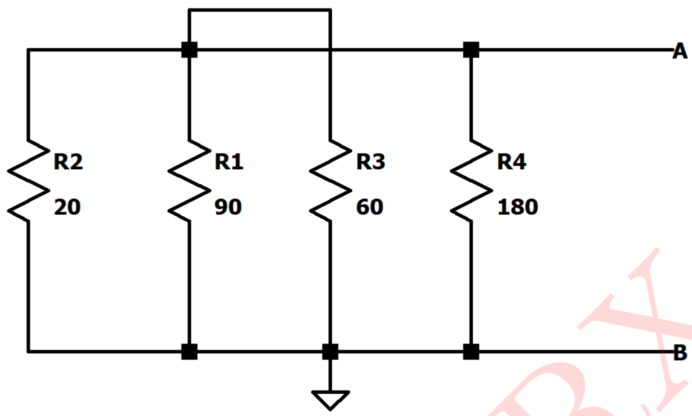


Figure 60: Circuit to calculate R_{Th}

From Figure 61:

For parallel circuit

$$\frac{1}{R_P} = \frac{1}{20} + \frac{1}{90}$$

$$R_P = \frac{180}{11} = 16.36\Omega$$

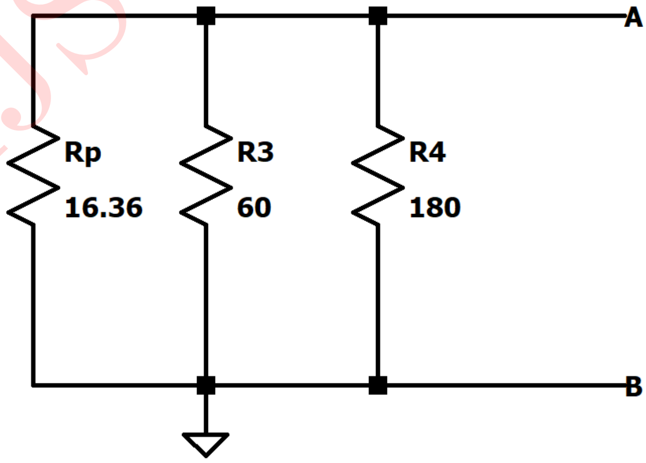


Figure 61: Modified Circuit for calculating parallel resistances

Frtom Figure 62:

For parallel circuit

$$\frac{1}{R_{Th}} = \frac{1}{180} + \frac{1}{60} + \frac{11}{180}$$

$$R_{Th} = 12\Omega$$

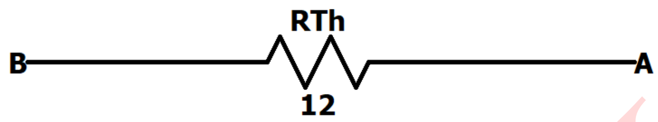


Figure 62: Modified Circuit for calculating parallel resistances

Thevenin's equivalent circuit:

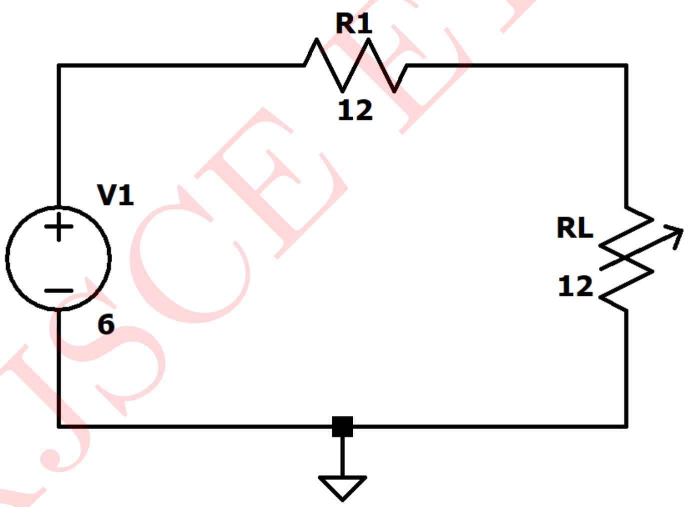


Figure 63: Thevenin's equivalent circuit

For maximum power

$$\mathbf{R_L = R_{Th} = 12\Omega}$$

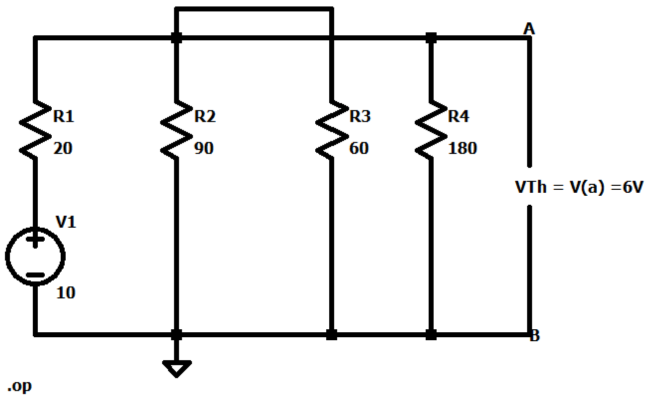
$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

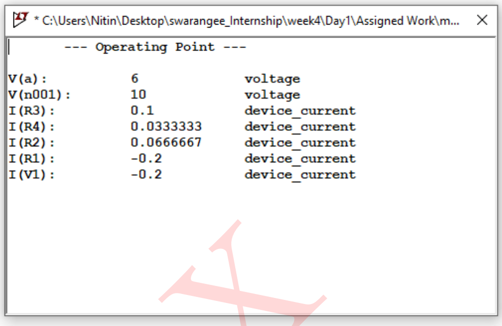
$$= \frac{(5.9994)^2}{4 \times 12}$$

$$\mathbf{P_{max} = 0.74985W}$$

SIMULATED RESULTS:

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




* C:\Users\Nitin\Desktop\swarangee_Internship\week4\Day1\Assigned Work\m...

```
--- Operating Point ---

V(a):       6           voltage
V(n001):    10          voltage
I(R3):      0.1         device_current
I(R4):      0.0333333   device_current
I(R2):      0.0666667   device_current
I(R1):      -0.2        device_current
I(V1):      -0.2        device_current
```

Figure 64: Circuit schematic and simulated results for V_{Th}

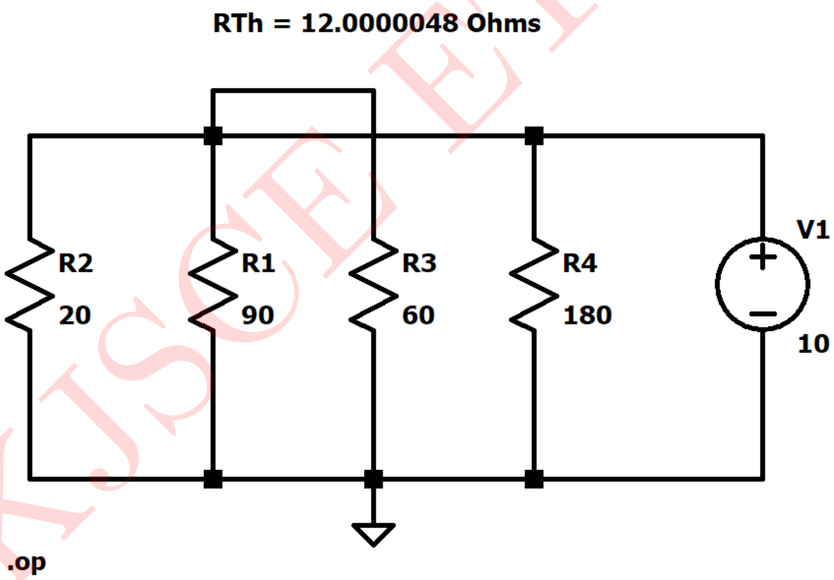


Figure 65: Circuit schematic and simulated results for R_{Th}

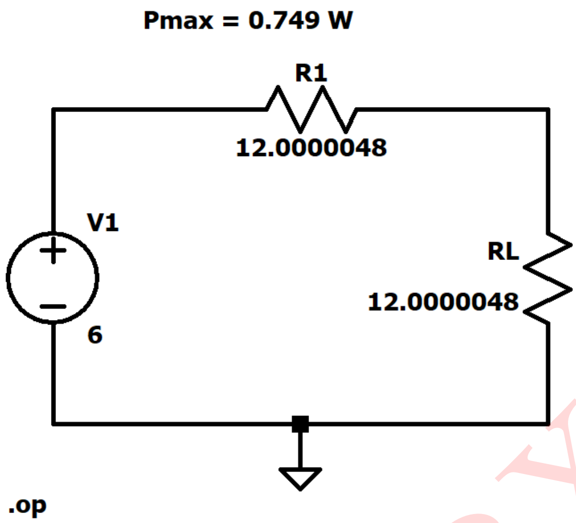


Figure 66: Circuit schematic and simulated results for P_{max}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$\mathrm{I(R_1)} = I(N_1)$	0.2A	0.2A
$\mathrm{I(R_2)} = I_2 - I_1$	0.066667A	0.066667A
$\mathrm{I(R_3)} = I_3 - I_2$	0.1A	0.1A
$\mathrm{I(R_4)} = I_3$	0.03333A	0.03333A
$\mathrm{V_{Th}}$	5.994V	5.994V
$\mathrm{R_{Th}}$	12Ω	12Ω
P_{max}	0.74985W	0.74985W

Table 12: Numerical 12

****