K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELEMENTS OF ELECTRICAL AND ELECTRONICS ENGINEERING
DC CRICUITS

Numerical 1: Find the current I_0 in Circuit 1.

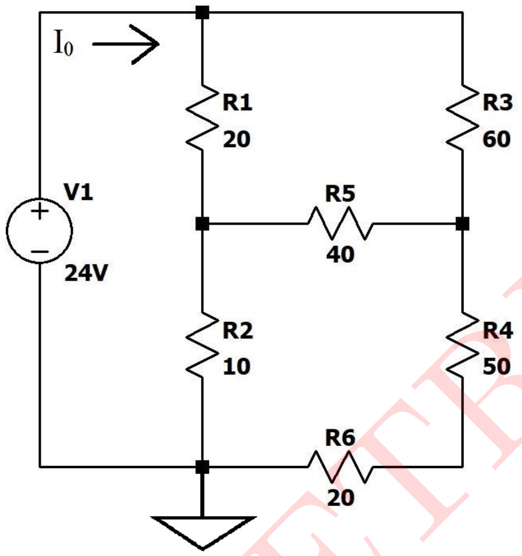

Figure 1: Circuit 1

Solution:
By using delta to star conversion,

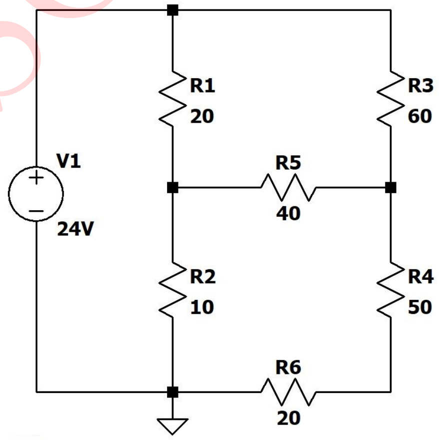

Figure 2: Modified circuit for figure 1

By further simplyfing we get,

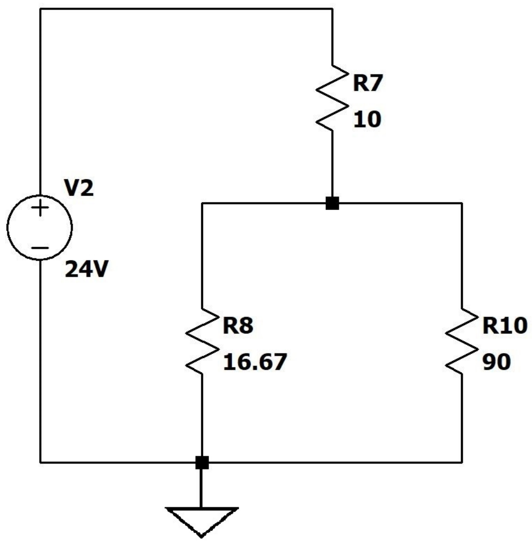

Figure 3: Modified circuit for figure 2

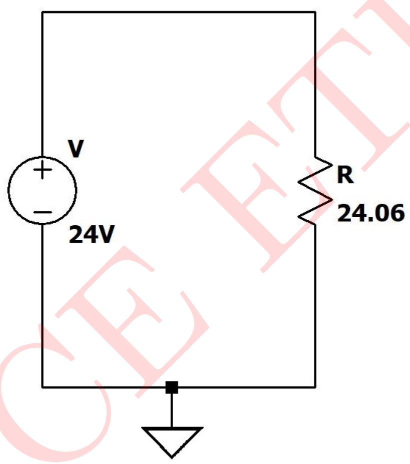

Figure 4: Modified circuit for figure 3

$$\therefore I_0 = \frac{V}{R}$$

$$\therefore I_0 = \frac{24}{24.064}$$

$$\therefore I_0 = \mathbf{0.9973\ A}$$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

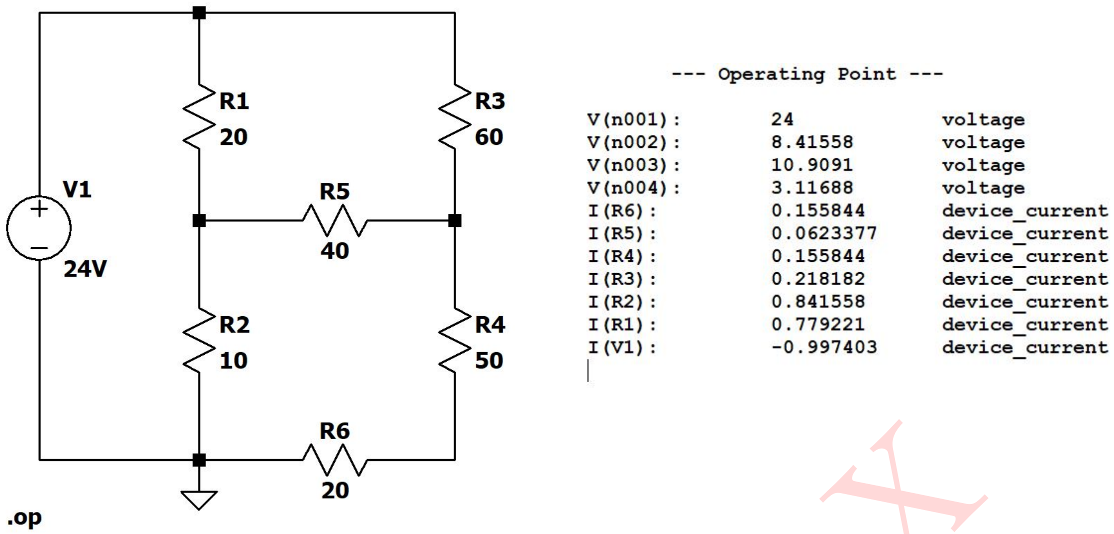

Figure 5: Circuit schematic and simulated results

Here,
$I_{V1} = I_0 = 0.9974\text{A}$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
I_0	0.9973A	0.9974A

Table 1: Numerical 1

Numerical 2: Find R_{ab} in the four way power divider circuit. Assume each element is 1Ω.

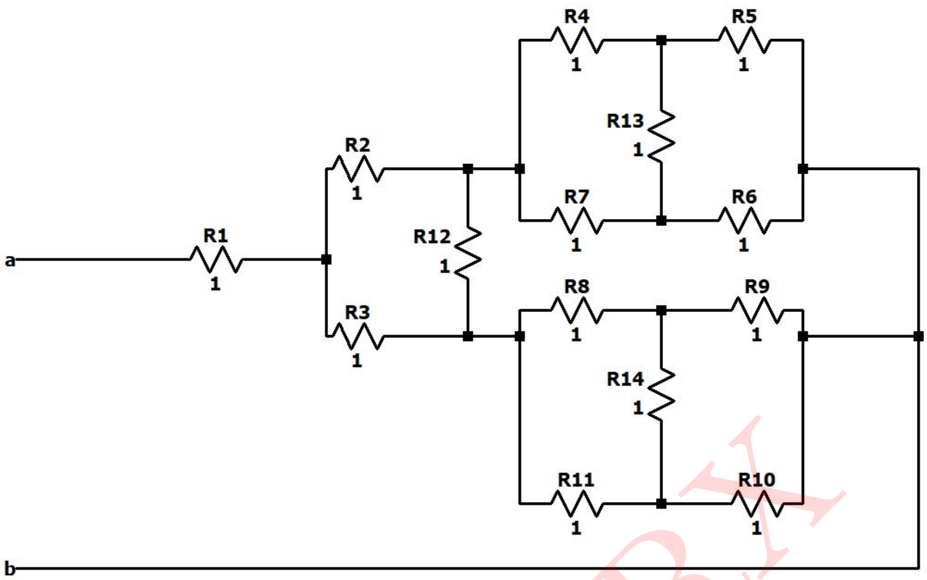

Figure 6: Circuit 2

Solution :
Since loop 1 and loop 2 form a wheatstone's bridge, current through R_{13} and R_{14} becomes zero. Therefore, R_{13} and R_{14} becomes open i.e. gets removed.

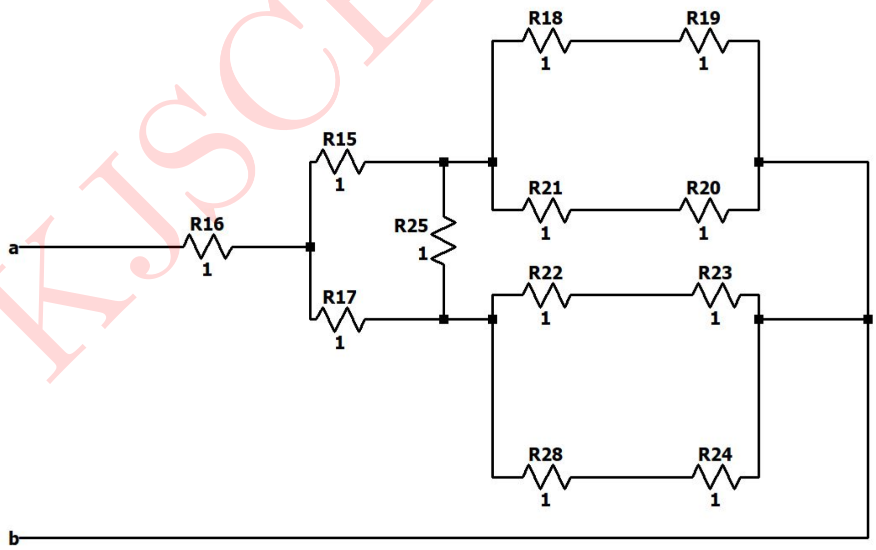

Figure 7: Modified circuit for figure 6

After simplifying the circuit we get,
Now, this loop also forms a wheatstone's bridge

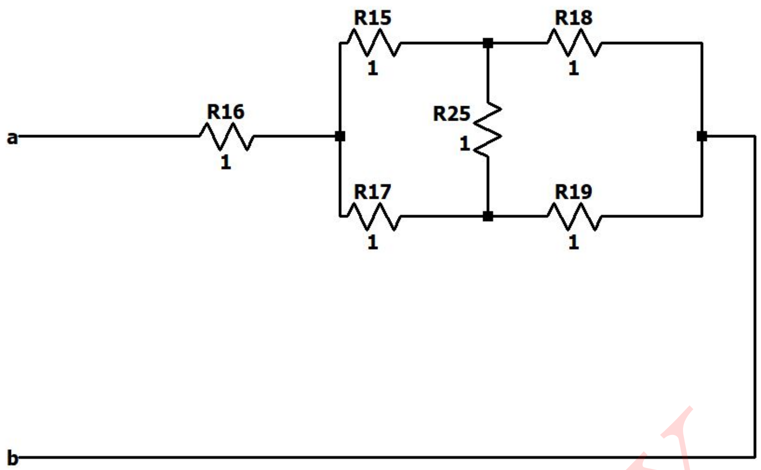

Figure 8: Modified circuit for figure 7

Therefore the resistance R_{25} gets removed.

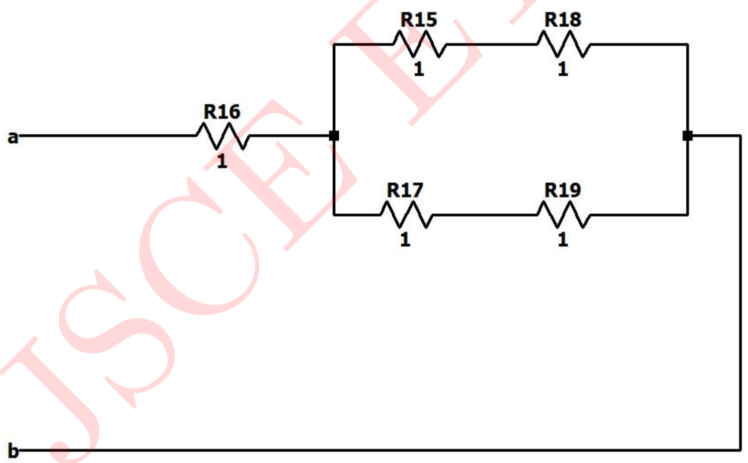

Figure 9: Modified circuit for figure 8

After simplyfing the circuit we get,

$$R_{ab} = \mathbf{2\Omega}$$

SIMULATED RESULTS:

The above circuit is simulated in LTspice. The results are presented below.

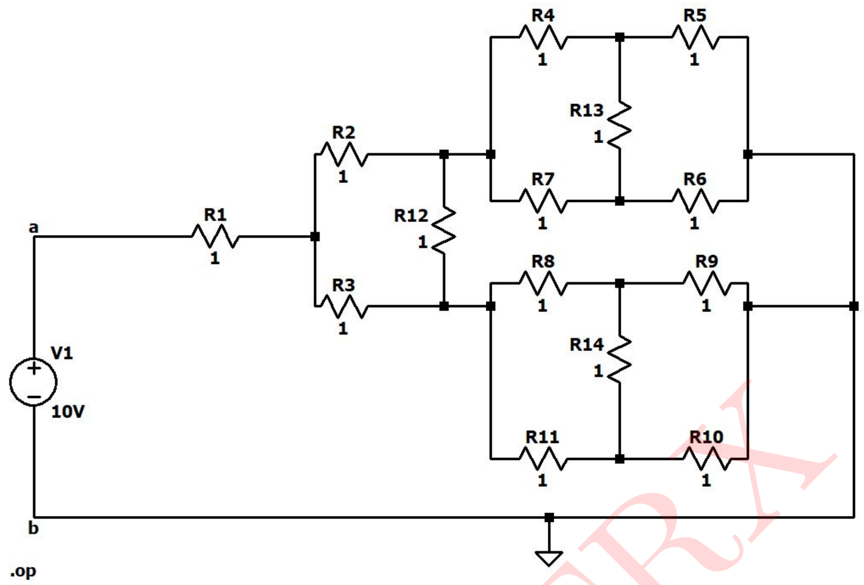

Figure 10: Circuit schematic

--- Operating Point ---

V(n001):	2.5	voltage
V(n004):	5	voltage
V(a):	10	voltage
V(n005):	2.5	voltage
V(n002):	1.25	voltage
V(n003):	1.25	voltage
V(n006):	1.25	voltage
V(n007):	1.25	voltage
I(R11):	-1.25	device_current
I(R14):	0	device_current
I(R13):	0	device_current
I(R12):	0	device_current
I(R10):	-1.25	device_current
I(R9):	-1.25	device_current
I(R8):	-1.25	device_current
I(R7):	-1.25	device_current
I(R6):	-1.25	device_current
I(R5):	-1.25	device_current
I(R4):	-1.25	device_current
I(R3):	-2.5	device_current
I(R1):	-5	device_current
I(R2):	-2.5	device_current
I(V1):	-5	device_current

Figure 11: Simulated results

Here,

$$R_{ab} = \frac{V_1}{I_{V1}}$$

$$R_{ab} = \frac{10}{5}$$

$$R_{ab} = \mathbf{2\Omega}$$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
R_{ab}	2 Ω	2 Ω

Table 2: Numerical 2

Numerical 3: Using superposition, find V_0 in the circuit 3.

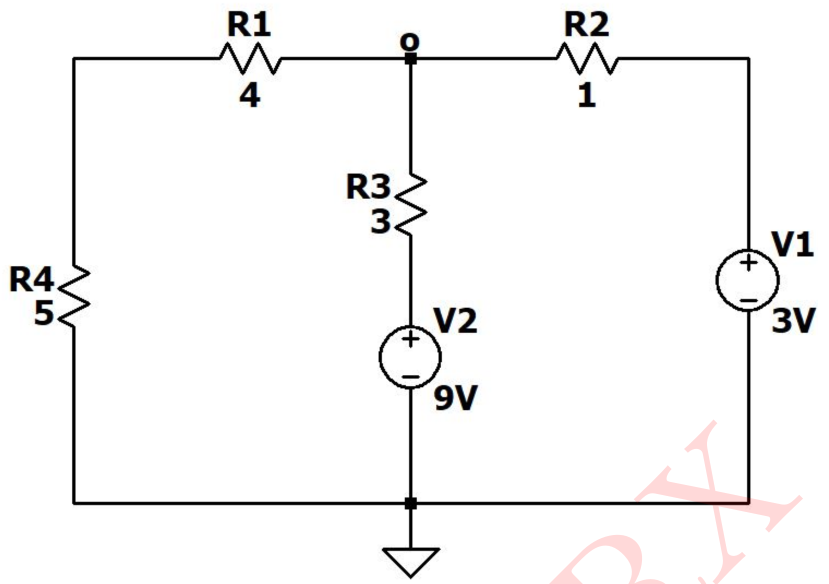

Figure 12: Circuit 3

Solution:
Step 1: When 3V source is acting alone,

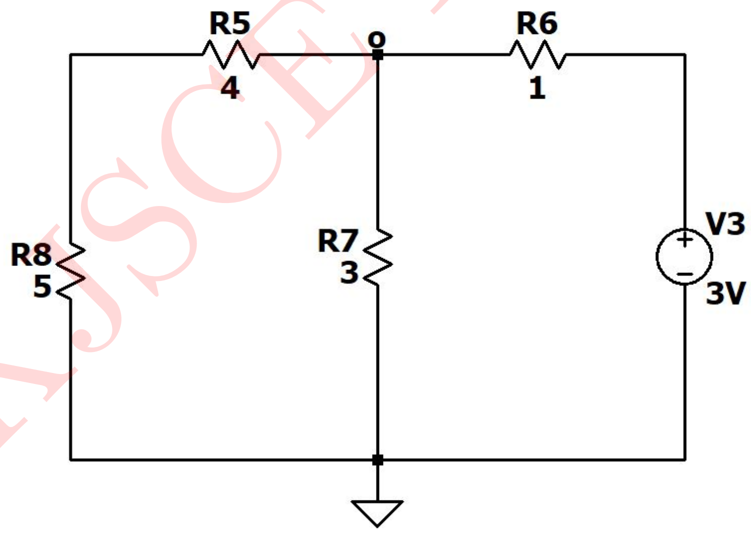

Figure 13: Modified circuit for figure 12

By further simplyfing we get,

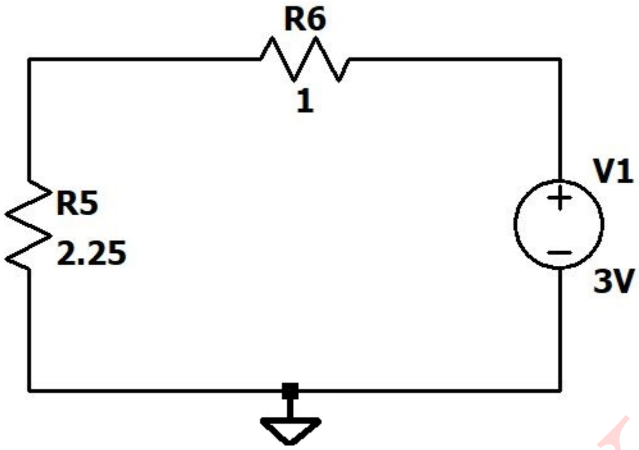

Figure 14: Modified circuit for figure 13

$$I_{ckt} = \frac{3}{3.25} = 0.9230$$
$$I_1 = 0.9230 \times \frac{3}{3+9}$$
$$I_1 = 0.2307A(\leftarrow)$$

Step 2: When 9V source is acting alone,

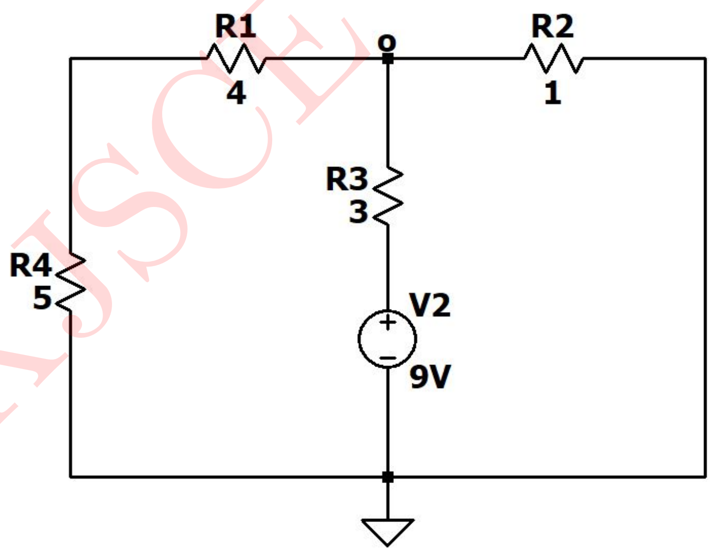

Figure 15: Modified circuit for figure 12

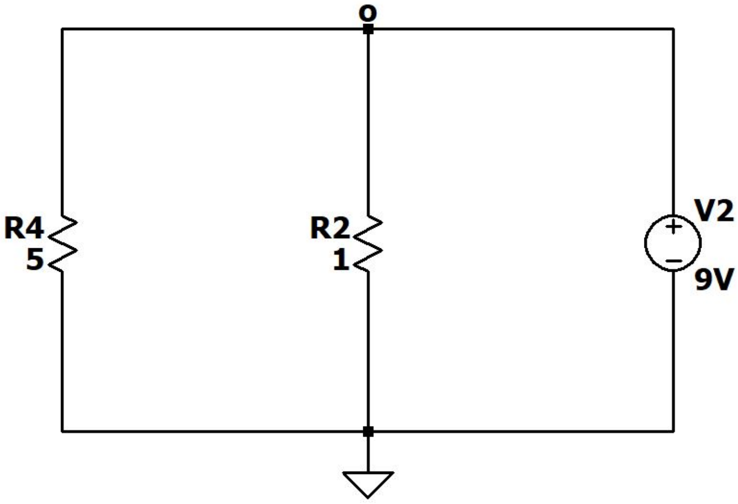

Figure 16: Modified circuit for figure 15

$$I_{ckt} = \frac{9}{3.9} = 2.3076A$$
$$\therefore I_2 = 2.3076 \times \frac{1}{1+9}$$
$$\therefore I_2 = 0.23076A(\leftarrow)$$

By Superposition Theorem,

$$\therefore I = I_1 + I_2$$
$$\therefore I = 0.2307 + 0.2307$$
$$\therefore I = 0.4615A(\rightarrow)$$
$$\therefore V_0 - 0 = I \times R$$
$$\therefore V_0 = 0.4615 \times (4+5)$$
$$\therefore V_0 = \mathbf{4.1526V}$$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

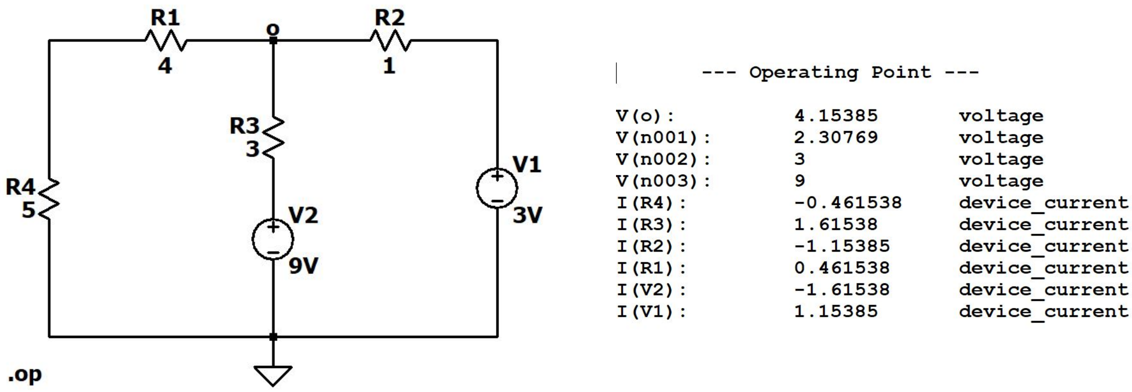

Figure 17: Circuit schematic and simulated results

Here,
$V_0 = 4.15385V$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
V_0	4.1526V	4.1538V

Table 3: Numerical 3

Numerical 4: Determine V_0 in circuit 4 using superposition principle.

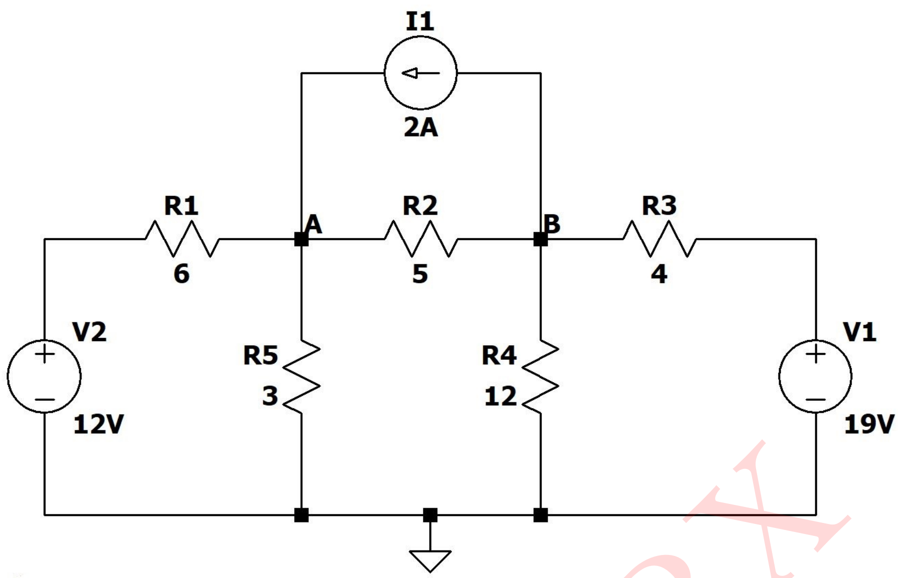

Figure 18: Circuit 4

Solution :
Step 1: When 2A source is acting alone,

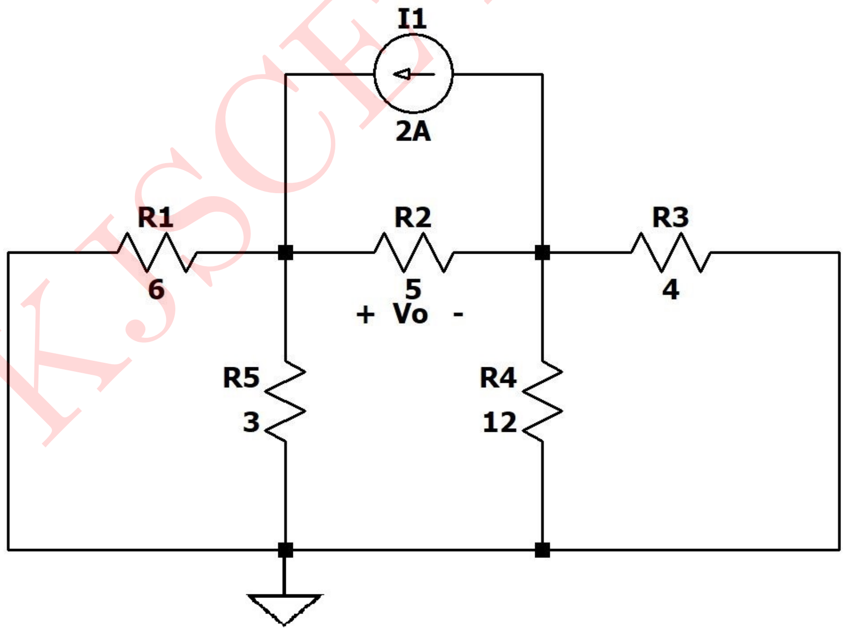

Figure 19: Modified circuit for figure 18

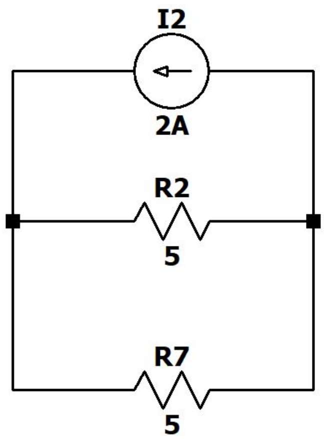

Figure 20: Modified circuit for figure 19

$\therefore I_1 = 2 \times \dfrac{5}{10}$
$\therefore I_1 = 1A(\rightarrow)$

Step 2: When 12V source is acting alone,

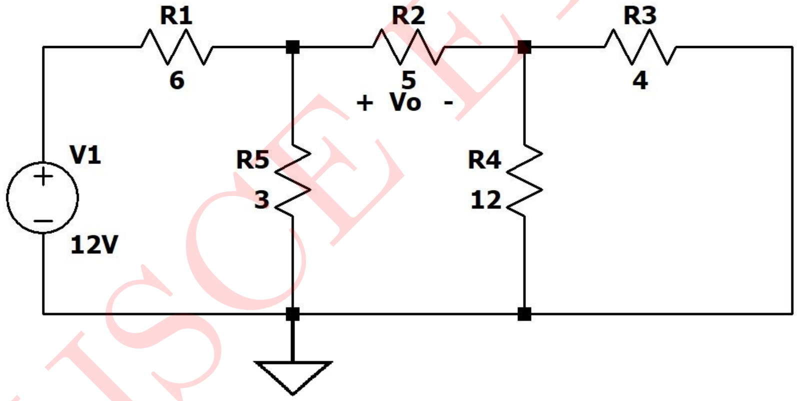

Figure 21: Modified circuit for figure 18

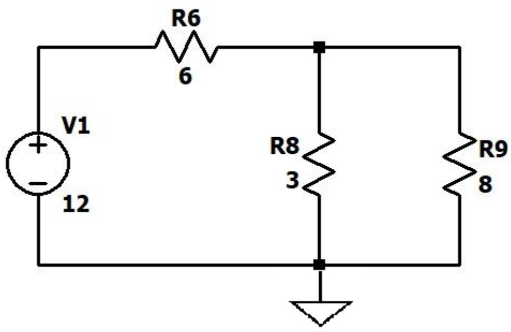

Figure 22: Modified circuit for figure 21

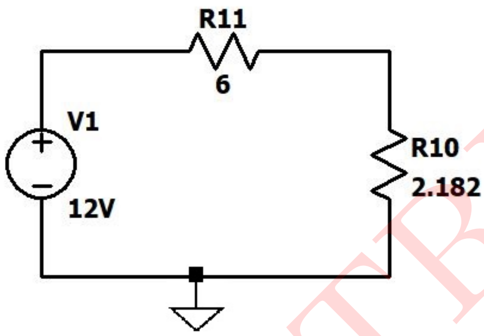

Figure 23: Modified circuit for figure 22

$$\therefore I_{ckt} = \frac{12}{6 + 2.182}$$
$$\therefore I_2 = 1.467 \times \frac{3}{3+8}$$
$$\therefore I_2 = 0.4A(\rightarrow)$$

Step 3: When 19V source is acting alone,

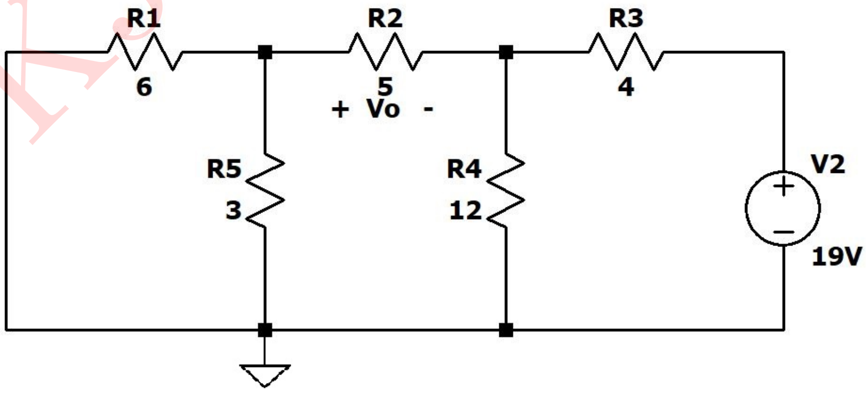

Figure 24: Modified circuit for figure 18

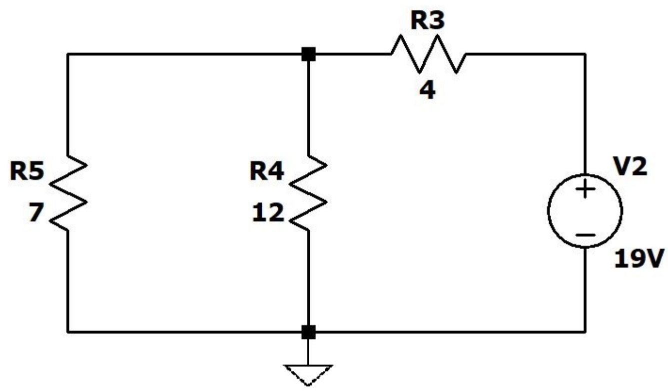

Figure 25: Modified circuit for figure 24

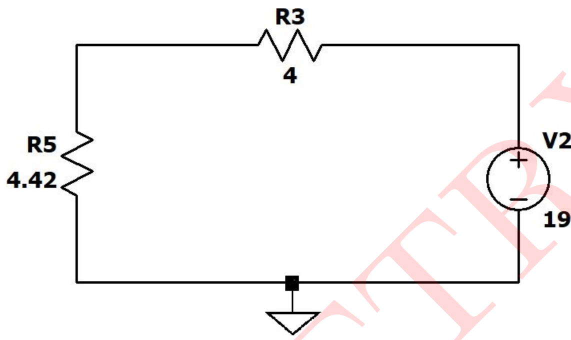

Figure 26: Modified circuit for figure 25

$$I_{ckt} = \frac{19}{8.42} = 2.256A$$
$$\therefore I_3 = 2.256 \times \frac{12}{7+12}$$
$$\therefore I_3 = 1.425A \leftarrow$$
$$\therefore I_3 = -1.425 \rightarrow$$

By Superposition Theorem,
$I_{5\Omega} = I_1 + I_2 + I_3$
$\therefore I_{5\Omega} = 1 + 0.4 - 1.425$
$\therefore I_{5\Omega} = -0.025(\rightarrow)$
$\therefore I_{5\Omega} = 0.025(\leftarrow)$

$V_0 = I_{5\Omega} \times R_{5\Omega}$
$\therefore V_0 = 0.025 \times 5$
$\therefore V_0 = \mathbf{0.125V}$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

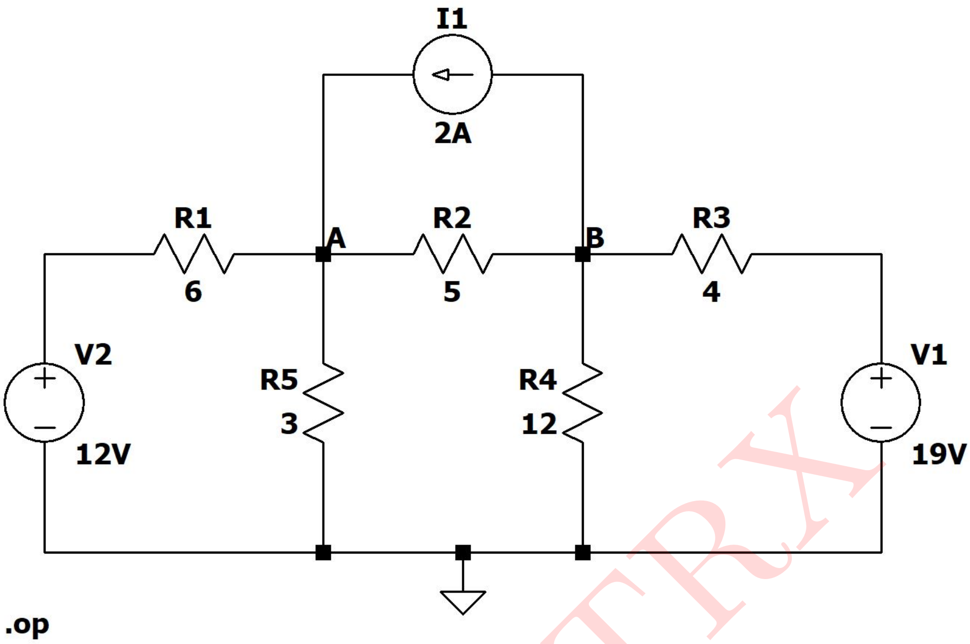

Figure 27: Circuit schematic

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--- Operating Point ---

V(a):          8.05          voltage
V(n001):       12            voltage
V(b):          8.175         voltage
V(n002):       19            voltage
I(I1):         2             device_current
I(R5):         -2.68333      device_current
I(R4):         -0.68125      device_current
I(R3):         2.70625       device_current
I(R2):         0.025         device_current
I(R1):         -0.658333     device_current
I(V2):         -0.658333     device_current
I(V1):         -2.70625      device_current
```

Figure 28: Simulated results

Here,
$V_0 = V_B - V_A = 8.175 - 8.050$
$\therefore V_0 = \mathbf{0.125V}$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
V_0	0.125V	0.125V

Table 4: Numerical 4

Numerical 5: Use Thevenin's theorem to find current in the branch AB of the network shown in Figure 29. All resistances are in ohms.

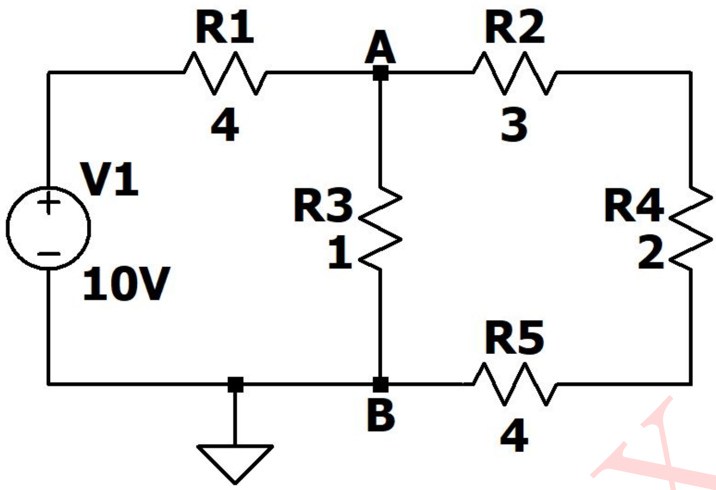


Figure 29: Circuit 5

Solution:
Step 1: Finding R_{TH},
Here, we need to replace the voltage source by a short circuit as shown in figure 30.

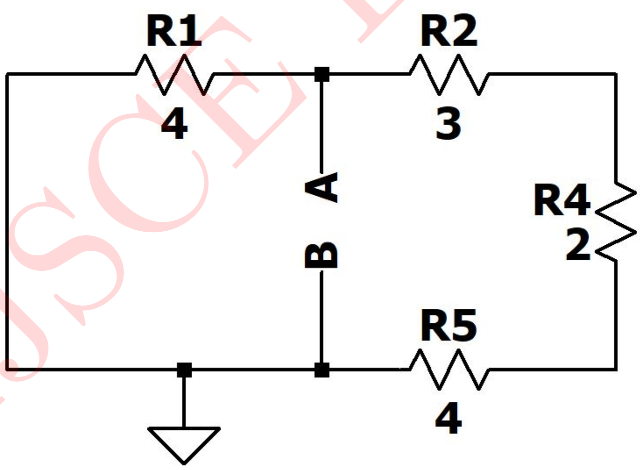


Figure 30: Modified circuit for figure 29 to find R_{TH}

After simplifiying the circuit we get,

$R_{AB} = R_{TH} = 2.769\Omega$

Step 2: Finding V_{TH},

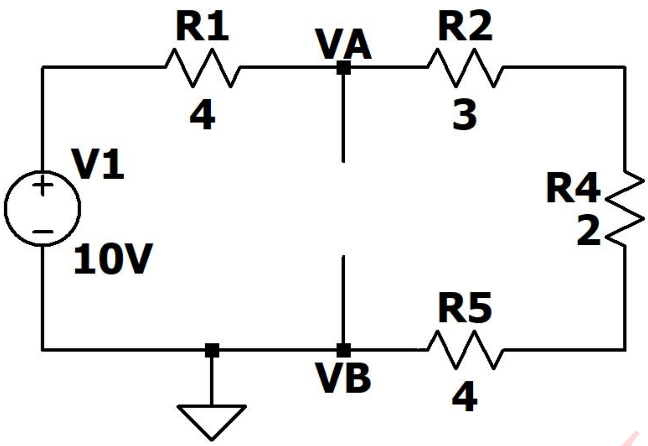


Figure 31: Modified circuit for figure 30 to find V_{TH}

By using nodal analysis,

$\therefore \frac{V_A - 10}{4} + \frac{V_A}{9} = 0$

$\therefore 13V_A - 90 = 0$

$\therefore V_{TH} = V_A = 6.9230V$

Step 3: Thevenin's equivalent circuit,
The circuit consists of resistance R_{TH} and R_L in series with voltage source V_{TH} as shown in figure 32.

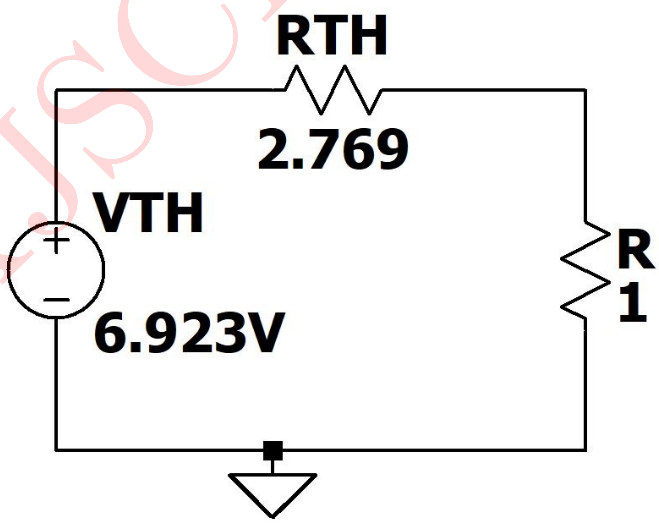


Figure 32: Thevenin's equivalent circuit

$I_{1\Omega} = \frac{6.923}{2.769 + 1} = 1.8368A$

$I_{AB} = I_{1\Omega} = \mathbf{1.8368A}$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

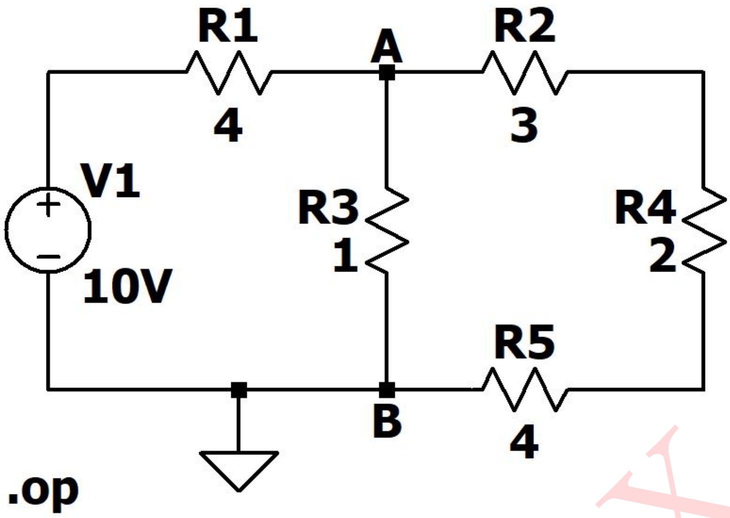


Figure 33: Circuit schematic

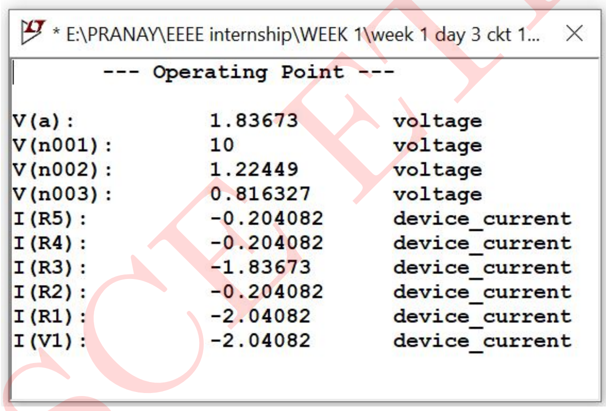


Figure 34: Simulated results

Here,
$I_{1\Omega} = I_{AB}$ = **1.83673A**

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
$I_{1\Omega}$	1.8369A	1.83673A

Table 5: Numerical 5

Numerical 6: Find the current that would flow if 2Ω resistor was connected between A and B as shown in figure 35. All resistances are in ohms.

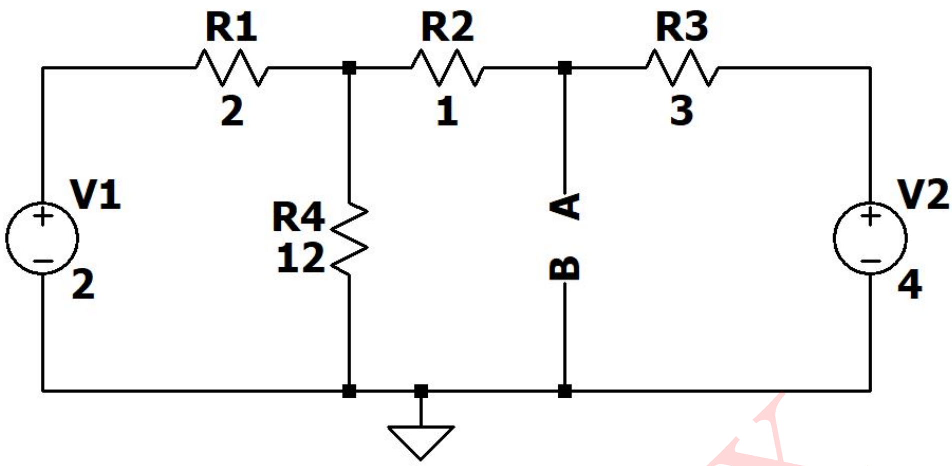


Figure 35: Circuit 6

Solution:
Step 1: Find R_{TH} or R_{AB},
Here, we need to replace voltage source with short circuit as shown in figure 35.

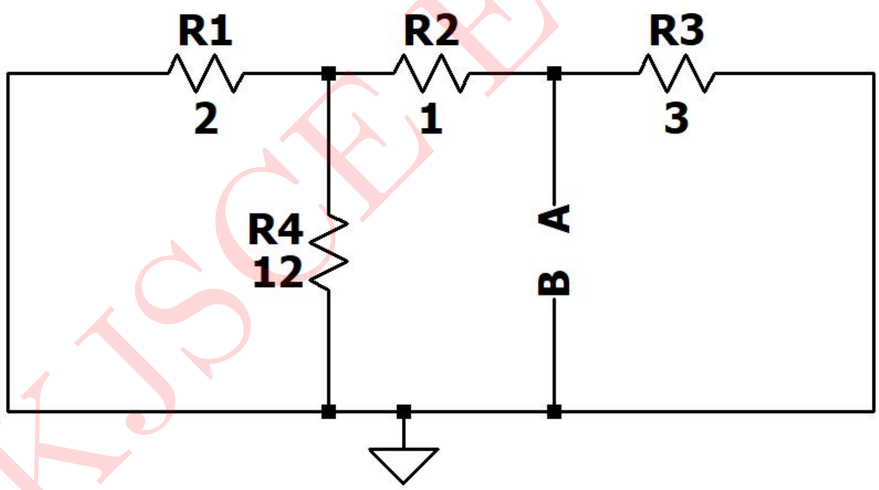


Figure 36: Modified circuit for figure 35 to find R_{TH}

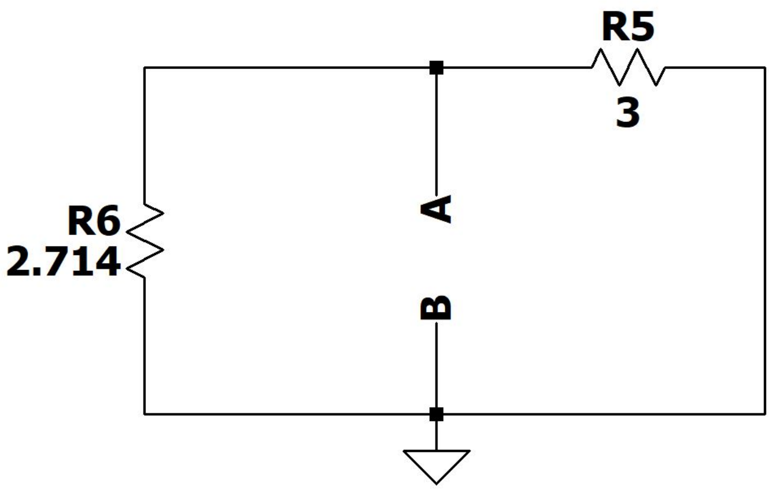


Figure 37: Modified circuit for figure 36 to find R_{TH}

$R_{AB} = R_{TH} = 1.425\Omega$

Step 2: Find V_{TH} or V_{AB},

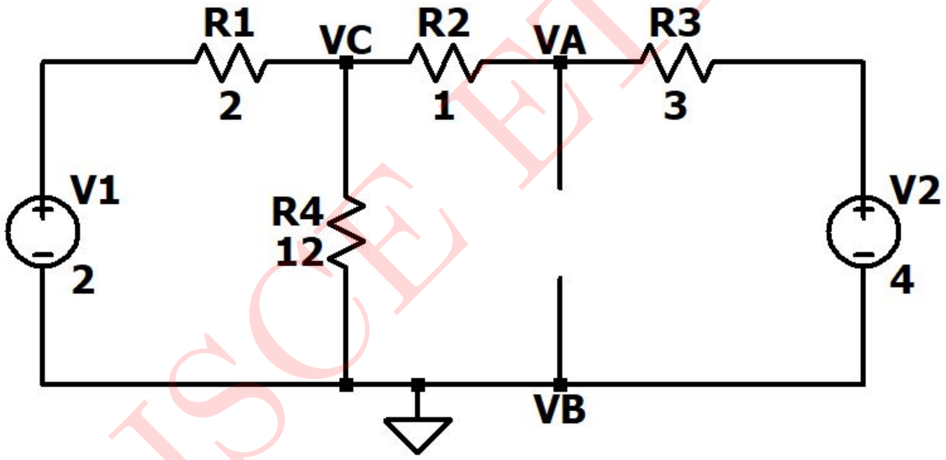


Figure 38: Modified circuit for figure 35 to find V_{TH}

By Nodal analysis,

Considering node V_C,

$\therefore \dfrac{V_C - V_A}{1} + \dfrac{V_C - 2}{2} + \dfrac{V_C}{12} = 0$

$\therefore -12V_A + 19V_C = 12$ ....(1)

Considering node V_A,

$\therefore \dfrac{V_A - 4}{3} + \dfrac{V_A - V_C}{1} = 0$

$\therefore 4V_A - 3V_C = 4$ ....(2)

After solving equation (1) and (2) we get,
$V_A = 2.8V$

Step 3: Thevenin's equivalent circuit,

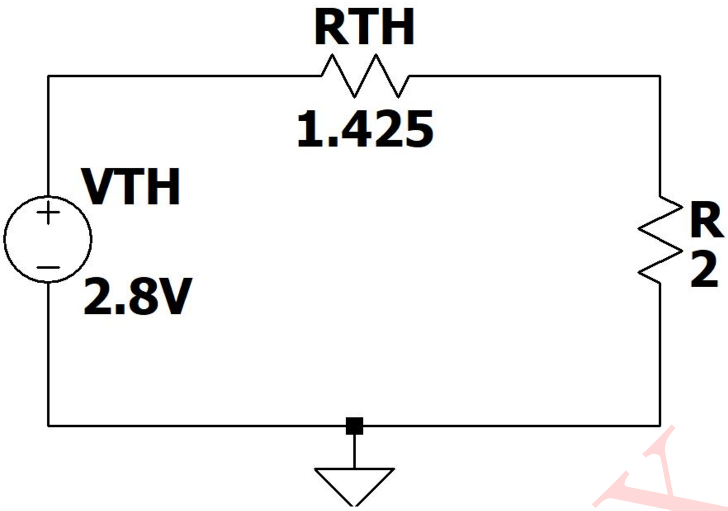


Figure 39: Thevenin's equivalent circuit

$I_{AB} = \dfrac{2.8}{1.425 + 2} = 0.8175A$

$I_{Ab} = I_{2\Omega}$ $=$ $\mathbf{0.8175A}$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

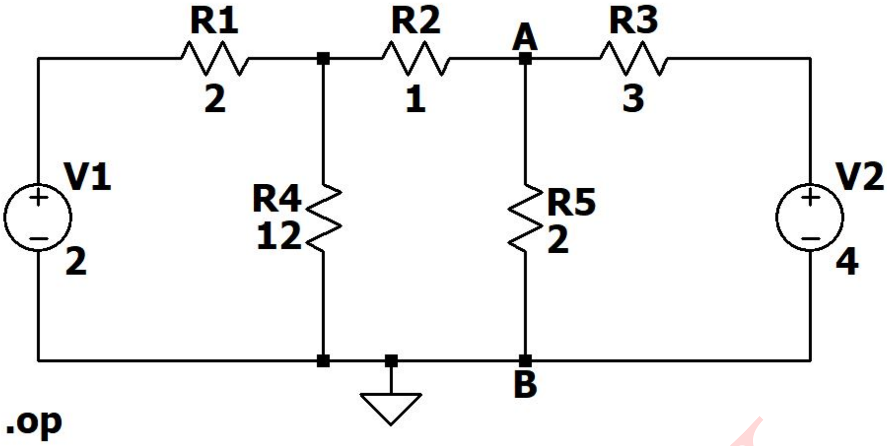
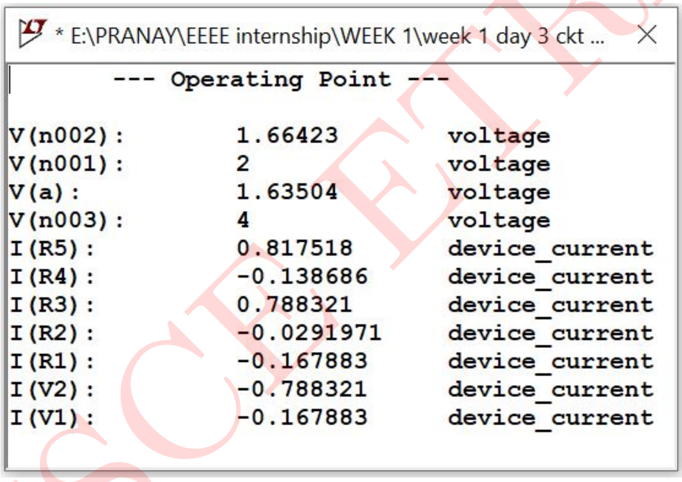


Figure 40: Circuit schematic



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       --- Operating Point ---

V(n002):        1.66423       voltage
V(n001):        2             voltage
V(a):           1.63504       voltage
V(n003):        4             voltage
I(R5):          0.817518      device_current
I(R4):          -0.138686     device_current
I(R3):          0.788321      device_current
I(R2):          -0.0291971    device_current
I(R1):          -0.167883     device_current
I(V2):          -0.788321     device_current
I(V1):          -0.167883     device_current
```

Figure 41: Simulated results

Here,
$I_{R5} = I_{AB}$ = **0.8175A**

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
I_{AB}	0.8175A	0.8175A

Table 6: Numerical 6

Numerical 7: Find the Thevenin and Norton equivalent circuits for the active network shown in Figure 42. All resistance are in ohms.

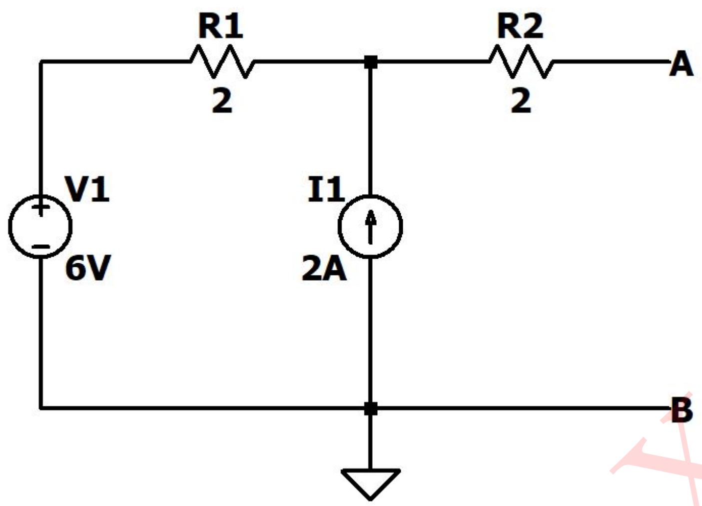


Figure 42: Circuit 7

1] For Thevenin's circuit:
Step 1: Finding V_{TH},

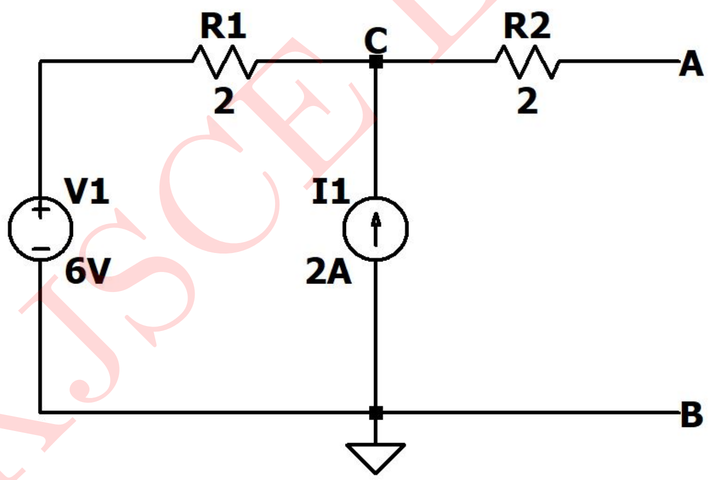


Figure 43: Modified circuit for figure 42 to find V_{TH}

By nodal analysis, Considering node C,

$$\frac{V_C - V_A}{2} - 2 + \frac{V_C - 6}{2} = 0$$

$\therefore 2V_C - V_A - 6 = 4$

$\therefore -V_A + 2V_C = 10$ ....(1)

Considering node A,

$V_A - V_C = 0$ ....(2)

On solving (1) and (2) we get,

$V_A = V_{TH}$ **= 10V**

Step 2: Finding R_{AB},
Here, we replace the voltage source by short circuit and current source by open circuit. Therefore the circuit gets reduced to figure 44.

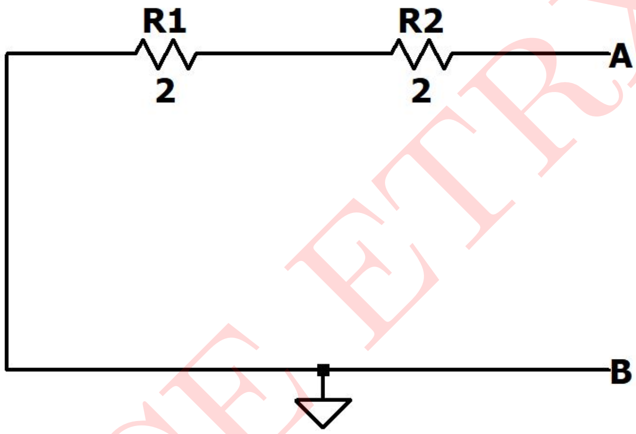


Figure 44: Modified circuit for figure 42 to find R_{TH}

Here, we replace the voltage source by short circuit and current source by open circuit.
$R_{AB} = 4\Omega$

Step 3: Thevenin's equivalent circuit,
The circuit consists of R_{TH} in series with voltage source V_{TH} as shown in figure 45,

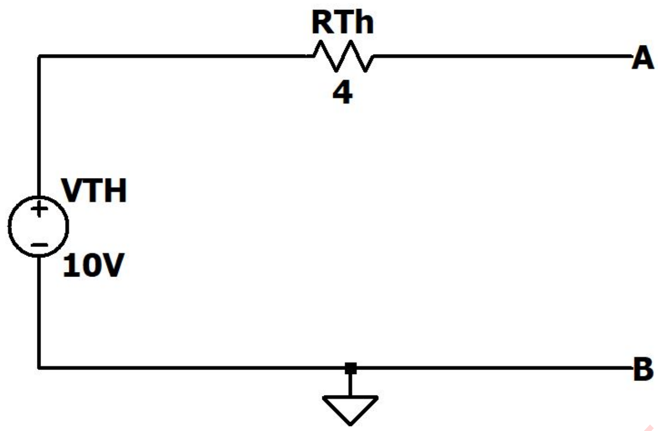


Figure 45: Thevenin's equivalent circuit

2] For Norton's circuit:

Step 1: Finding I_{SC},

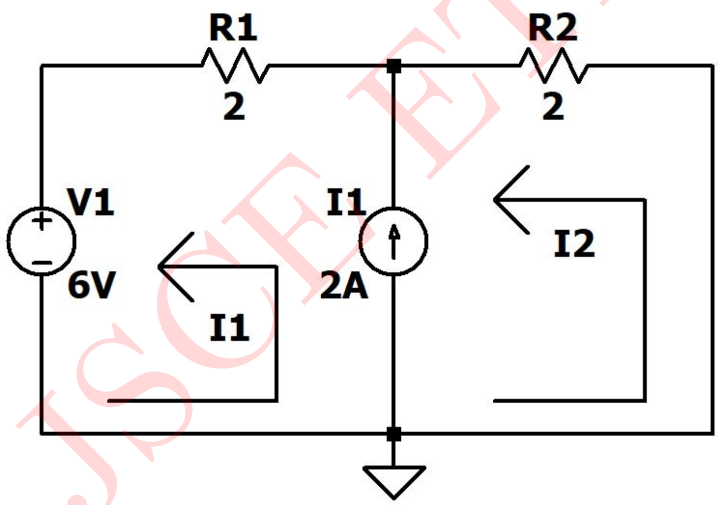


Figure 46: Modified circuit for figure 42 to find I_{SC}

By supermesh,

Supermesh equation,

$I_1 - I_2 = 2$ ....(3)

Applying mesh analysis to outer loop,

$I_1 + I_2 = 3$ ....(4)

On solving equation (3) and (4) we get,

$I_2 = I_{SC}$ $=$ **2.5A**

Step 2: Norton's equivalent circuit,
We know,
$R_{th} = R_N = 4\Omega$

The circuit consists of R_N in parallel with current source I_{SC} as shown in the figure 47,

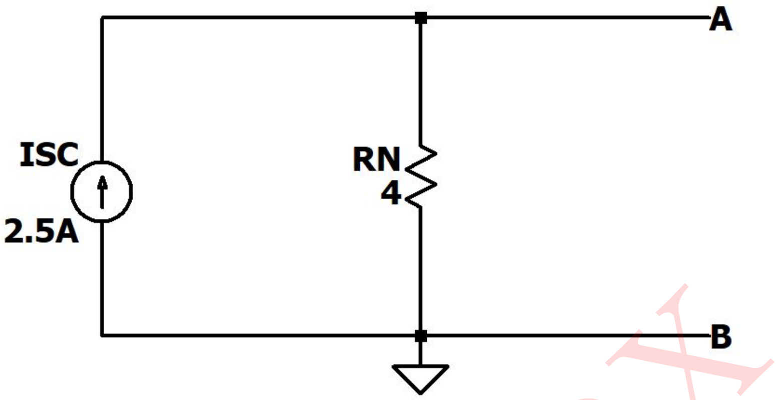


Figure 47: Norton's equivalent circuit

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

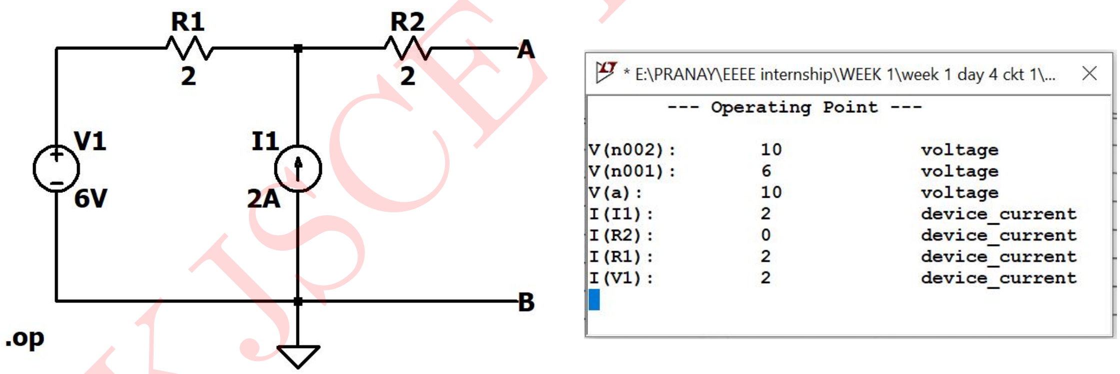


Figure 48: Circuit schematic and simulated results: To find V_{TH}

Here,
$V_{TH} = V_A = \mathbf{10V}$

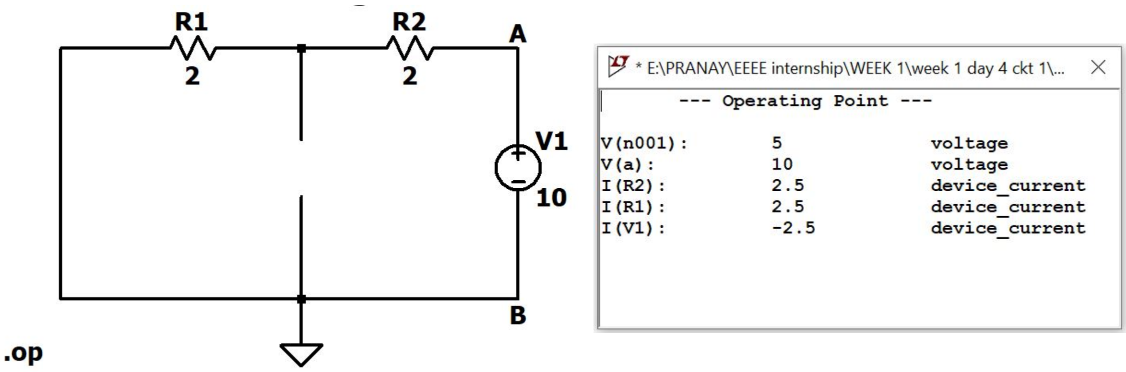


Figure 49: Circuit schematic and simulated results: To find R_{TH}

Here,

$$R_{TH} = R_{AB} = \frac{V_A}{I_{V1}}$$

$$\therefore R_{TH} = R_{AB} = \frac{10}{2.5}$$

$$\therefore R_{TH} = R_{AB} = 4\Omega$$

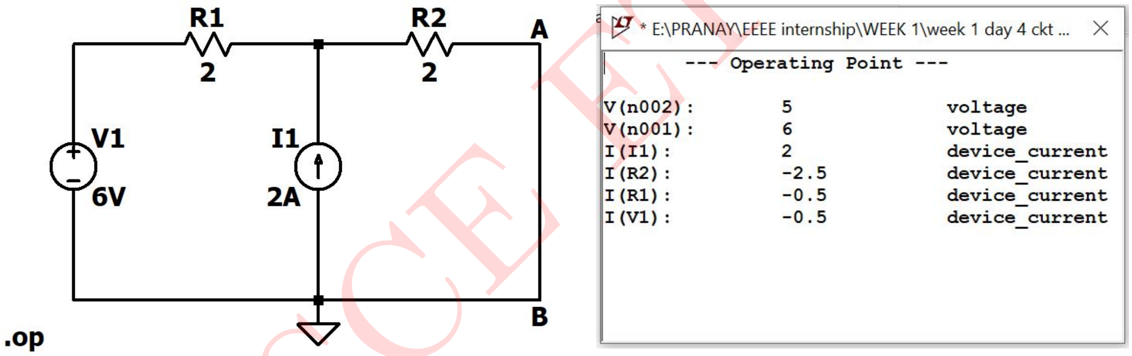


Figure 50: Circuit schematic and simulated results: To find I_{SC}

Here, $I_{SC} = I_{R2} = \mathbf{2.5A}$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
V_{TH}	10V	10V
I_{SC}	2.5A	2.5A
R_{AB}	4Ω	4Ω

Table 7: Numerical 7

Numerical 8: Determine current and voltage across 3kΩ resistor in Figure 51.

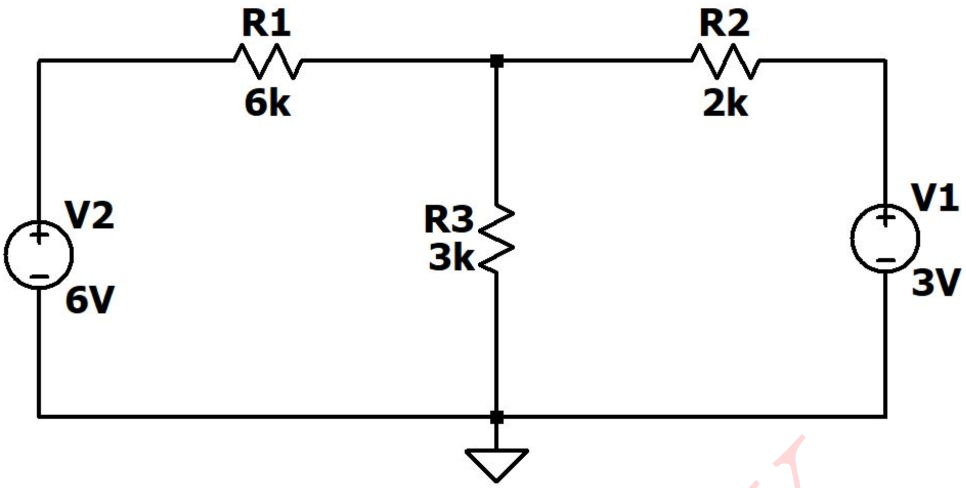


Figure 51: Circuit 8

Step 1: Finding I_{SC} or I_N,
Here, we need to replace 3kΩ resistor with a short circuit.

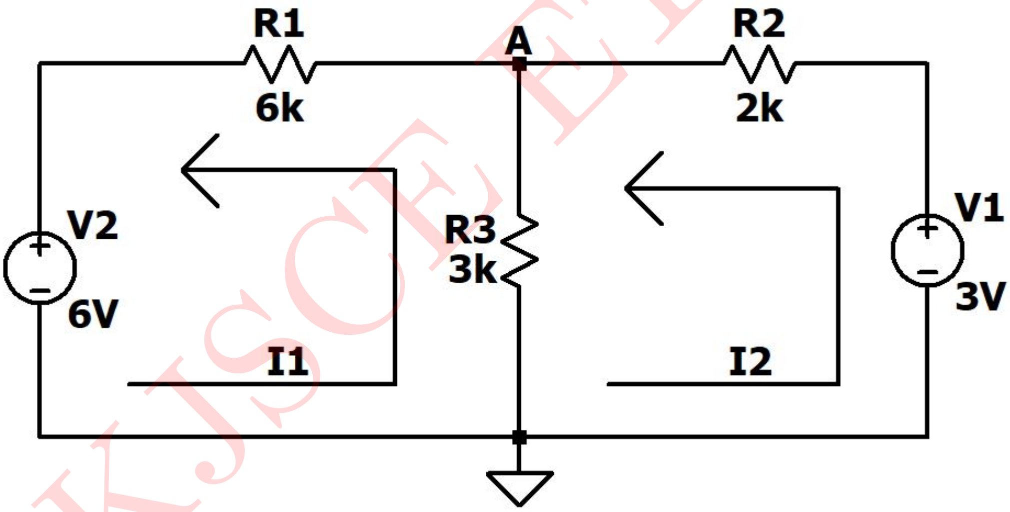


Figure 52: Modified circuit for figure 51 to find I_{SC}

By applying mesh analysis we get,

$-10^3 \times 6I_1 = 6$

$\therefore I_1 = -1 \times 10^{-3} = -1mA$

$-10^3 \times 2I_2 = 3$

$\therefore I_1 = 1.5mA$

$I_{SC} = I_2 - I_1$

$\therefore I_{SC} = 1.5 - (-1)$

$\therefore I_{SC} = 2.5mA$

Step 2: Finding R_{AB} or R_N,
Here, we need to replace both the voltage source with short circuit.As shown in the figure 53.

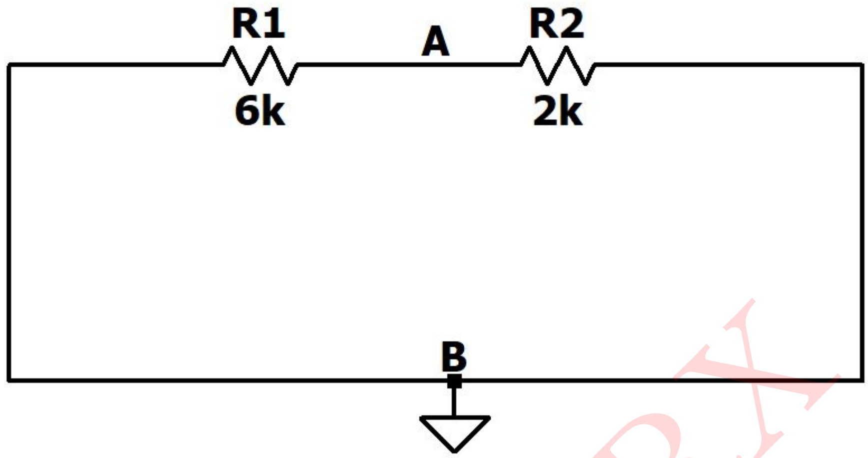


Figure 53: Modified circuit for figure 51 to find R_{TH}

After solving we get,

$R_{AB} = 6\Omega \mid\mid 2\Omega$

$\therefore R_{AB} = 1.5\text{k}\Omega$

Step 3: Norton's equivalent circuit,
The circuit consists of R_N in parallel with current source I_{SC} as shown in the figure 54.

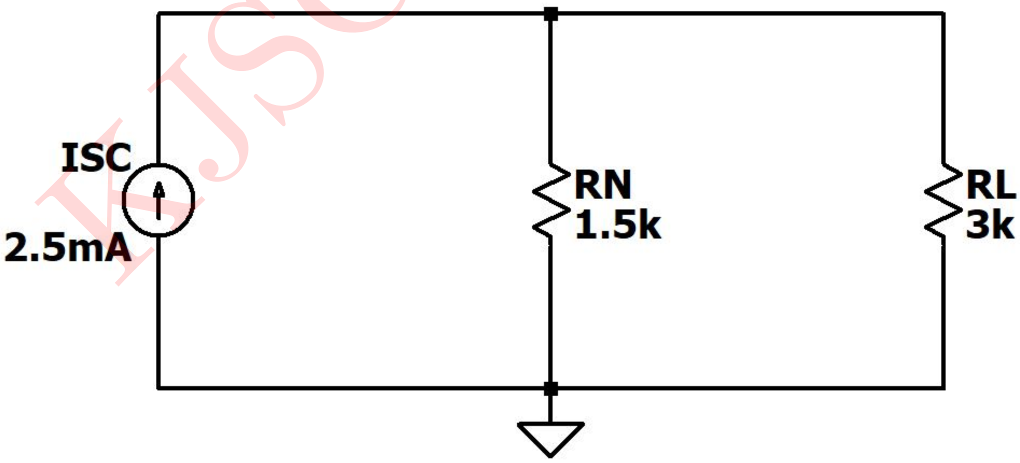


Figure 54: Norton's equivalent circuit

By using current division formula,

$$I_{3k\Omega} = 2.5 \times 10^{-}3 \times \frac{1.5 \times 10^3}{(1.5+3) \times 10^3}$$
$$\therefore I_{3k\Omega} = \mathbf{0.8333mA}$$

$$V_{3k\Omega} = I \times R = 0.8333 \times 10^{-}3 \times 3 \times 10^3$$
$$\therefore V_{3k\Omega} = \mathbf{2.5V}$$

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below. Here,

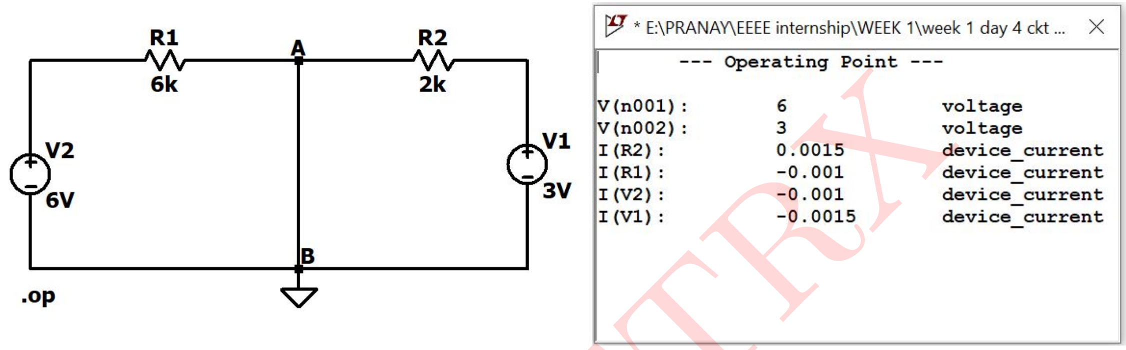


Figure 55: Circuit schematic and simulated results: To find V_{TH}

$$I_{SC} = I_{AB} = I_{R2} - I_{R1}$$
$$\therefore I_{SC} = I_{AB} = 0.0015 - (-0.001)$$
$$\therefore I_{SC} = I_{AB} = 0.0025 = 2.5mA$$

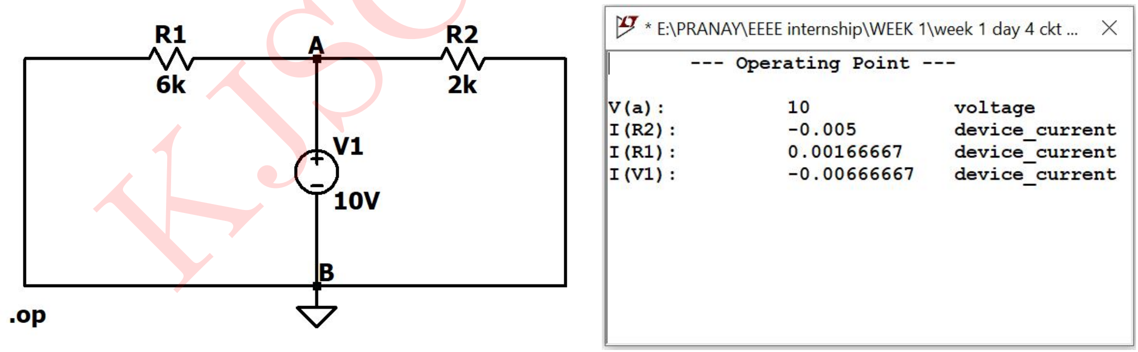


Figure 56: Circuit schematic and simulated results: To find R_{TH}

Here,
$$R_N = R_{AB} = \frac{V1}{I_{V1}}$$
$$\therefore R_N = R_{AB} = \frac{10}{0.006667}$$
$$\therefore R_N = R_{AB} = 1.5k\Omega$$

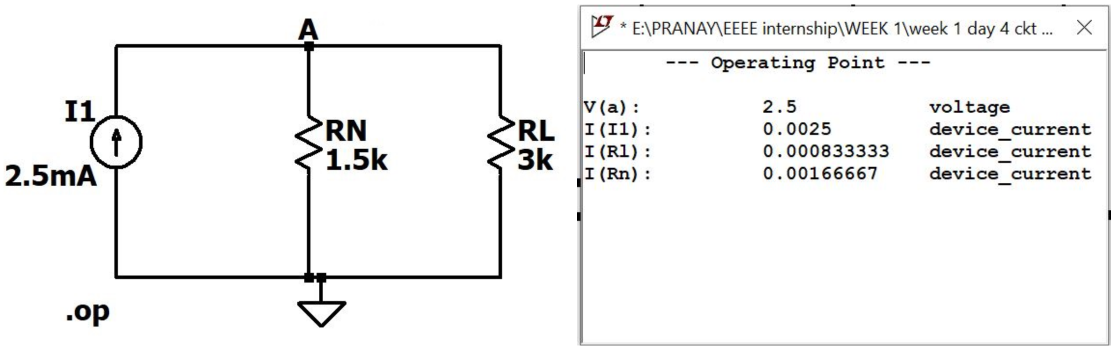


Figure 57: Circuit schematic and simulated results: To find I_{SC}

Here,
$V_A = V_{3\Omega} = \mathbf{2.5V}$

$I_{RL} = I_{3\Omega} = \mathbf{0.8333mA}$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
$I_{3k\Omega}$	0.8333mA	0.8333mA
$V_{3k\Omega}$	2.5V	2.5V

Table 8: Numerical 8

Numerical 9: Find the value of R_L for maximum power transfer in the Figure 58. Find the maximum power.

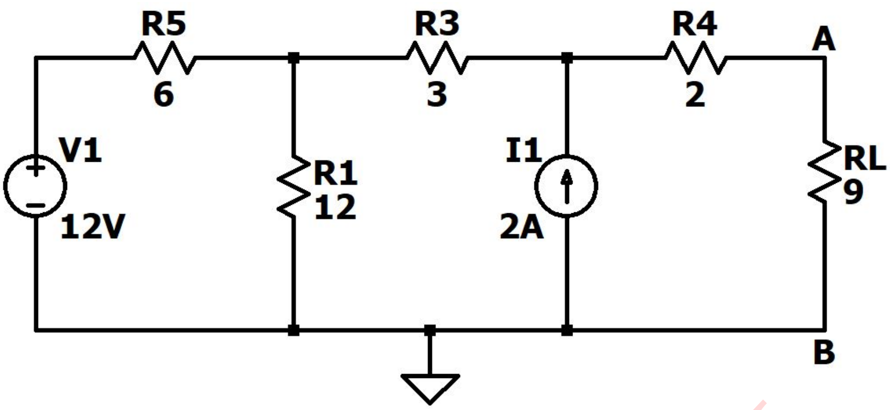


Figure 58: Circuit 9

Solution:
Step 1: Finding R_{TH},
Here, we need to replace the voltage source by a short circuit and current source by open circuit as shown in figure 59.

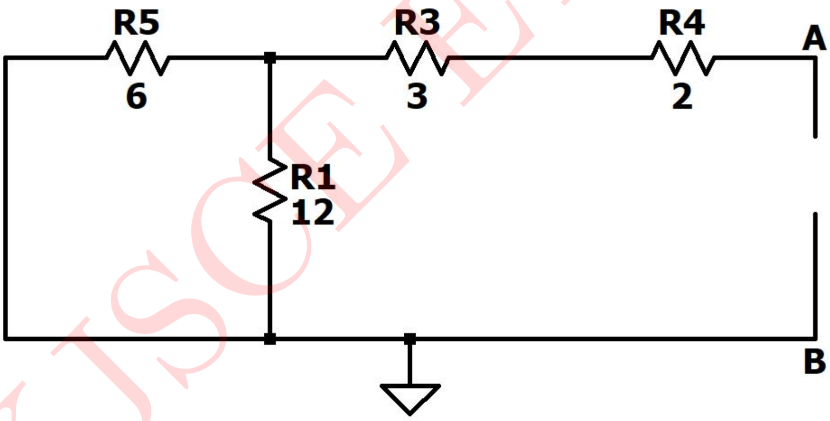


Figure 59: Modified circuit for figure 58 to find R_{TH}

After simplifiying the circuit we get,

$R_{AB} = R_{TH} = 6||12 + 3 + 2$

$R_{AB} = R_{TH} = 4 + 5$

$R_{AB} = R_{TH} = 9\Omega$

Step 2: Finding V_{TH},

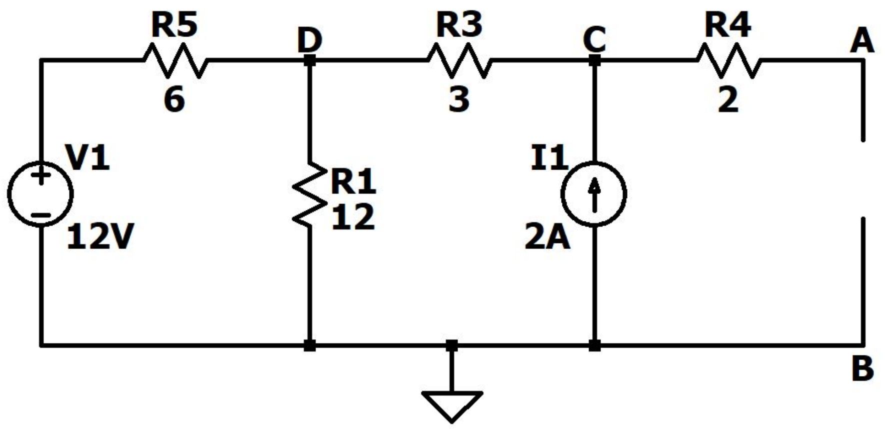


Figure 60: Modified circuit for figure 58 to find V_{TH}

By using nodal analysis,

Considering node A,

$\therefore \dfrac{V_A - V_C}{2} = 0$

$\therefore V_A - V_C = 0$ ....(1)

Considering node C,

$\therefore \dfrac{V_C - V_A}{2} + \dfrac{V_C - V_D}{3} = 2$

$\therefore -3V_A + 5V_C - 2V_D = 12$ ....(2)

Considering node D,

$\therefore \dfrac{V_D - 12}{6} + \dfrac{V_D}{12} + \dfrac{V_D - V_C}{3} = 0$

$\therefore -4V_C + 7V_D = 0$ ....(3)

On solving equations (1),(2) and (3) we get,

$V_A = 22V$

For maximum power transfer,

$R_L = R_{TH} = 9\Omega$

Maximum power,

$P_{max} = \dfrac{(V_{TH})^2}{4R_L}$

$P_{max} = \dfrac{(22)^2}{4 \times 9}$

P_{max} = **13.44W**

SIMULATED RESULTS:
The above circuit is simulated in LTspice. The results are presented below.

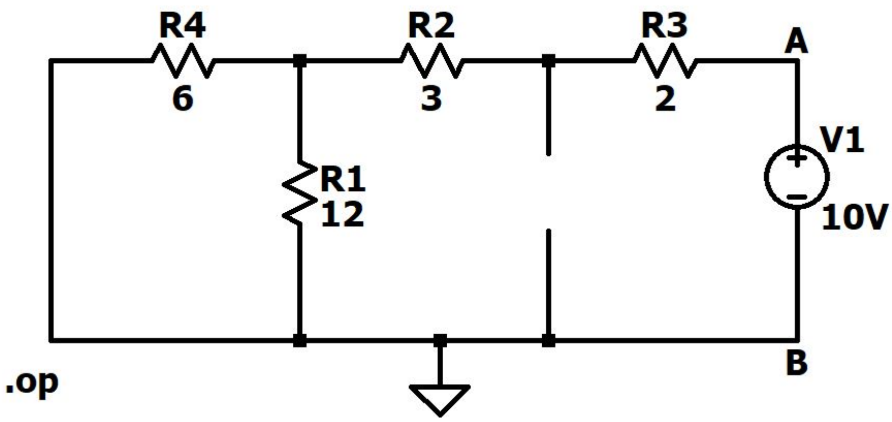
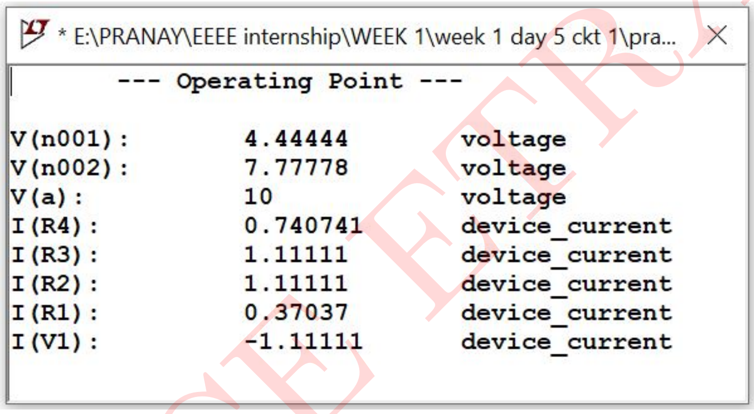


Figure 61: Circuit schematic for finding R_{TH}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--- Operating Point ---

V(n001):	4.44444	voltage
V(n002):	7.77778	voltage
V(a):	10	voltage
I(R4):	0.740741	device_current
I(R3):	1.11111	device_current
I(R2):	1.11111	device_current
I(R1):	0.37037	device_current
I(V1):	-1.11111	device_current

Figure 62: Simulated results for finding R_{TH}

Here,
$I_{V_1} = 1.111A$

$R_{AB} = \frac{V_1}{I_{V_1}} = \frac{10}{1.111}$

$R_{AB} = R_{TH} = 9.00\Omega$

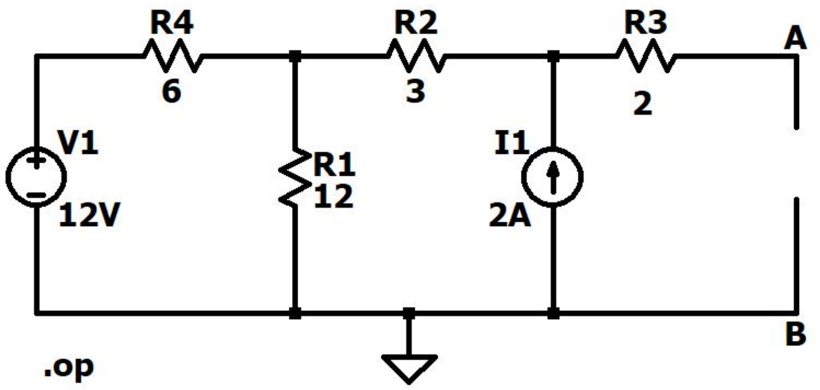


Figure 63: Circuit schematic for finding V_{TH}

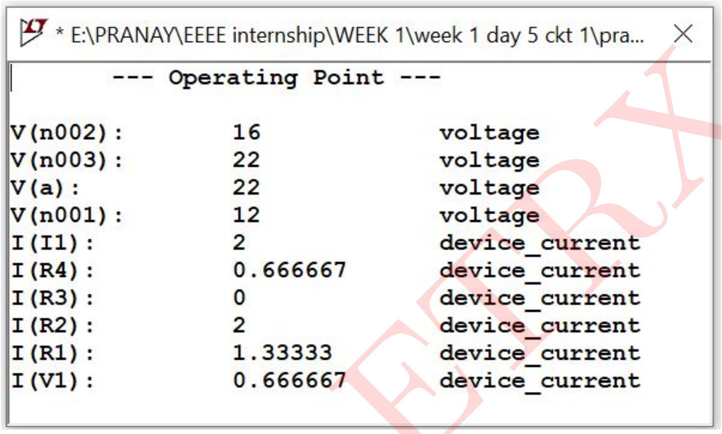


Figure 64: Simulated results for finding V_{TH}

Here,
$V_{TH} = V_{AB} = 22V$

For maximum power transfer,

$R_L = R_{TH} = 9\Omega$

Maximum power,

$$P_{max} = \frac{(V_{TH})^2}{4R_L}$$

$$P_{max} = \frac{(22)^2}{4 \times 9}$$

$$P_{max} = \mathbf{13.44W}$$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
R_L	9Ω	9Ω
P_{max}	13.44W	13.44W

Table 9: Numerical 9

Numerical 10: Consider the bridge circuit. Is the bridge balanced? If the 10kΩ resistance is replaced by an 18kΩ resistor, what resistor connected between A-B absorbs the maximum power? What is the power?

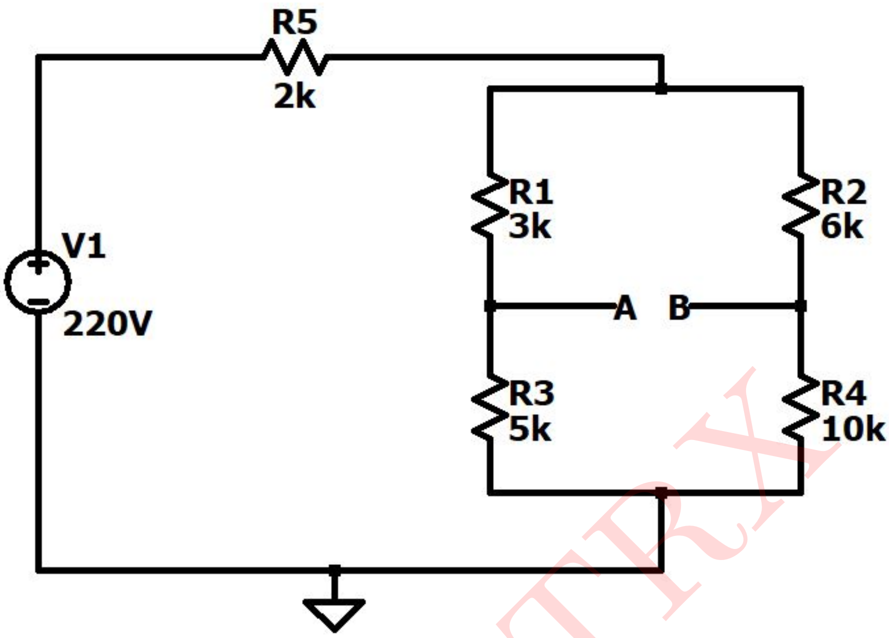


Figure 65: Circuit 10

Solution:

Part 1: To find whether the bridge is balanced or not.

$$\therefore \frac{R_1}{R_2} = \frac{3 \times 10^3}{5 \times 10^3} = 0.6$$

$$\therefore \frac{R_3}{R_4} = \frac{6 \times 10^3}{10 \times 10^3} = 0.6$$

$$\therefore \frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Since the ratio of resistances is equal the bridge is balanced.

Part 2: Solving futher by replacing 10kΩ resistor with 18kΩ resistor.

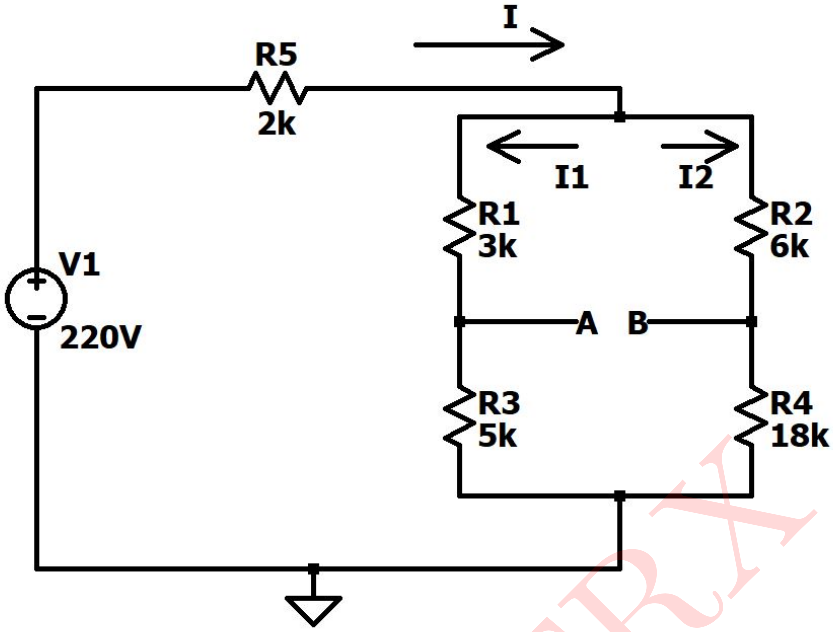


Figure 66: Modified circuit for figure 65 to solve part 2

Step 1: Find V_{TH} or V_{AB},

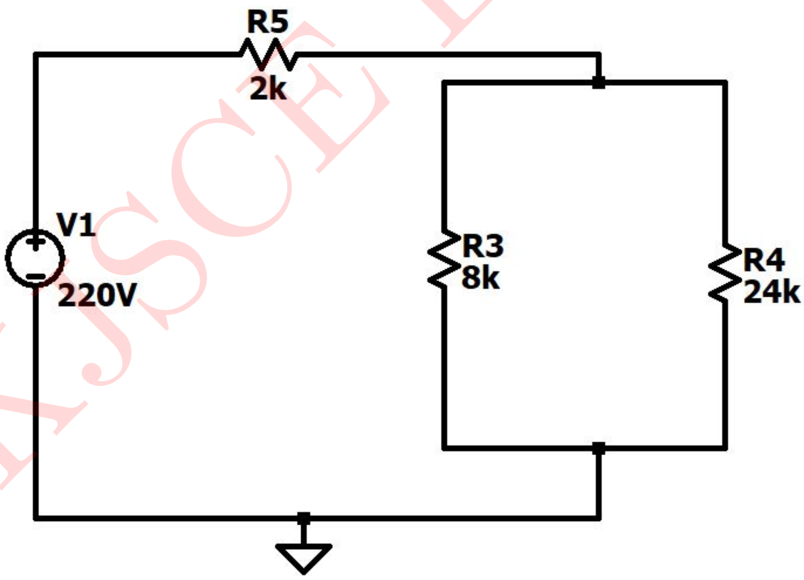


Figure 67: Modified circuit for figure 66 to find V_{TH}

$$I = \frac{200}{8 \times 10^3}$$
$$I = 27.5mA$$
$$I_2 = 27.5 \times \frac{8}{8+24} = 6.875mA$$
$$I_1 = 27.5 \times \frac{24}{8+24} = 20.625mA$$

Writing V_{TH} equation,

$V_{TH} - 3 \times 20.625 + 6 \times 6.875 = 0$

$V_{TH} = V_{AB} = 20.625V$

Step 2: Find R_{TH} or R_{AB},
Here, we need to replace voltage source with short circuit as shown in figure 68.

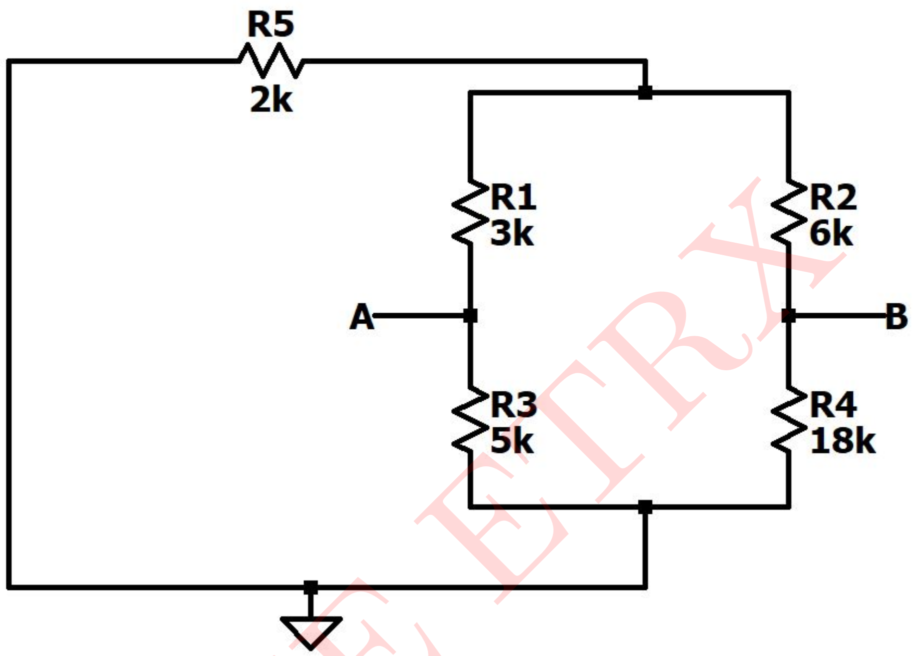


Figure 68: Modified circuit for figure 65 to find R_{TH}

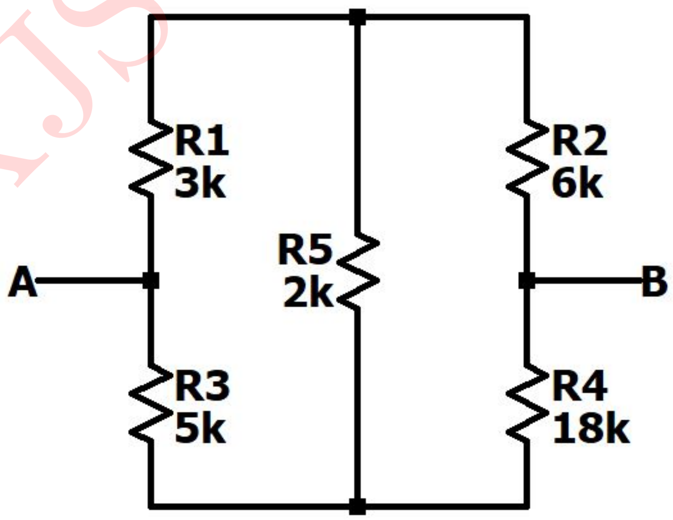


Figure 69: Modified circuit for figure 68 to find R_{TH}

Using delta to star conversion,

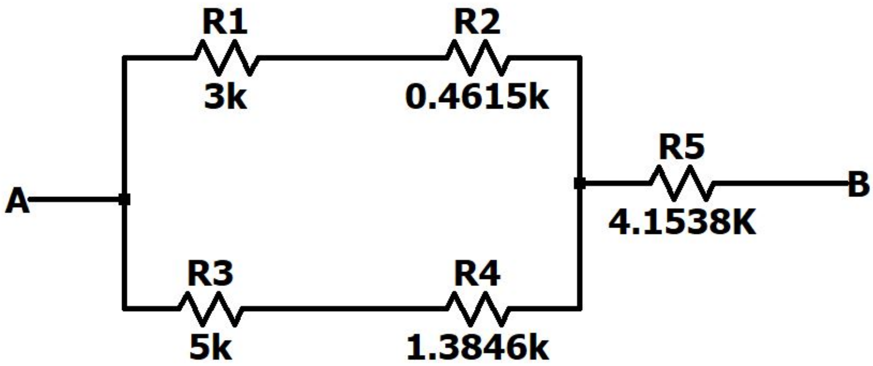


Figure 70: Modified circuit for figure 69 to find R_{TH}

After simplifing we get,

$R_{TH} = 6.3846k\Omega$

For maximum power transfer,

$R_{AB} = R_{Th} = 6.3846k\Omega$

Maximum power,

$$P_{max} = \frac{(V_{TH})^2}{4R_L}$$

$$P_{max} = \frac{(20.625)^2}{4 \times 6.346 \times 10^3}$$

P_{max} **= 16.656mW**

SIMULATED RESULTS:

The above circuit is simulated in LTspice. The results are presented below.

Part 1: To find whether the bridge is balanced or not.

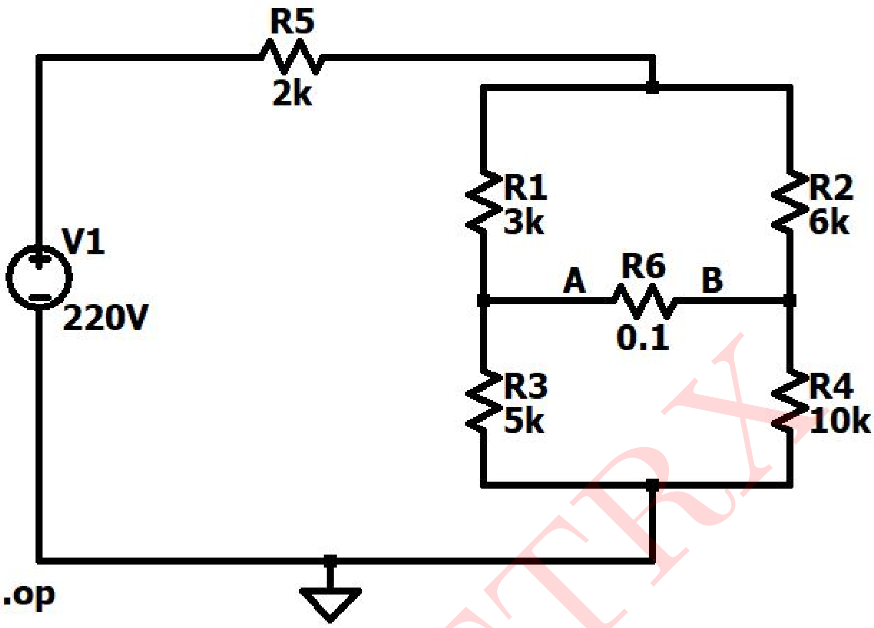


Figure 71: Circuit schematic

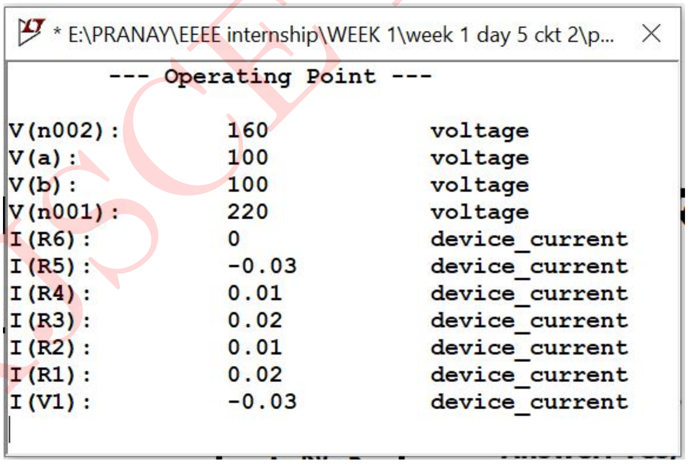


Figure 72: Simulated results

Since, current in the branch AB is zero the circuit forms a Wheatstone's bridge. Hence the bridge is balanced.

Part 2: Solving futher by replacing 10kΩ resistor with 18kΩ resistor.

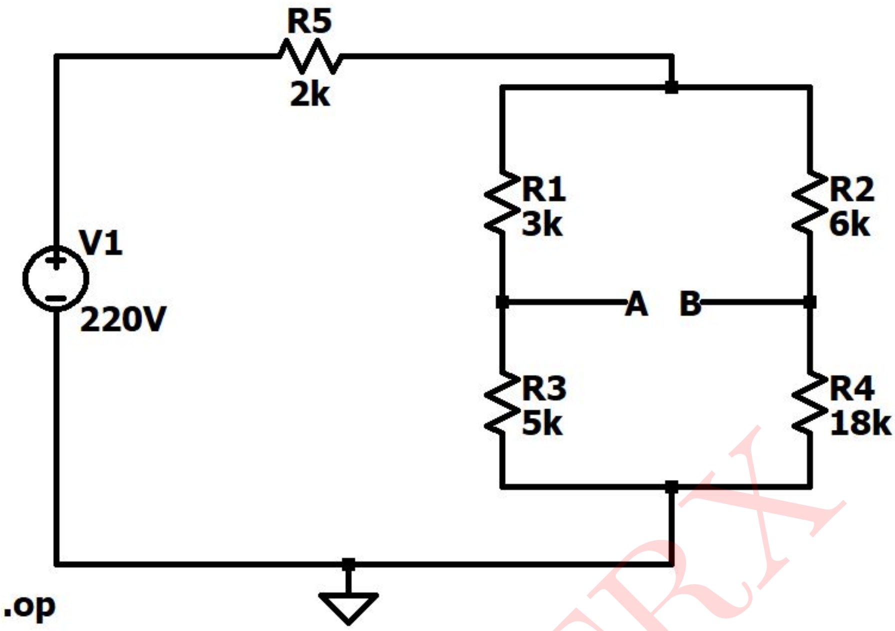


Figure 73: Circuit schematic for finding V_{TH}

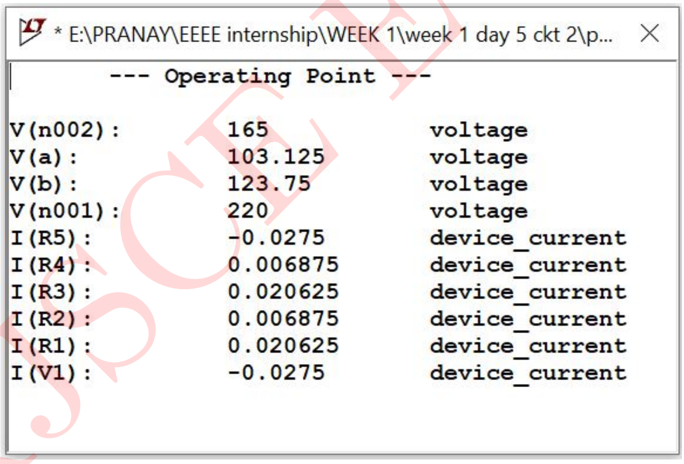


Figure 74: Simulated results for finding V_{TH}

Here,

$V_A = 103.125V$

$V_B = 123.75V$

$\therefore V_{TH} = V_{BA} = V_B - V_A$

$\therefore V_{TH} = V_{BA} = 123.75 - 103.125$

$\therefore V_{TH} = V_{BA} = 20.625V$

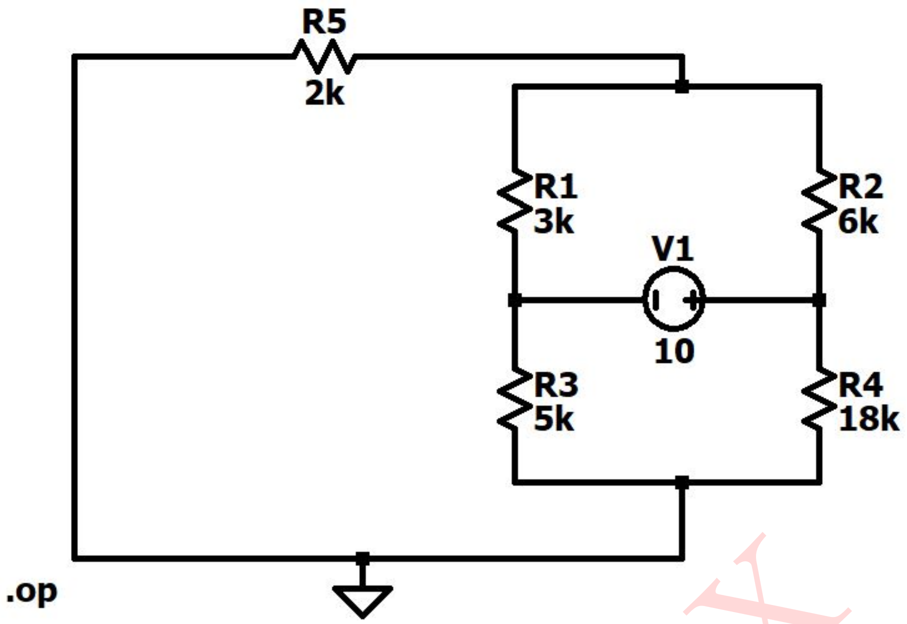
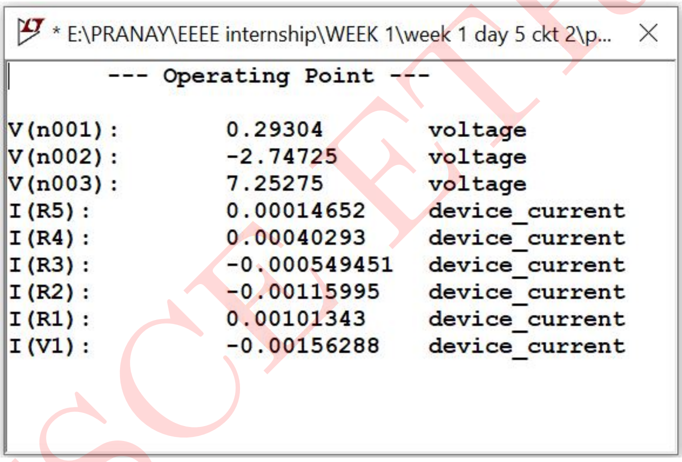


Figure 75: Circuit schematic for finding R_{TH}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```
       --- Operating Point ---

V(n001):         0.29304        voltage
V(n002):         -2.74725       voltage
V(n003):         7.25275        voltage
I(R5):           0.00014652     device_current
I(R4):           0.00040293     device_current
I(R3):           -0.000549451   device_current
I(R2):           -0.00115995    device_current
I(R1):           0.00101343     device_current
I(V1):           -0.00156288    device_current
```

Figure 76: Simulated results for finding R_{TH}

Here,

$I_{V_1} = 0.00156288A$

$R_{AB} = R_{TH} = \dfrac{V_1}{I_{V_1}}$

$R_{AB} = R_{TH} = \dfrac{10}{0.00156288}$

$R_{AB} = R_{TH} = 6.39844\Omega$

For maximum power transfer,

$R_{AB} = R_{Th} = 6.3846k\Omega$

Maximum power,

$$P_{max} = \frac{(V_{TH})^2}{4R_L}$$

$$P_{max} = \frac{(20.625)^2}{4 \times 6.346 \times 10^3}$$

$$P_{max} = \mathbf{16.656mW}$$

Comparison table between theoretical and simulated values:

Parameter	Theoretical value	Simulated values
R_{AB}	6.3846Ω	6.3844Ω
P_{max}	16.656mW	16.657mW

Table 10: Numerical 10