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

Numerical 1: (a) Consider the wheatstone shown in the figure calculate V_a, V_b, V_{ab}
(b) Rework Part (a) if the ground is placed at A instead of O
(Solve analytically using any technique and verify theoretical results with simulated values)

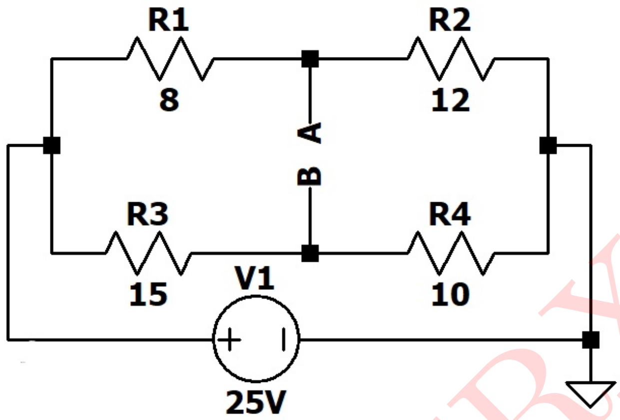

Figure 1: Circuit 1

Solution:
Part a:

We can observe that the source voltage in a circuit is divided among the resistors 8KΩ, 12KΩ, 15kΩ and 10kΩ

$\therefore$ voltage at terminals can be find out by voltage divider rule

Using voltage divider rule,

$V_a = \dfrac{12}{12+8} \times 25 = 15V$

$V_b = \dfrac{10}{10+15} \times 25 = 10V$

$V_{ab} = V_a - V_b = 15 - 10 = 5V$

Part b:

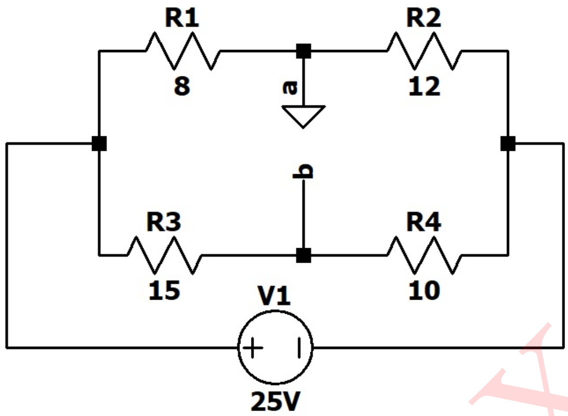

Figure 2: Circuit 1b

Since the terminal A is grounded
$V_a = 0V$
Now, $V_{ab} = V_{cb} + V_{ac}$ ...(from circuit 1b)

Again by voltage divider rule,

$V_{cb} = \dfrac{15}{15+10} \times 25 = 15V$ and

$V_{ac} = \dfrac{-8}{8+12} \times 25$

$V_{ac} = -10\mathrm{V}$

Since $V_{ab} = V_{cb} + V_{ac}$

$\therefore V_{ab} = 15 - 10 = 5V$

$V_b = -V_{ab} = -5V$

SIMULATED RESULTS:

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

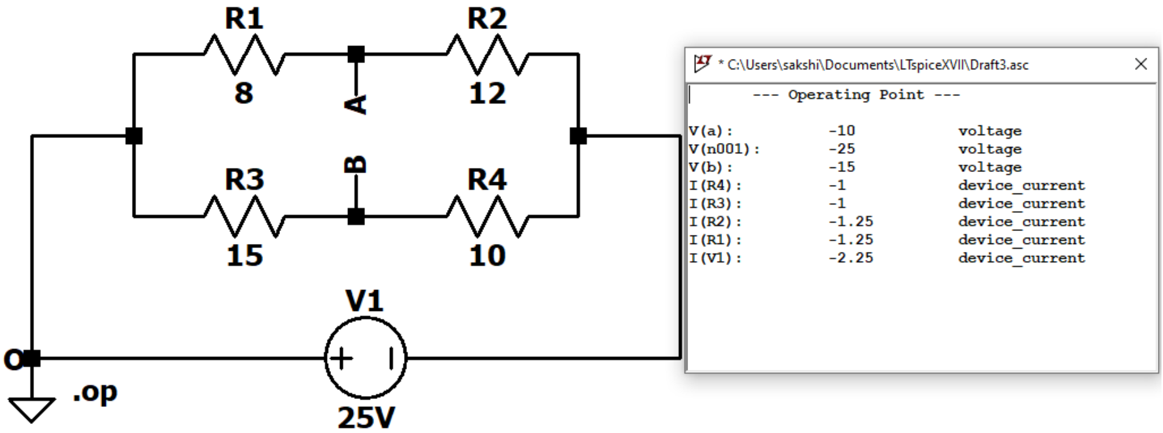

Figure 3: Circuit schematic and simulated results

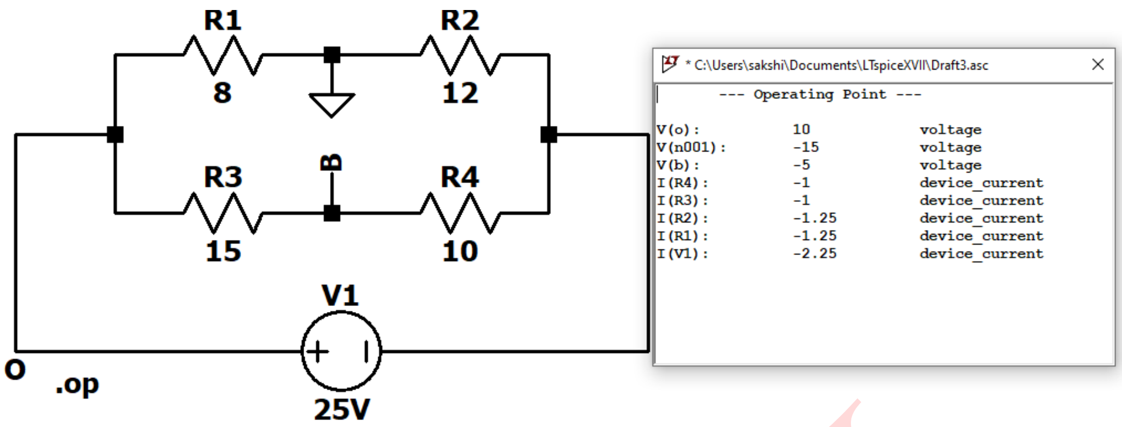

Figure 4: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_a	$15V$	$15V$
V_b	$10V$	$10V$
V_{ab}	$5V$	$5V$

Parameters	Theoretical Values	Simulated Values
V_a	$0V$	$0V$
V_b	$-5V$	$-5V$
V_{ab}	$5V$	$5V$

Numerical 2: Find R_{TH} in eight way divider shown in figure 5

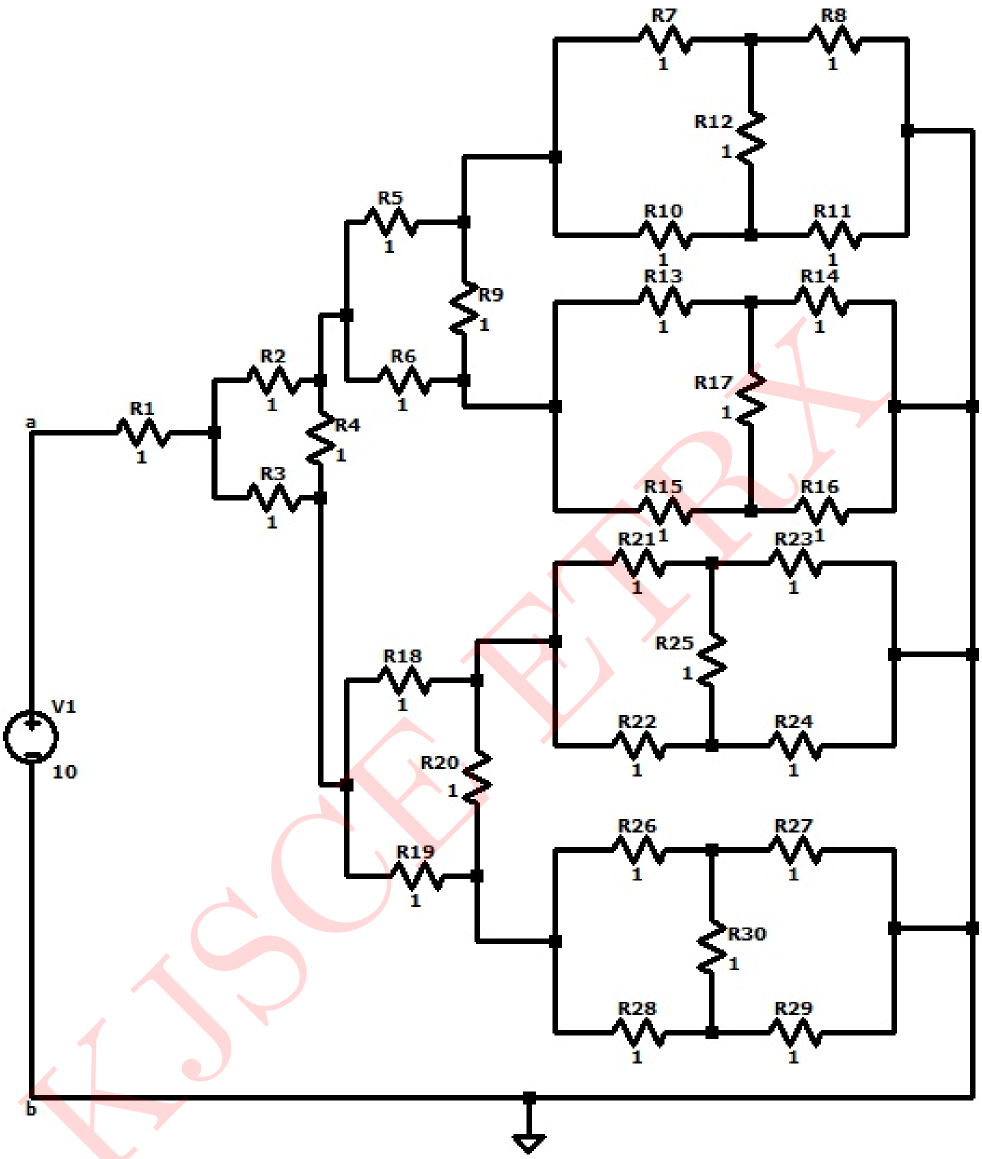

Figure 5: Circuit 2

Solution:

Since all the resistances are 1Ω and wheatstone networks are balanced

Circuit in figure 5 can be simplified as follows:

The Wheatstone network in circuit of figure 5 is-

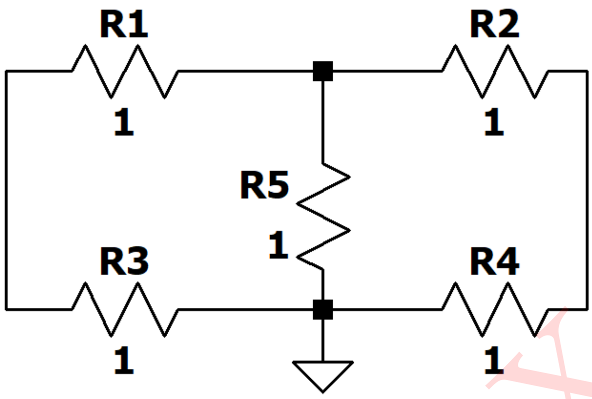

Figure 6: Modified circuit for figure 5

As bridge is balanced we can neglect the middle 1Ω resister

$\therefore$ Circuit in figure 6 will reduce to:

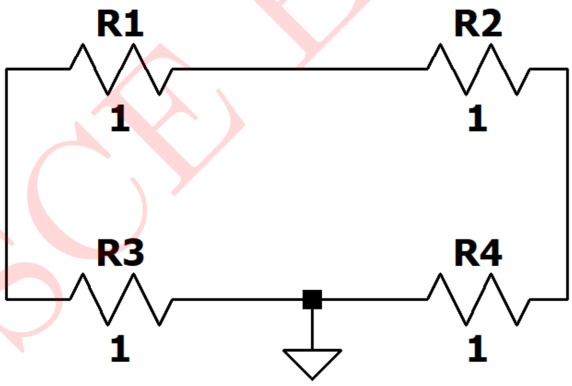

Figure 7: Modified circuit for figure 6

Here two 1Ω resistances are in series and their resultant is in parallel with each other .

$$V_a = \frac{2 \times 2}{2+2}$$

∴ Circuit in figure 7 will reduce to:

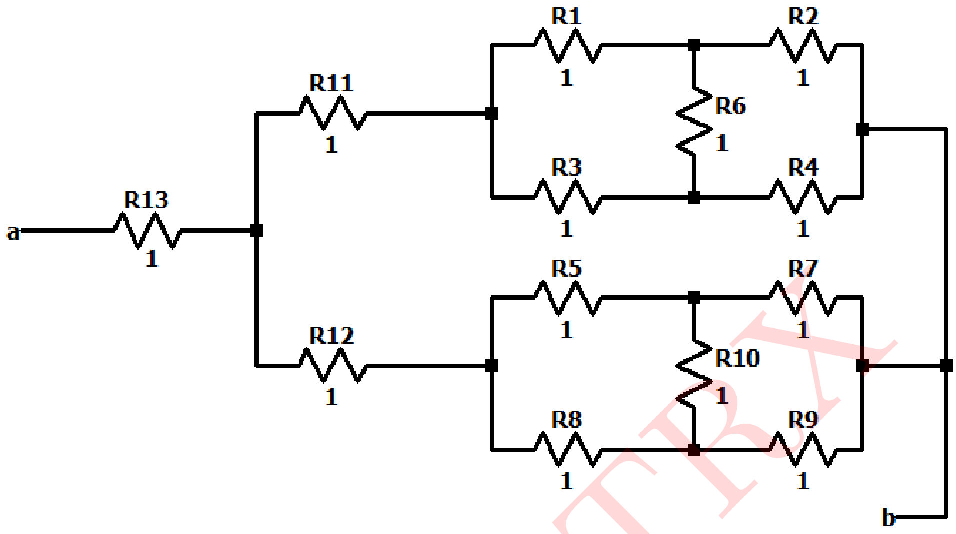

Figure 8: Modified circuit for figure 7

Again by the same method of wheatstone network, circuit in figure 8 will reduce to:

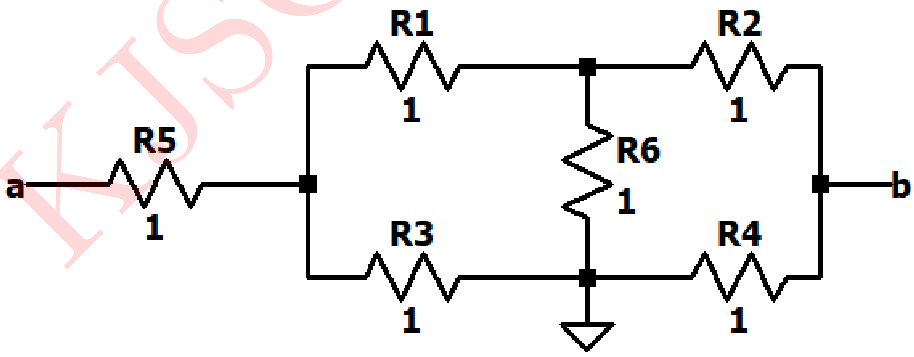

Figure 9: Modified circuit of figure 8

Here if we simply the wheatstone network, we will get two 1Ω resisters in series

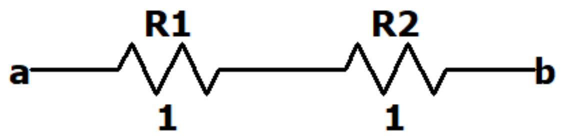

Figure 10: Modified circuit of figure 9

Hence, both resistances are in series
$R_{eq} = (1 + 1) = 2\Omega$

SIMULATED RESULTS:

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

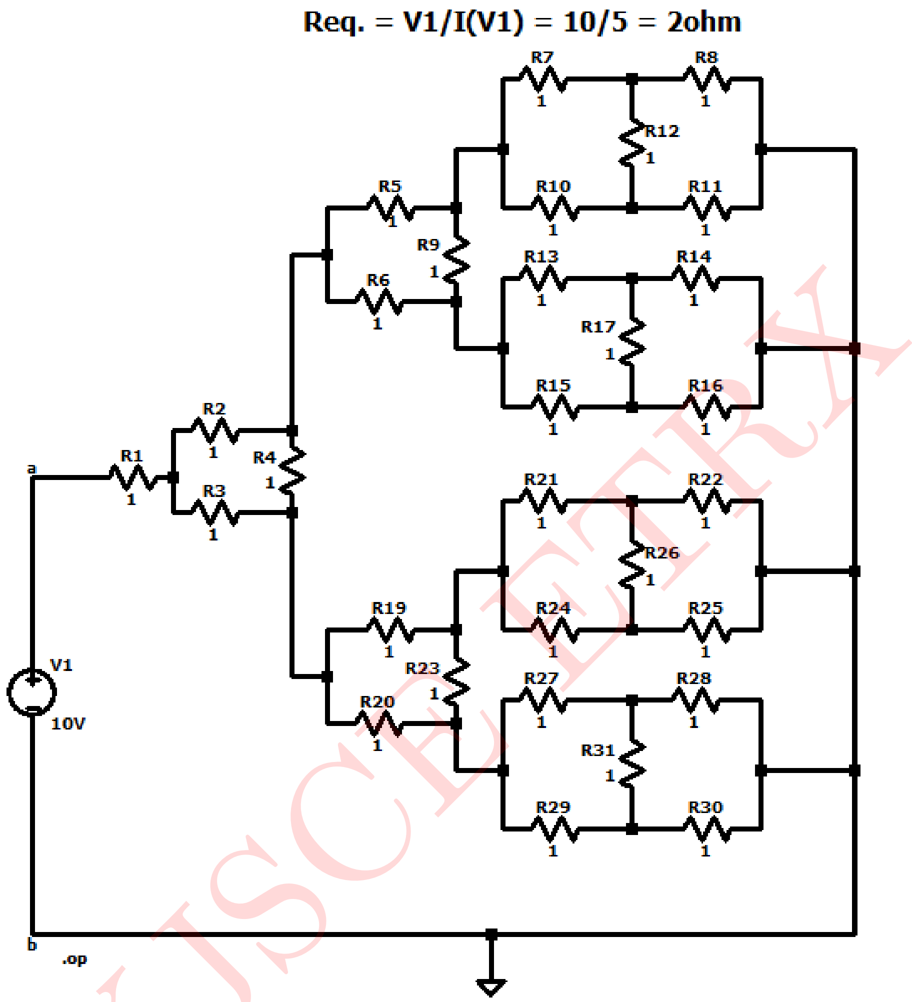

Figure 11: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
R_{eq}	2Ω	2Ω

Numerical 3:
Use Superposition Theorem to find V_O in the circuit shown in figure 12

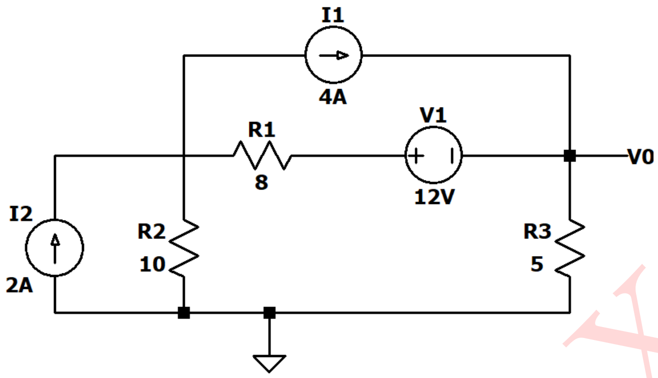

Figure 12: Circuit 3

Solution:

Let, $V_O = V_1 + V_2 + V_3$
where V_1, V_2 and V_3 are voltages due to independent sources

(i) To find V_1, consider I_2 and V_1 inactive and I_1 active

$\therefore$ Circuit in figure 12 will be-

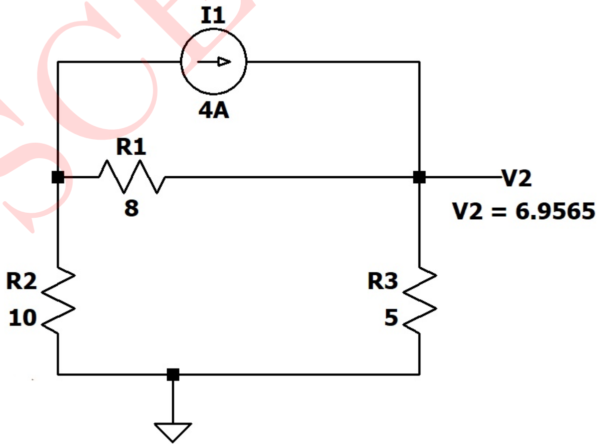

Figure 13: Modified circuit for figure 12(i)

From the circuit, $I_1 = 4A$

To find I_2, applying kirchhoff's voltage law for circuit:

$-10I_2 - 5I_2 - 8(I_2 - I_1) = 0$

$8I_1 - 23I_2 = 0$....(i)

Since, $I_1 = 4A$

$\therefore I_2 = \dfrac{32}{23} = 1.3913A$

$V_1 = I_2{\times}5 = 1.3913{\times}5 = 6.9565V$

(ii) To find V_2, consider I_2 and V_1 inactive and I_1 active.

$\therefore$ Circuit in figure 12 will be-

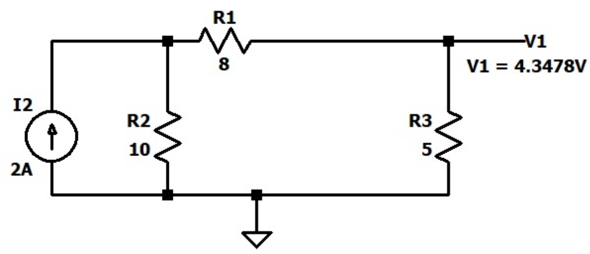

Figure 14: Modified circuit for figure 12(ii)

There are two meshes in the following circuit, consider the current through mesh 1 and 2 is I_x and I_y respectively

From the circuit, $I_x = 2A$

To find I_y, applying kirchhoff's voltage law for circuit:

$-10(I_y - I_x) - 8I_y - 5I_x = 0$

$10I_x - 23I_y = 0$ ....(ii)

Since, $I_x = 2A$

$\therefore I_y = \dfrac{20}{23} = 0.8695A$

$V_2 = I_y \times R_3 = 0.8695 \times 5 = 4.3478V$

(iii) To find V_3, consider I_1 and I_2 inactive and V_1 active

$\therefore$ Circuit in figure 12 will be-

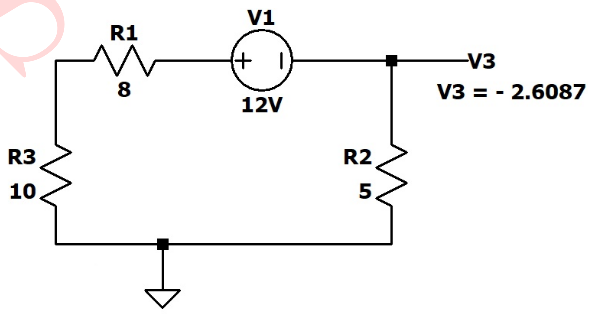

Figure 15: Modified circuit for figure 12(iii)

By voltage divider rule,

$V_3 = \dfrac{5}{5+10+8} \times (-12)$

$V_3 = \dfrac{-60}{23} = -2.6087V$

$V_3 = -2.6087V$

since, $V_O = V_1 + V_2 + V_3$

$V_O = 4.3478 + 6.9565 - 2.6087$

$\therefore V_O = 8.696V$

SIMULATED RESULTS:

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

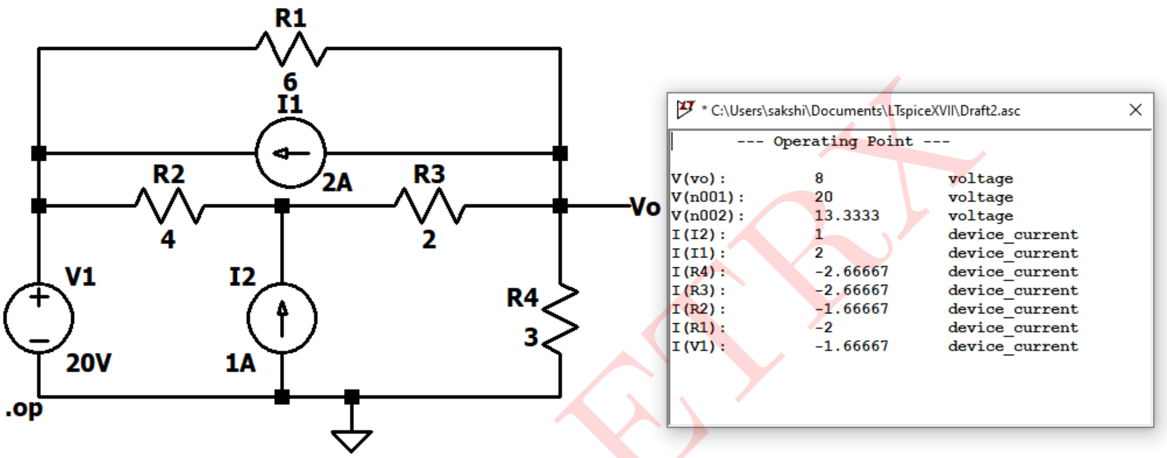

Figure 16: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_1	$6.9565V$	$6.9565V$
V_2	$4.3478V$	$4.3478V$
V_3	$-2.6087V$	$-2.6087V$
V_O	$8.696V$	$8.696VV$

Numerical 4: Use Superposition Theorem to find V_O in the circuit shown in figure 17

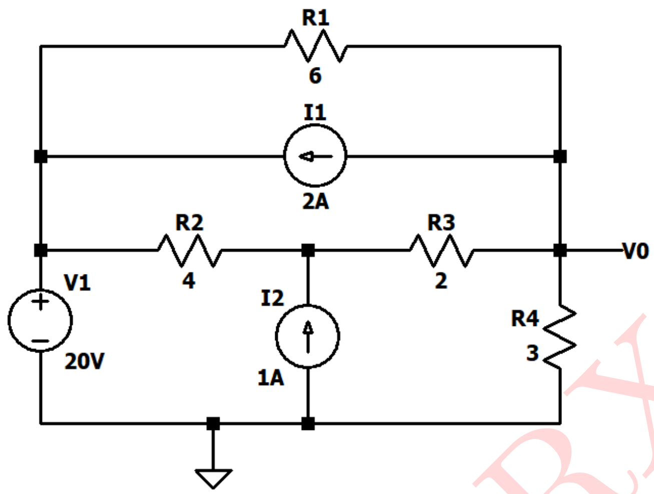

Figure 17: Circuit 4

Solution:

Let, $V_O = V_1 + V_2 + V_3$

where V_1, V_2 and V_3 are voltages due to independent sources

(i) To find V_1, consider I_2 and V_1 inactive and I_1 active

$\therefore$ Circuit in figure 17 will be:

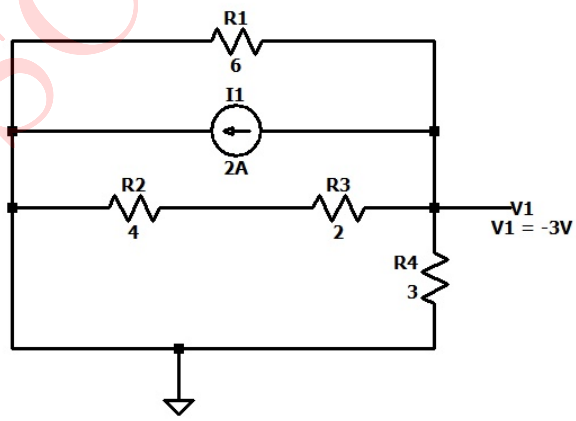

Figure 18: Modified circuit for figure 17(i)

The 6Ω resister is in parallel with 4Ω and 2Ω resisters which are connected in series

$$R_{eq} = \frac{6 \times 6}{6+6} = 3\Omega$$

$\therefore$ By current divider rule,

$V_1 = 3{\times}(-1) = -3V$

(ii) To find V_2, consider I_1 and V_1 inactive and I_2 active

$\therefore$ Circuit in figure 17 will be:

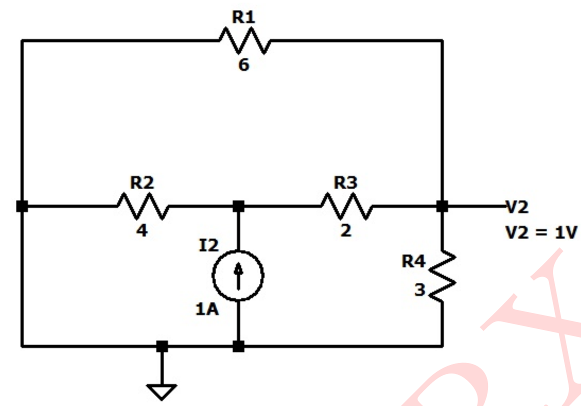

Figure 19: Modified circuit for figure 17(ii)

The 4Ω and 2Ω resistors are in series and their resultant is in parallel with 3Ω resistor

$$R_{eq} = \frac{3 \times 6}{3+6} = 2\Omega$$

By current divider rule,

$$V_2 = \frac{2}{4+2+2} \times 4 = 1V$$

$$V_2 = 1V$$

(iii) To find V_3, consider I_1 and I_2 inactive and V_1 active

$\therefore$ Circuit in figure 17 will be:

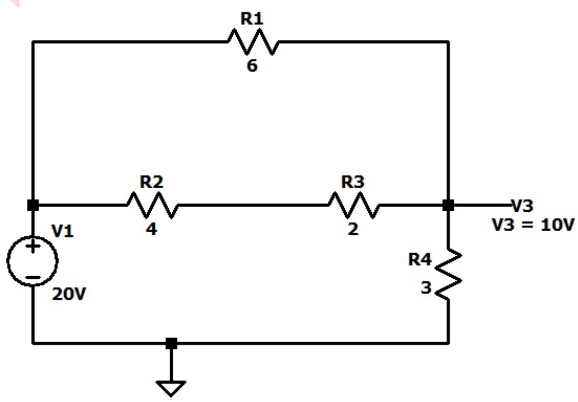

Figure 20: Modified circuit for figure 17(iii)

The 4Ω and 2Ω resistors are in series and their resultant is in parallel with 6Ω resistor

$$R_{eq} = \frac{6 \times 6}{6+6} = 3\Omega$$

By current divider rule,

$$V_3 = \frac{20}{2} = 10V$$

$V_3 = 10V$

since, $V_O = V_1 + V_2 + V_3$

$V_O = -3 + 1 + 10 = 8V$

$\therefore V_O = 8V$

SIMULATED RESULTS:

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

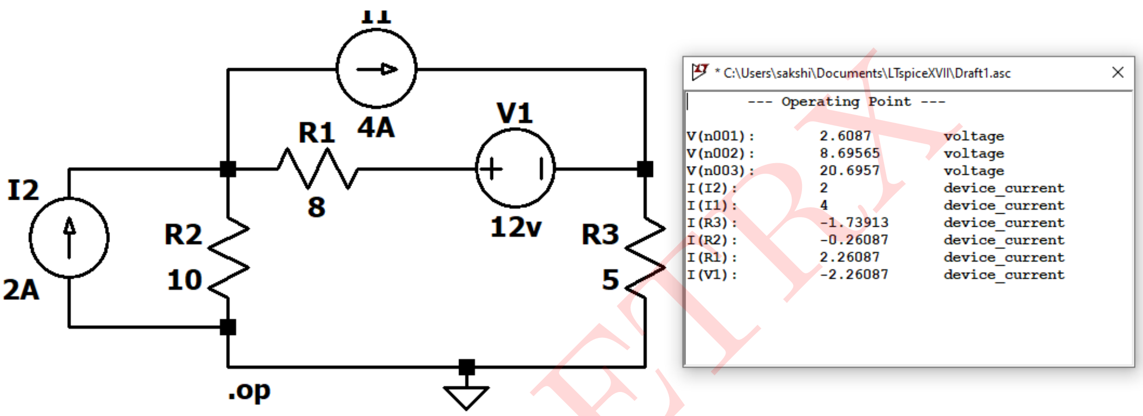

Figure 21: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_1	$-3V$	$-3V$
V_2	$1V$	$1V$
V_3	$10V$	$10V$
V_O	$8V$	$8V$

Numerical 5: Use Thevenin's theorem to calculate the potential difference across ternimal V_a and V_b shown in the figure 22

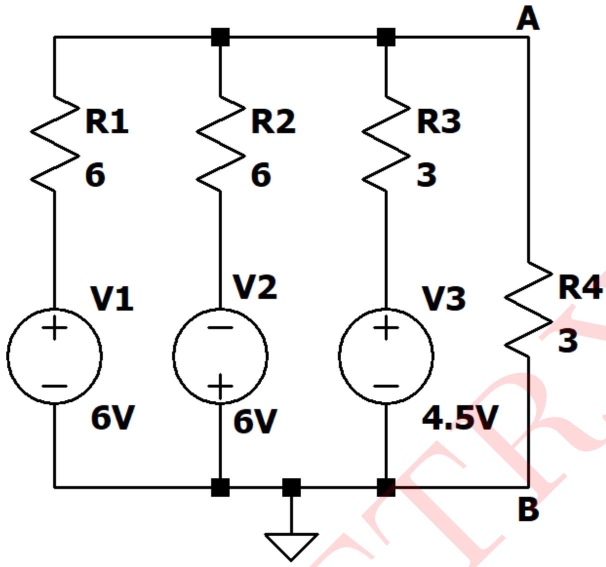

Figure 22: Circuit 5

Solution:
(i) To find Thevenin's voltage V_{TH}, replace load resistance(3Ω) with open circuit voltage V_{TH}

The resultant circuit will be:

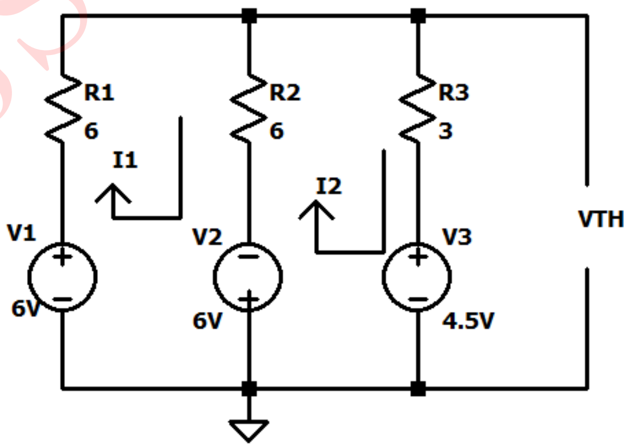

Figure 23: Modified circuit for figure 22(i)

Applying Kirchhoff's voltage law (KVL) for mesh 1:

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

i.e. $12I_1 - 6I_2 = 12$ ....(i)

Applying Kirchhoff's voltage law (KVL) for mesh 2:

$-6 - 6(I_2 - I_1) - 3I_2 - 4.5 = 0$

i.e. $6I_1 - 9I_2 = 10.5$ ....(ii)

$\therefore$ Solving equations (i) and (ii)

$I_1 = 0.625$A and

$I_2 = -\mathbf{0}.75$A

$V_{TH} = V_{AB} = 4.5 + 3I_2$

$= 4.5 + 3(-0.75) = 4.5 - 2.25 = 2.25V$

(ii) To find Thevenin's resistance R_{TH}, replace all active sources by there internal resistances

The resultant circuit will be:

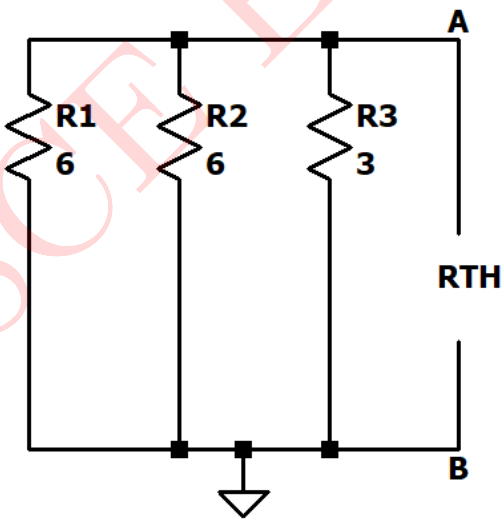

Figure 24: Modified circuit for figure 22(ii)

Here two 6Ω resisters are in parallel and there resultant is in parallel with 3Ω

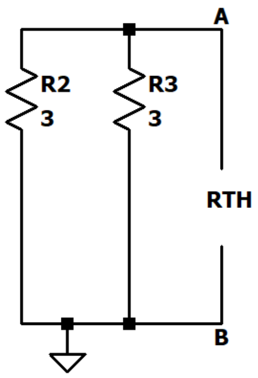

Figure 25: Modified circuit for figure 24

Now again two 3Ω resistances are in parallel

$\therefore R_{TH} = 1.5\Omega$

$\therefore$ Thevenin's equivalent circuit will be:

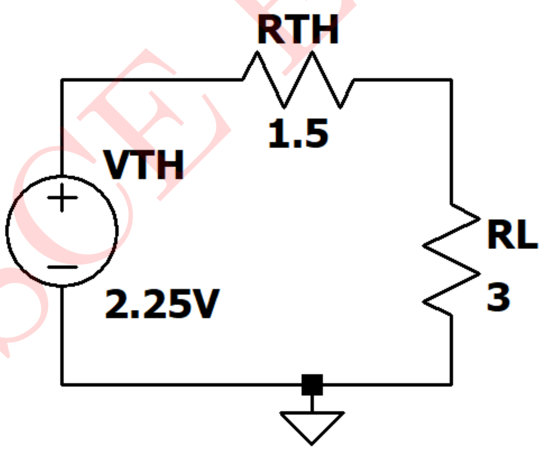

Figure 26: Thevenin's equivalent circuit

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

$$I_L = \frac{2.25}{3 + 1.5}$$

$I_L = 0.5$A

$V_{AB} = I_L R_L = 0.5{\times}3 = 1.5$V

SIMULATED RESULTS:

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

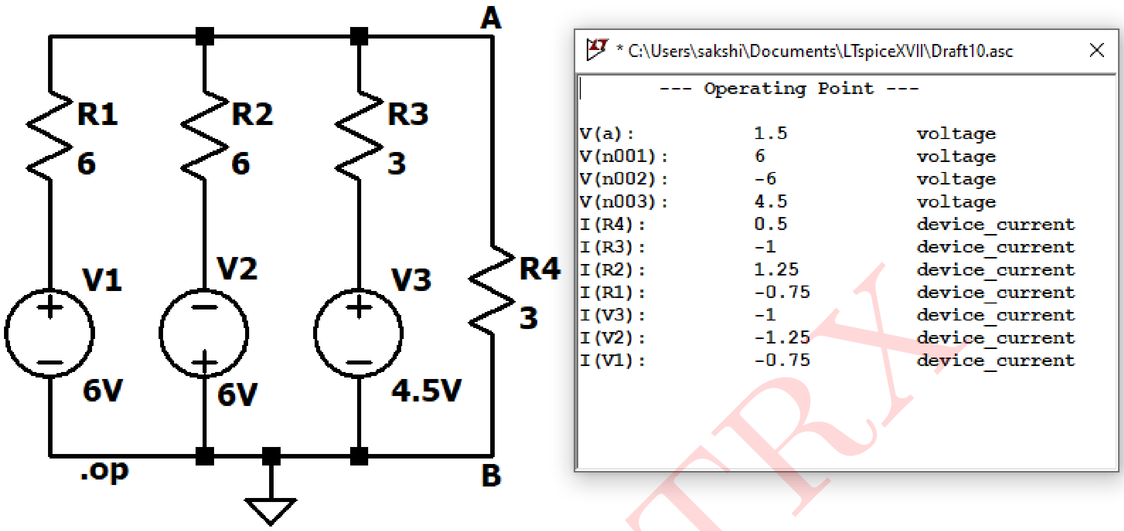

Figure 27: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	$2.25V$	$2.25V$
R_{TH}	1.5Ω	1.5Ω
V_{AB}	$1.5V$	$1.5V$
I_L	$0.5A$	$0.5A$

Numerical 6: Find the current flowing through the load resistance of 10Ω connected Across terminals V_a and V_b using the Thevenin's theorem for circuit shown in figure 28

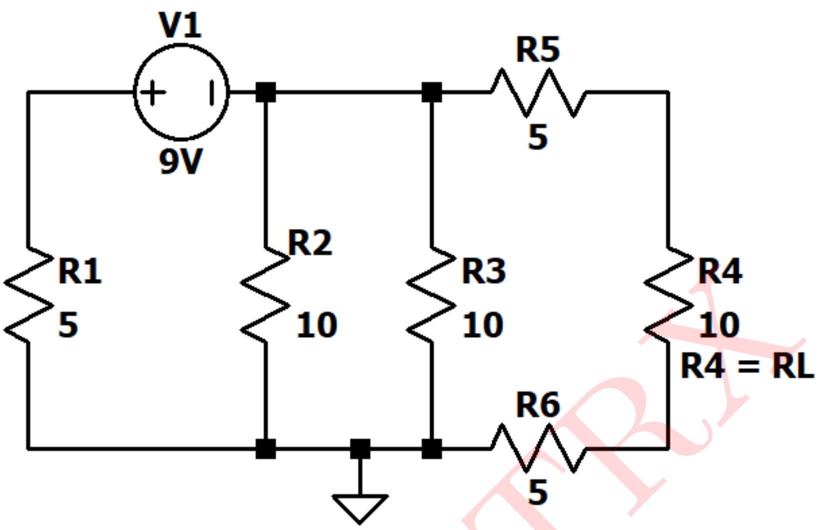

Figure 28: Circuit 6

Solution:
(i) To find Thevenin's voltage V_{TH}, replace load resistance(10Ω) with open circuit voltage V_{TH}

The resultant circuit will be:

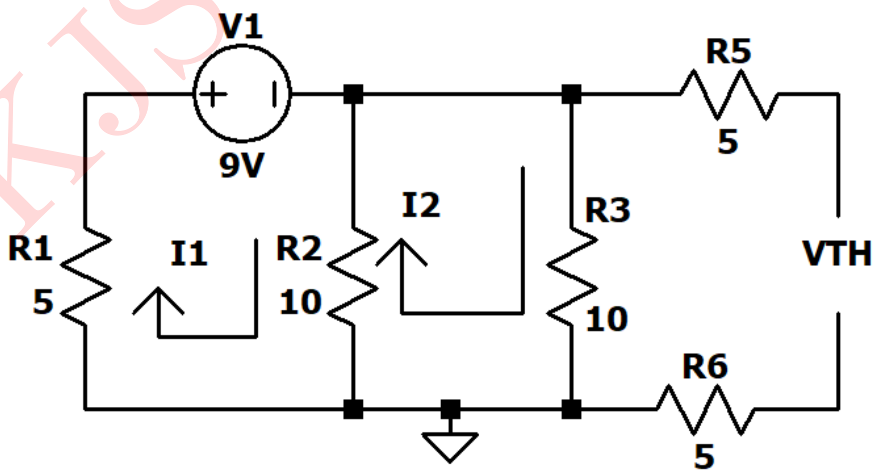

Figure 29: Modified circuit for figure 28(i)

Applying Kirchhoff's voltage law (KVL) for mesh 1:

$-5I_1 - 10(I_1 - I_2) + 9 = 0$

i.e. $15I_1 - 10I_2 = 9$ ....(i)

Applying Kirchhoff's voltage law (KVL) for mesh 2:

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

i.e. $10I_1 - 20I_2 = 0$ ....(ii)

$\therefore$ Solving equations (i) and (ii)

$I_1 = 0.9$A and

$I_2 = 4.5$A

$V_{TH} = V_{AB} = 5I_2 - 10I_2 + 5I_2$

$V_{TH} = -\mathbf{10}\times 4.5$

$V_{TH} = -\mathbf{4}.5$V

(ii) To find Thevenin's resistance R_{TH}, replace all active sources by there internal resistances

The resultant circuit will be:

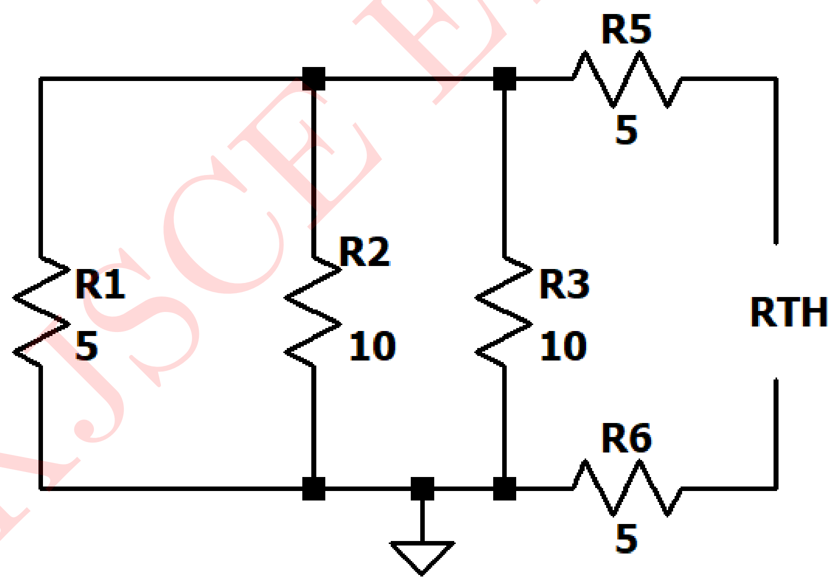

Figure 30: Modified circuit for figure 28(ii)

Here, 5Ω and 10Ω resistances are in parallel

Therefore circuit will be:

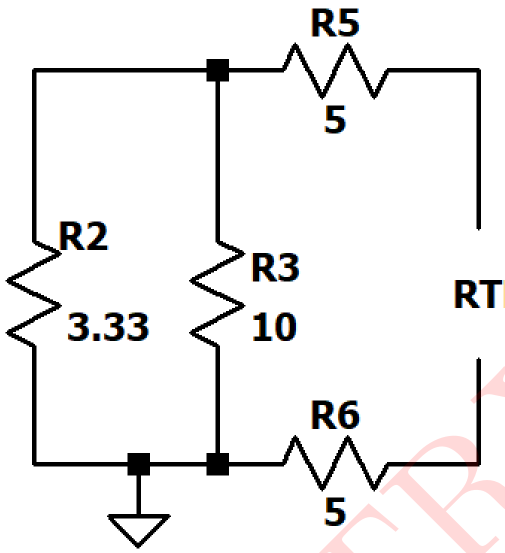

Figure 31: Modified circuit for figure 30

$\therefore R_{TH} = 12.5\Omega$

Thevenin's equivalent circuit will be:

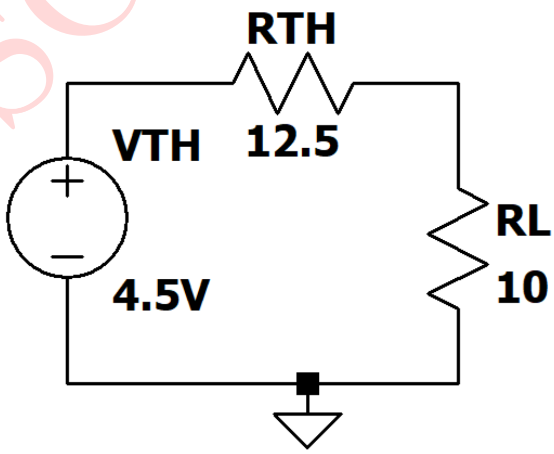

Figure 32: Thevenin's equivalent circuit

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

$$I_L = \frac{-4.5}{12.5 + 10}$$

$$I_L = -\mathbf{0}.2\text{A}$$

SIMULATED RESULTS:

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

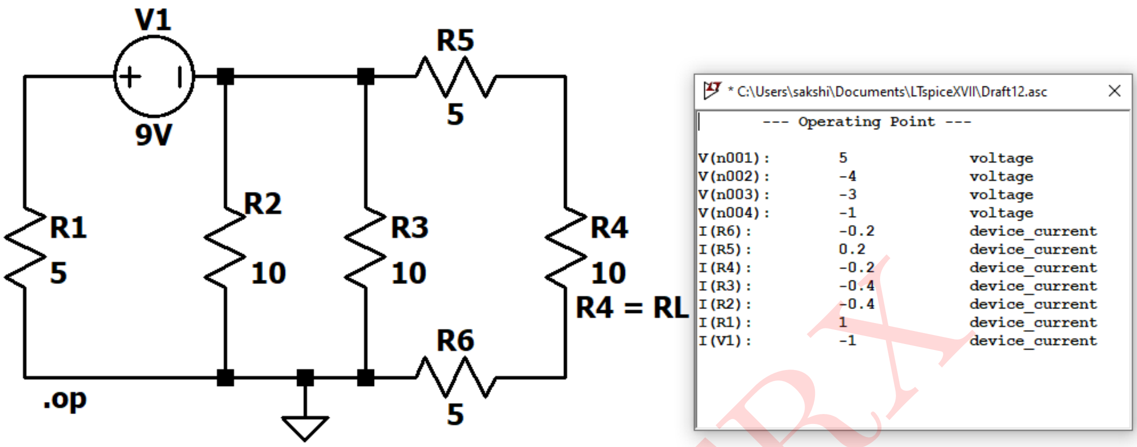

Figure 33: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	-4.5V	-4.5V
R_{TH}	12.5Ω	12.5Ω
I_L	-0.2A	-0.2A

Numerical 7: Obtain the Thevenin and Norton equivalent circuit for the circuit in figure 34 given that all resistances are in Ω

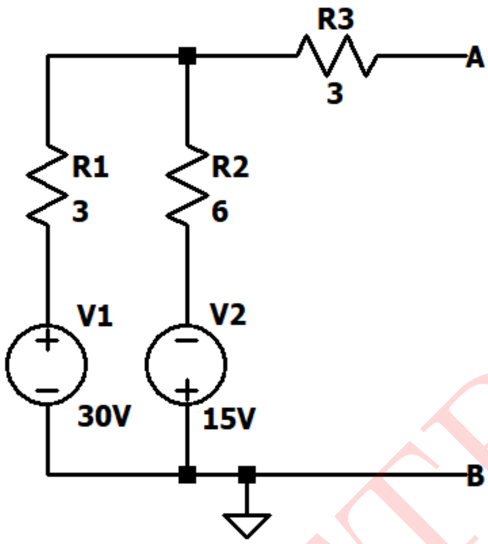

Figure 34: Circuit 7

Solution:

i)To find short circuit current I_{SC}

The resultant circuit will be:

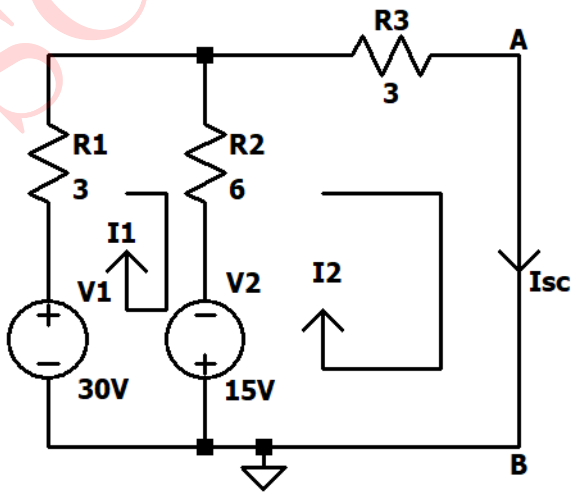

Figure 35: Modified circuit for figure 34(i)

Applying Kirchhoff's voltage law (KVL) for mesh 1:

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

i.e. $3I_1 - 2I_2 = 15$ ....(i)

Applying Kirchhoff's voltage law (KVL) for mesh 2:

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

i.e. $2I_1 - 3I_2 = 5$ ....(ii)

$\therefore$ Solving equations (i) and (ii)

$I_1 = 7$A and

$I_2 = I_{SC} = 3$A

ii)To find Thevenin's resistance R_{TH}, replace all active sources by there internal resistances

The resultant circuit will be:

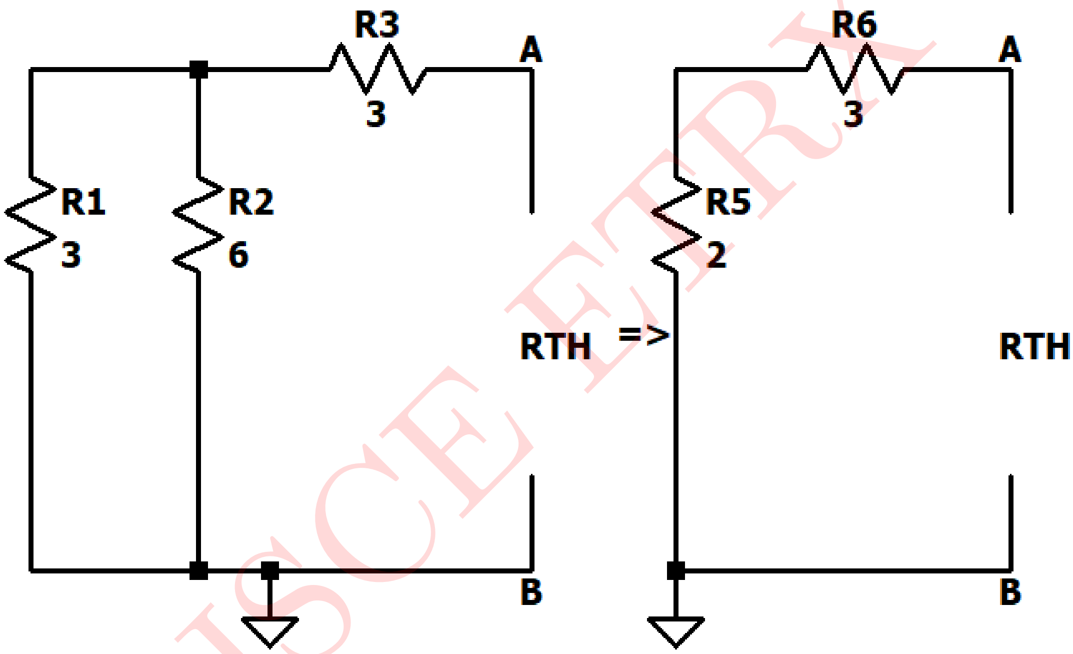

Figure 36: Modified circuit for figure 34(ii)

$\therefore R_{TH} = 5\Omega$

iii)To find Thevenin's voltage V_{TH}

The circuit will be:

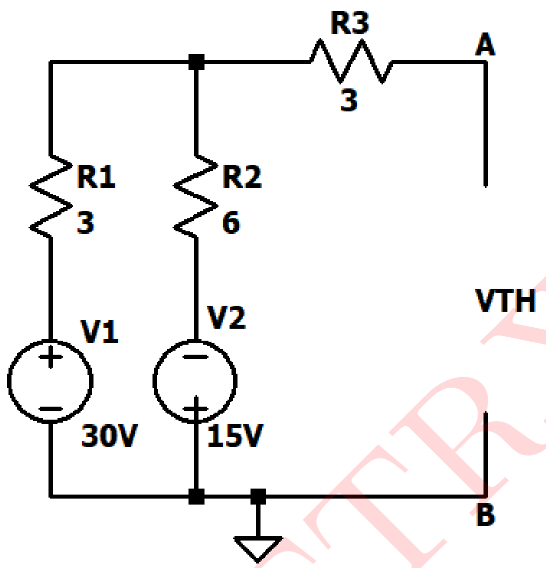

Figure 37: Modified circuit for figure 34(iii)

With the terminal A and B open, two voltage sources are connected in subtractive series

$\therefore V_{TH} = V_{AB} = (30 - 15)V = 15V$

Nortons's equivalent circuit will be:

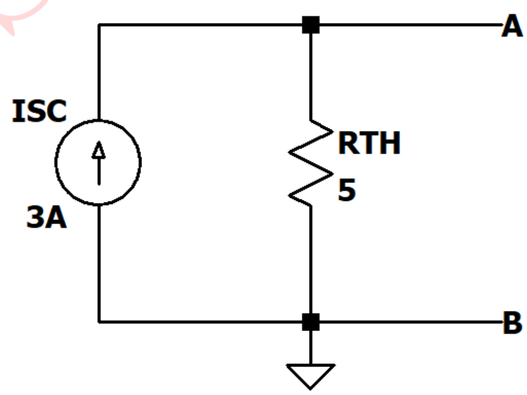

Figure 38: Norton's equivalent circuit

Thevenin's equivalent circuit will be:

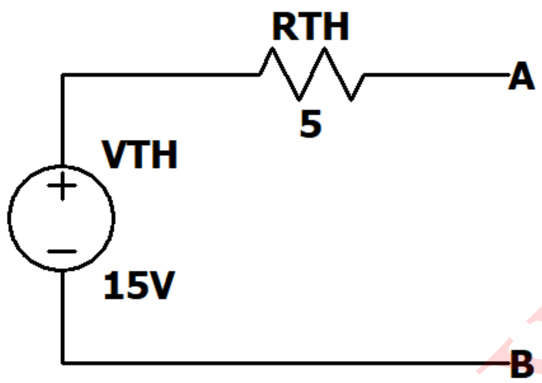

Figure 39: Thevenin's equivalent circuit

SIMULATED RESULTS:

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

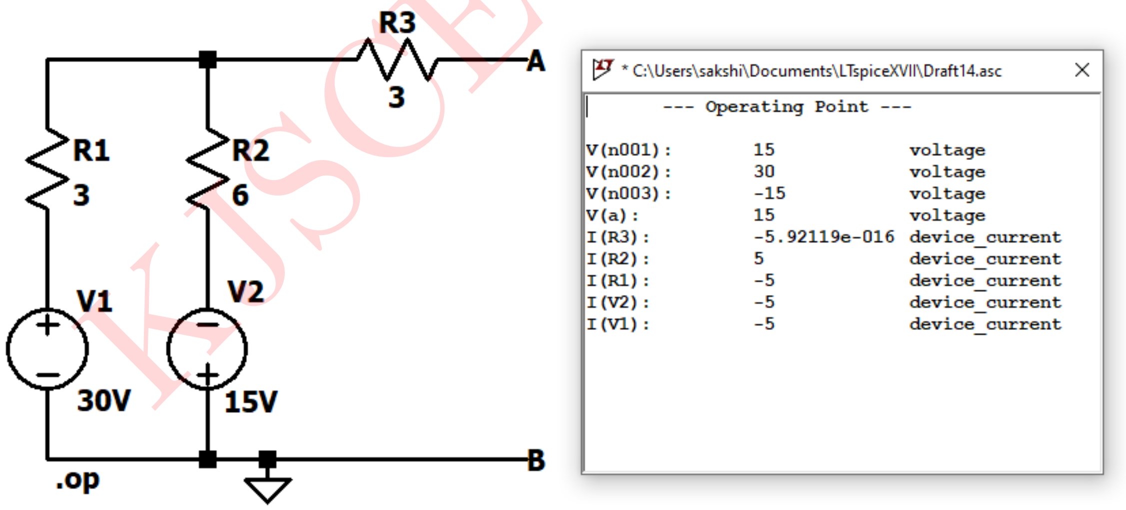

Figure 40: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	$15V$	$15V$
R_{TH}	5Ω	5Ω
I_{SC}	$3A$	$3A$

Numerical 8: Solve the circuit shown in figure 41 determine unknown current by method of Thevenin's and Norton's equivalent circuit

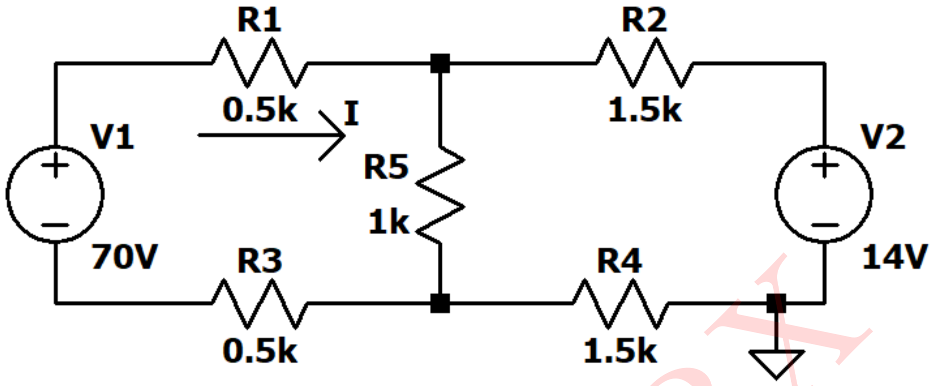

Figure 41: Circuit 8

Solution:
Load resistance $R_L = 0.5\text{K}\Omega$

i)To find Thevenin's voltage V_{TH}

The resultant circuit will be:

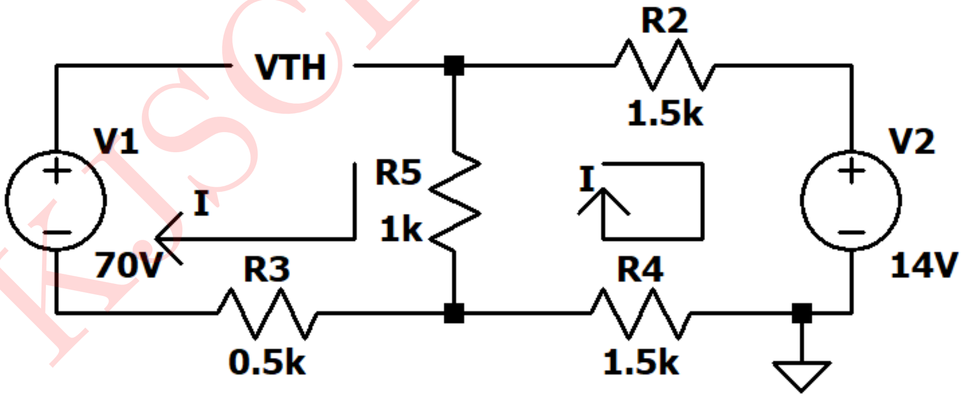

Figure 42: Modified circuit for figure 41(i)

Applying Kirchhoff's voltage law (KVL),

$-1.5I - 1I - 1.5I = 14$

$\therefore I = 3.5\text{mA}$

For $V_{AB} = V_A - 70 + 1000 \times 3.5 = V_B$

$V_B = V_{TH} = 66.5V$

ii)To find Thevenin's resistance R_{TH}

The resultant circuit will be:

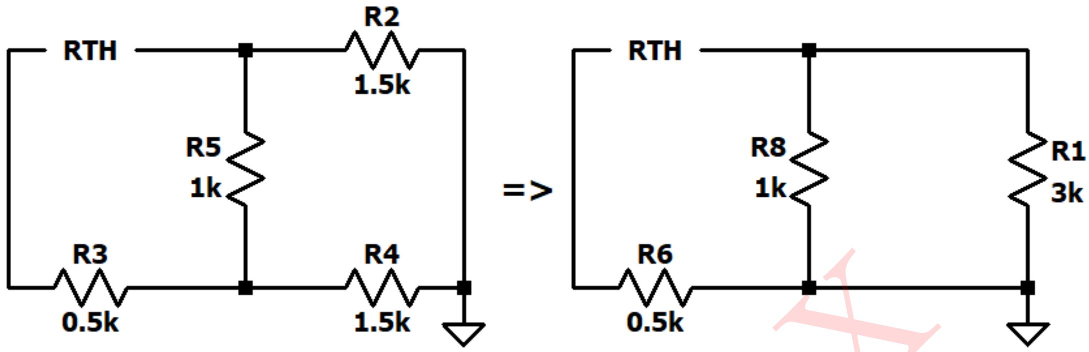

Figure 43: Modified circuit for figure 41(ii)

$R_{TH} = 1.25\text{K}\Omega$

Thevenin's equivalent circuit will be:

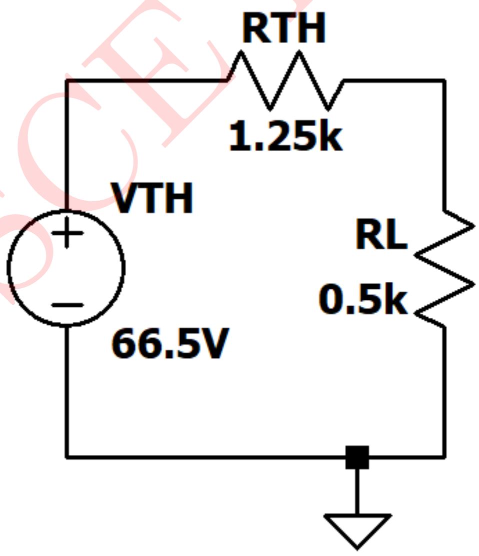

Figure 44: Thevenin's equivalent circuit

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

$$I_L = \frac{66.5}{1.25 + 0.5}$$

$$I_L = -\mathbf{3}8\text{mA}$$

iii)To find short circuit current I_{SC}

The circuit will be:

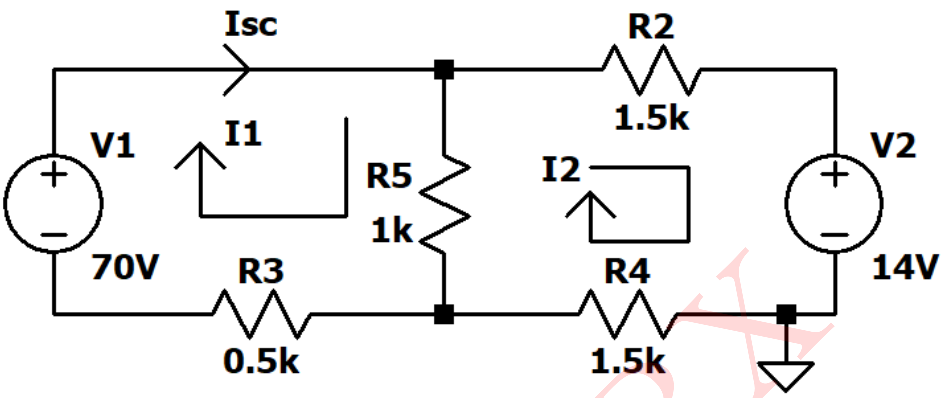

Figure 45: Modified circuit for figure 41(iii)

Applying Kirchhoff's voltage law (KVL) for mesh 1:

$70 - 0.5I_1 - 1(I_1 - I_2) = 0$

i.e. $I_1 - I_2 = 70$ ....(i)

Applying Kirchhoff's voltage law (KVL) for mesh 2:

$-1.5I_2 - 1.5I_2 - (I_2 - I_1) - 14 = 0$

i.e. $I_1 - 4I_2 = 14$ ....(ii)

$\therefore$ Solving equations (i) and (ii)

$I_1 = I_{SC} = 53.2$A

Also, $R_{TH} = 1.25\text{K}\Omega$

Nortons's equivalent circuit will be:

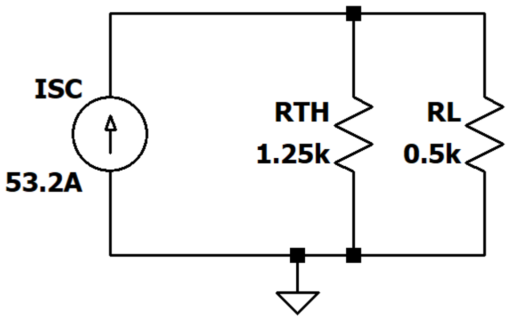

Figure 46: Norton's equivalent circuit

$$I_L = I = \frac{V_{TH}R_N}{R_{TH} + R_L} \text{ ....}(R_{TH} = R_N\ )$$

$$I_L = \frac{66.5}{1.25 + 0.5}$$

$$I_L = I = 38\text{mA}$$

SIMULATED RESULTS:

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

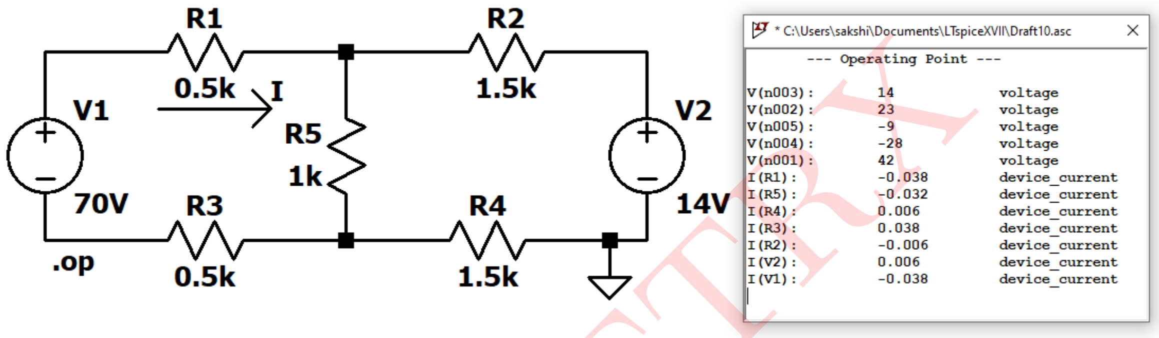

Figure 47: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{TH}	$66.5V$	$66.5V$
R_{TH}	$1.25\text{K}\Omega$	$1.25\text{K}\Omega$
I_{SC}	$53.2mA$	$53.2mA$
I	$38mA$	$38mA$

Numerical 9: Solve the circuit shown in figure 48 determine unknown voltage or current By method of Norton's theorem

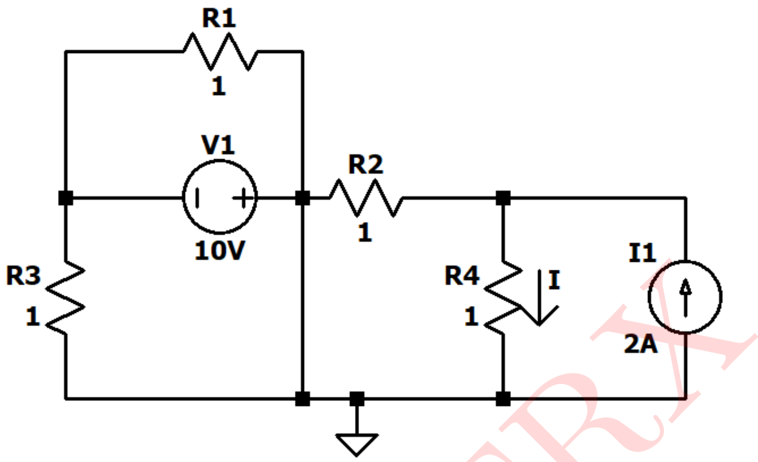

Figure 48: Circuit 9

Solution:
Load resistance $R_L = 1\Omega$
i) To find short circuit current I_{SC}

The circuit will be:

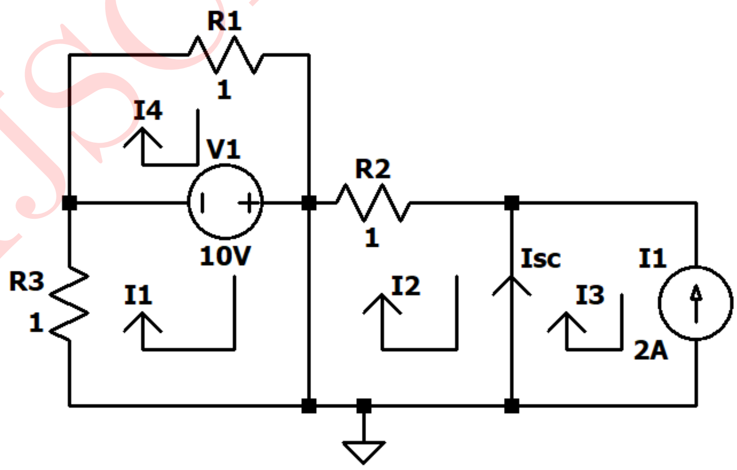

Figure 49: Modified circuit for figure 48(i)

By observations, current through short circuit branch, $I_{SC} = 2\text{A}$

ii) To find Thevenin's resistance R_{TH}

The resultant circuit will be:

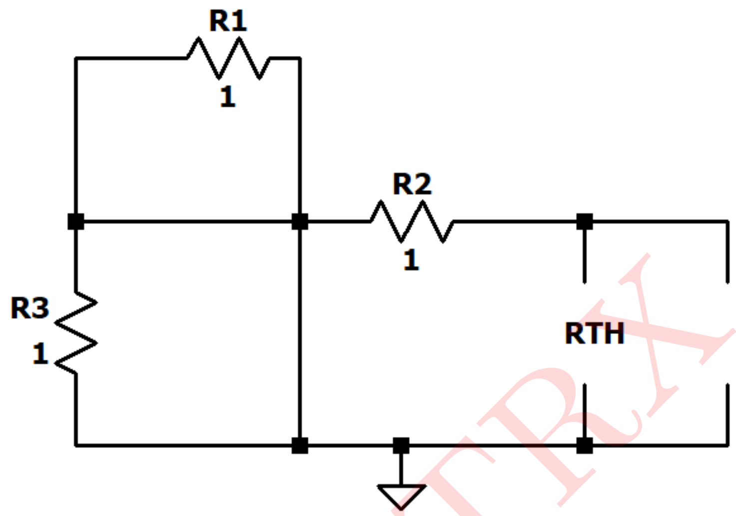

Figure 50: Modified circuit for figure 48(ii)

By calculation, $R_{TH} = 1\Omega$

Norton's equivalent circuit will be:

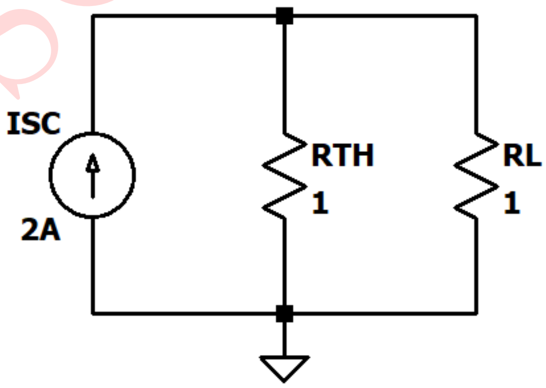

Figure 51: Norton's equivalent circuit

$I_L = \dfrac{V_{TH} \times R_N}{R_N + R_L}$

$I_L = \dfrac{200}{1+1}$

$I_L = I = 1\text{A}$

SIMULATED RESULTS:

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

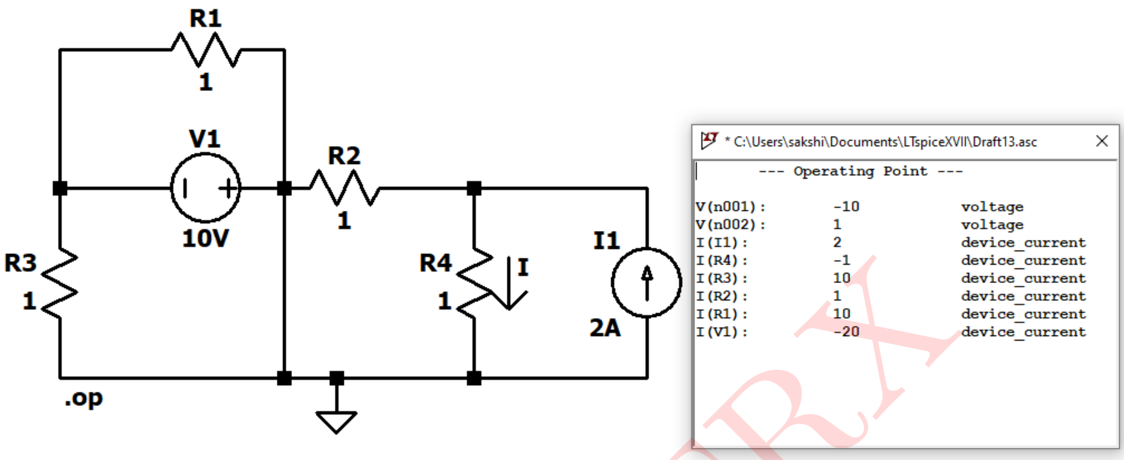

Figure 52: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
R_{TH}	1.25Ω	1.25Ω
I_{SC}	2A	2A
I	$1A$	$1A$

Numerical 10: In given figure 53 what value of R will allow maximum power transfer to the load? Also calculate the maximum total load power.

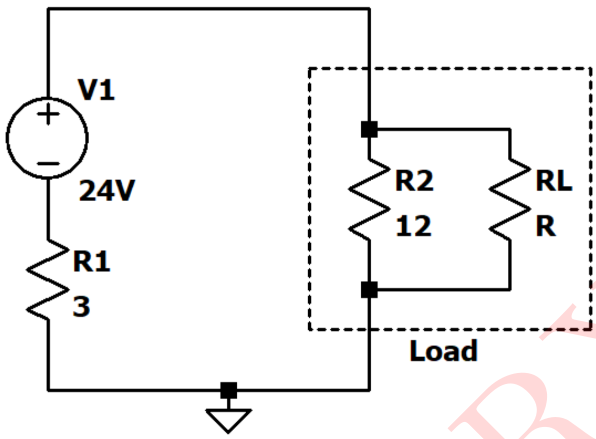

Figure 53: Circuit 10

Solution: Both resistances R and 12Ω are in parallel

$\therefore$ Their resultant will be load resistance R_L

To find R_{TH}, remove all active sources by their internal resistances

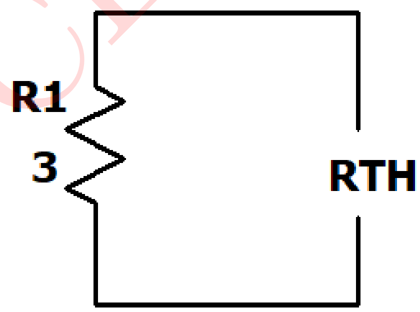

Figure 54: Modified circuit for figure 53

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

By maximum power transfer theorem, to allow maximum power transfered through the load $R_{TH} = R_L$

Since $R_{TH} = 3\Omega$

$3\Omega = \dfrac{12R}{12+R}$

$12R = 36 + 3R$

$R = 4\ \Omega$

Hence value of R should be 4Ω to allow maximum power to be transfered

$\therefore$ Load resistance $R_L = \dfrac{48}{16} = 3\Omega$

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

$\therefore P_{MAX.} = \dfrac{V^2}{4R_L}$

$P_{MAX.} = \dfrac{24^2}{4 \times 3}$

$P_{MAX.} = \dfrac{576}{12} = 48W$

The maximum power through $R_L = 3\Omega$ is $48W$

SIMULATED RESULTS:

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

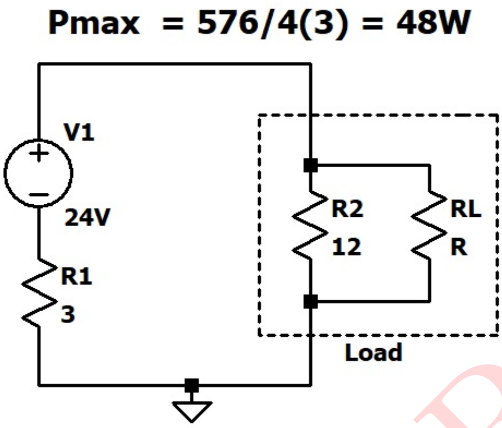

Figure 55: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
R_{TH}	3Ω	3Ω
P_{MAX}	$48W$	$48W$

Numerical 11: Find the value of adjustable resistance R which result in maximum power transfer across the terminal AB in the circuit of figure 56

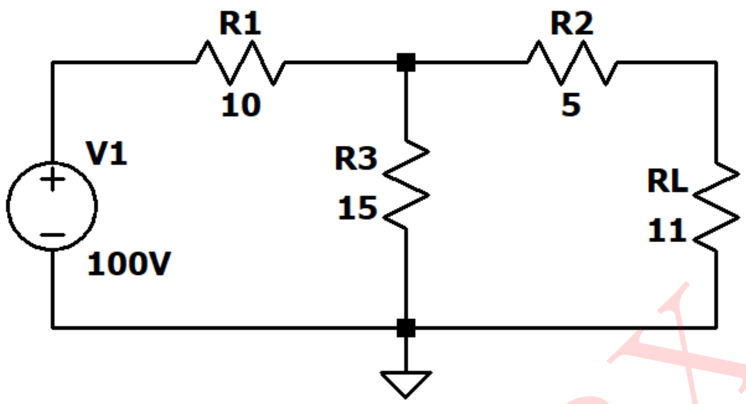

Figure 56: Circuit 11

Solution:

By Thenenin's Theorem

To find Thevenin's voltage V_{TH}:

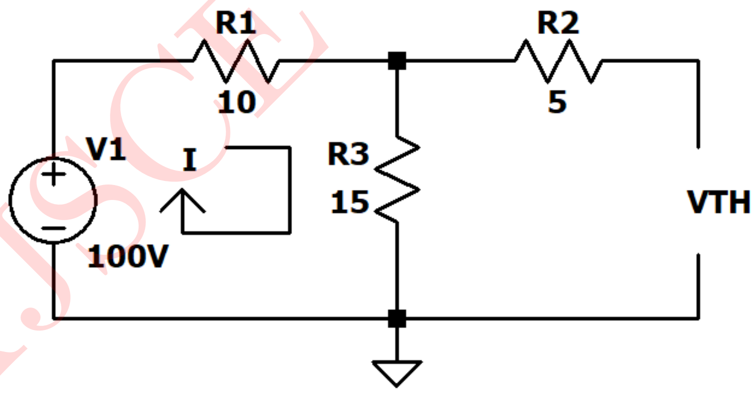

Figure 57: Modified circuit for figure 56(i)

Apply Kirchhoff's Voltage Law(KVL):

$100 - 10I - 15I = 0$

$I = 4A$

$V_{AB} = V_{TH} = 15I$

$V_{TH} = 15 \times 4 = 60V$

$\therefore V_{TH} = 60V$

To find Thevenin's resistance R_{TH}:

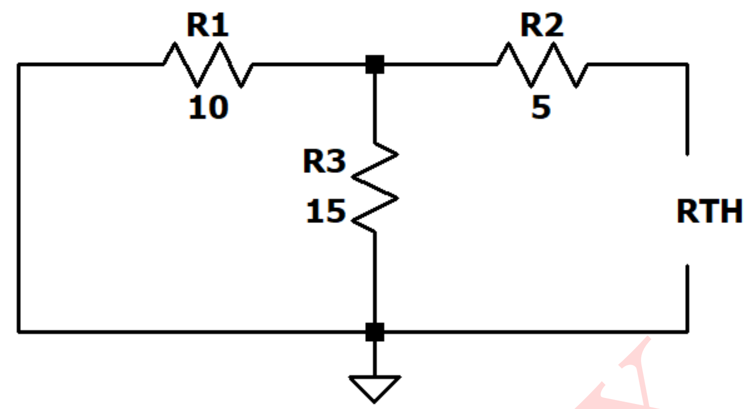

Figure 58: Modified circuit for figure 56(ii)

Here 10Ω and 15Ω resistances are in parallel and their resultant is in series with 5Ω

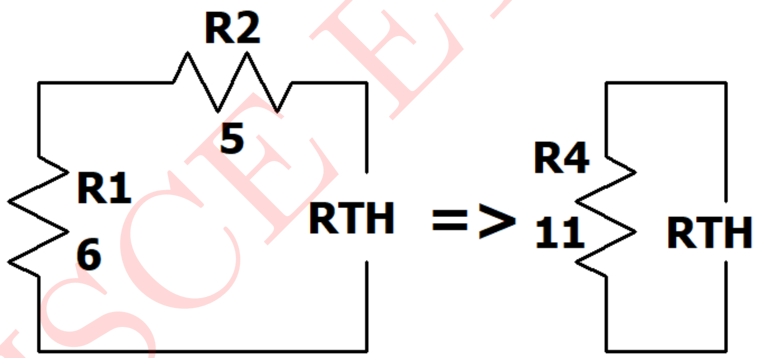

Figure 59: Modified circuit for figure 58

$R_{TH} = \frac{10 \times 15}{10 + 15} + 5$

$R_{TH} = 11\Omega$

By maximum power transfer theorem, for maximum power to be transfered across terminal AB, $R_{TH} = R_L$

$R_{TH} = R_L = 11\Omega$

$\therefore P_{MAX.} = \frac{V^2}{4R_L}$

$P_{MAX.} = \frac{60^2}{4 \times 11}$

$P_{MAX.} = \frac{3600}{44} = 81.818W$

The maximum power through R_L is $81.818W$

SIMULATED RESULTS:

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

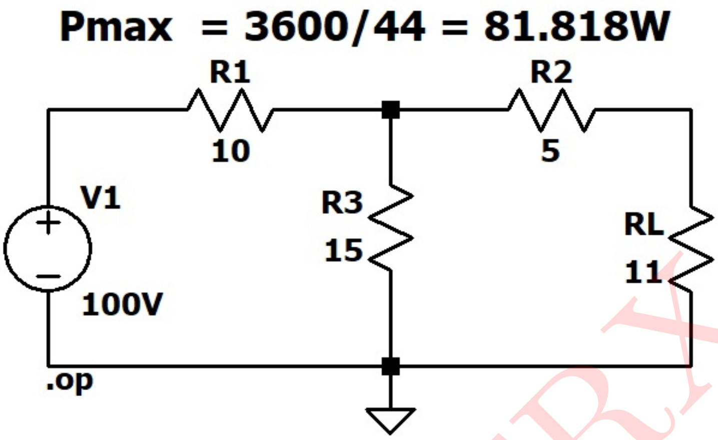

Figure 60: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
R_{th}	11Ω	11Ω
V_{TH}	$60V$	$60V$
P_{MAX}	$81.818W$	$81.818W$