Electrical Science: 2021-22
Lecture 5
Thevenin’s Theorem

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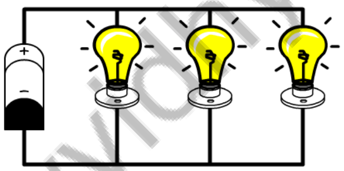
Thevenin's Theorem

Applications of Thevenin's Theorem

In many real life applications, the load connected to a circuit often changes as per the requirement of the consumer, while all the remaining elements of the circuit remain fixed.

Examples, Domestic loads connected to power supply, Loads connected to the SMPS of a CPU, Loads connected at the output of a audio amplifier.



A change in the load changes the operating conditions in the circuit and the entire circuit needs to be analysed again.

Thevenin's theorem provides a technique by which the entire fixed part of the circuit is replaced by a very simple equivalent of a voltage source in series with an impedance which makes it easy to analyse the variation of load on a complex circuit.

Thevenin's Theorem

What is Thevenin's Theorem ?

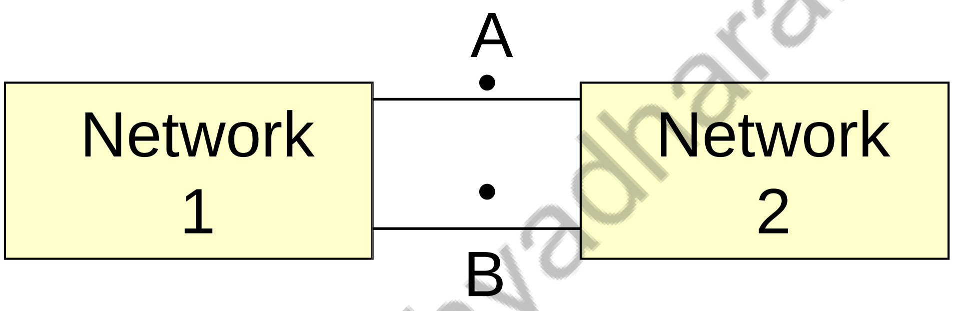
A **linear** two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off.

Thevenin's theorem provides a technique by which the entire fixed part of the circuit is replaced by a very simple equivalent of a voltage source in series with an impedance.

Linear Circuit: A linear circuit is one whose output is linearly related (or directly proportional) to its input i.e. containing only linear elements eg. R, L, C, transformer

Thevenin's Theorem

Consider the following:

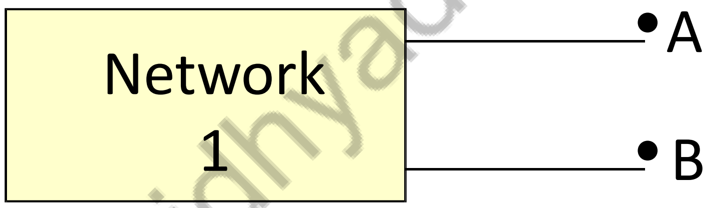


Coupled networks

For purposes of discussion, at this point, we consider that both networks are composed of **resistors and independent voltage and current sources**

Thevenin's Theorem

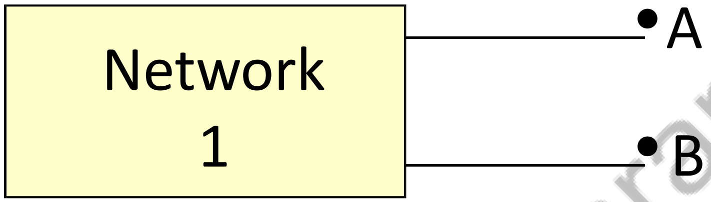
Suppose Network 2 is detached from Network 1 and we focus temporarily only on Network 1.



Network 1, open-circuited.

Network 1 can be as complicated in structure as one can imagine. (maybe 100 meshes, 200 resistors, 10 voltage sources and 20 current sources)

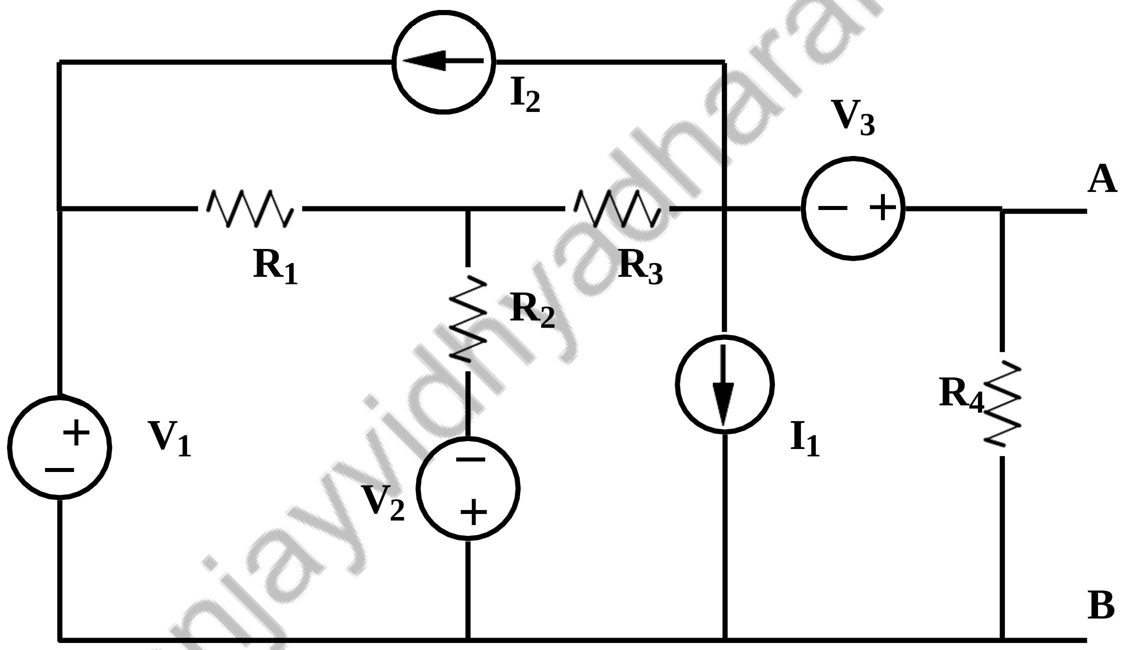
Thevenin's Theorem



- Now place a voltmeter across terminals A-B and read the voltage, called open-circuit voltage (V_{oc}).
- No matter how complicated Network 1 is, we read one voltage. It is either positive at A, (with respect to B) or negative at A.
- We call this voltage V_{oc} and we also call it $V_{THEVENIN} = V_{Th}$
- We now deactivate all sources of Network 1.
- To deactivate a voltage source?
  - Remove the source and replace it with a short circuit.
- To deactivate a current source?
  - Remove the current source.

Thevenin's Theorem

Consider the following circuit.

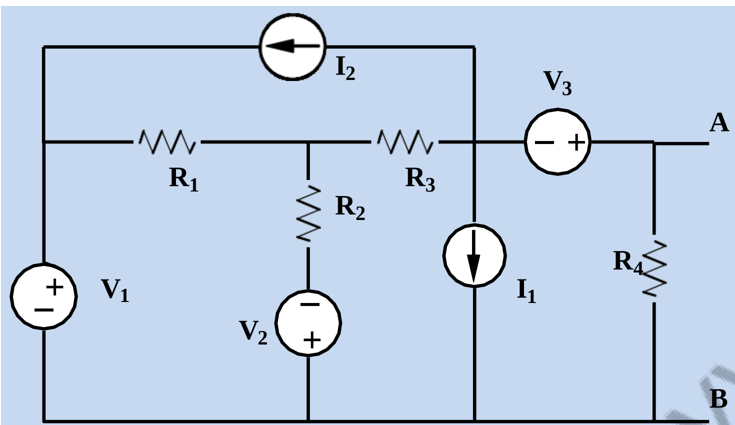


A typical circuit with independent sources

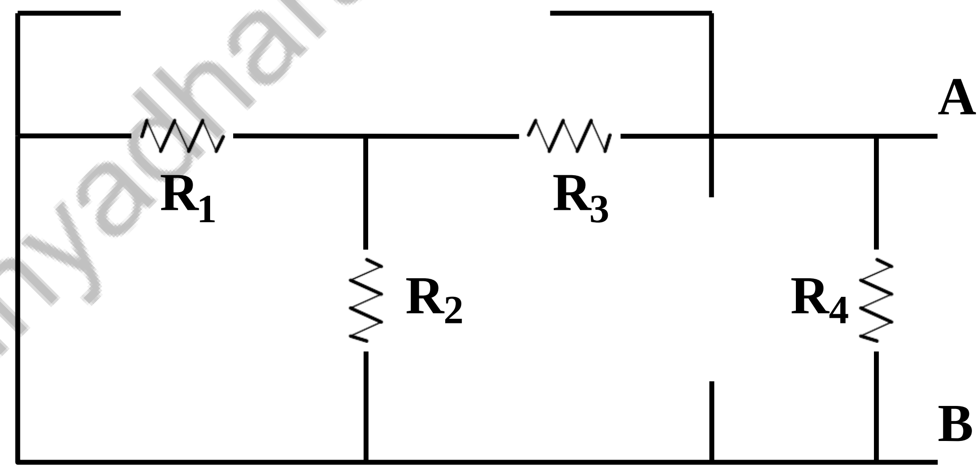
How do we deactivate the sources of this circuit?

Thevenin's Theorem

When the sources are deactivated the circuit appears



Original Circuit

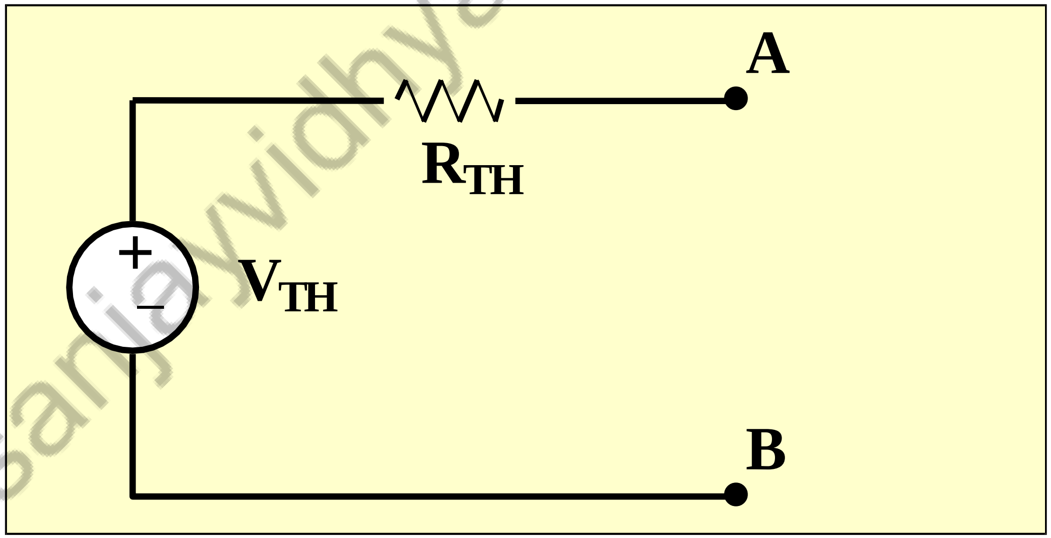


Circuit with deactivated sources

- Now place an ohmmeter across A-B and read the resistance.
  - If $R_1 = R_2 = R_4 = 20\ \Omega$ and $R_3 = 10\ \Omega$
  - then the meter reads ?? Ω

Thevenin's Theorem

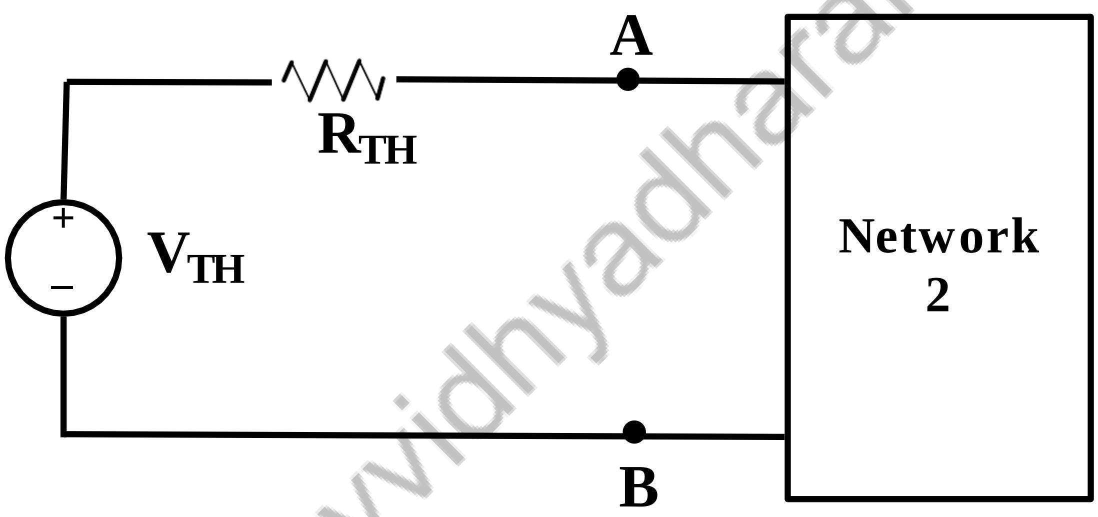
- Ohmmeter reading → $R_{THEVENIN}$ and shorten this to R_{TH}.
- Therefore, the important results are that we can replace Network 1 with the following network.



Thevenin equivalent structure.

Thevenin's Theorem

We can now tie (reconnect) Network 2 back to terminals A-B.

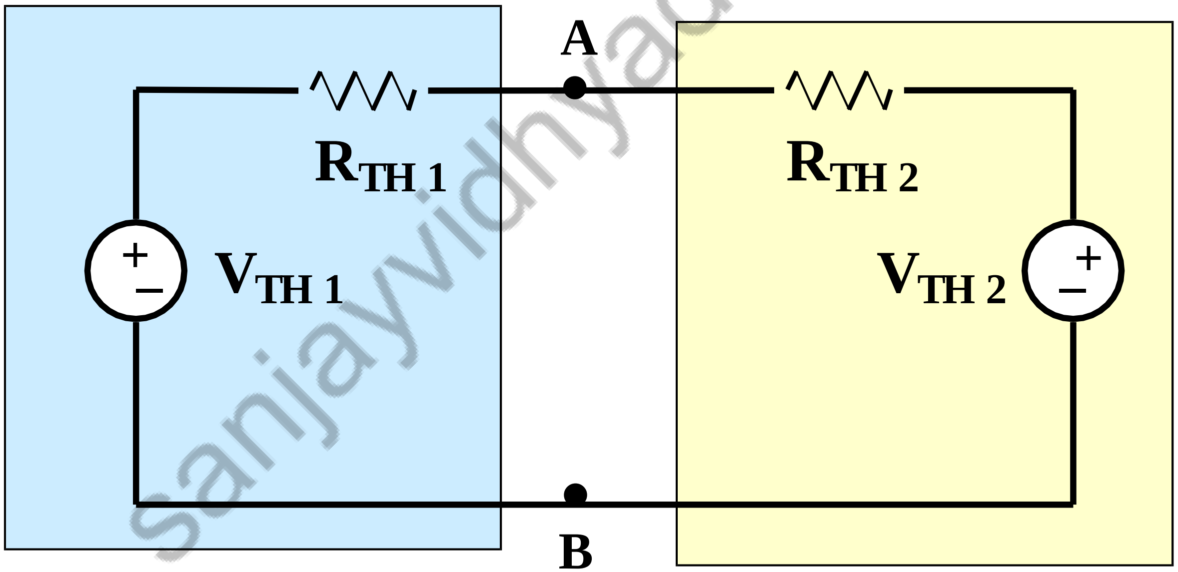


System with Network 1 replaced by the Thevenin equivalent circuit.

- Now, calculations desired in Network 2 can be made
- Will give the same results as if we still had Network 1 connected.

Thevenin's Theorem

We can also replace Network 2 with a Thevenin voltage and Thevenin resistance.



The network system replaced by Thevenin voltages and resistances.

Thevenin's Theorem

Finding the Thevenin equivalent Voltage:

If the terminals a-b are made open-circuited (by removing the load), no current flows, then the open circuit voltage across the terminals a-b is equal to the voltage source V_{Th} . Thus, V_{Th} is the open-circuit voltage across the terminal i.e. $V_{Th} = V_{oc}$

Finding the Thevenin equivalent Resistance:

Case 1: When the networks has no Dependent Sources

- Turn off all the independent sources, then R_{Th} is the input resistance of the network looking between terminals a and b.

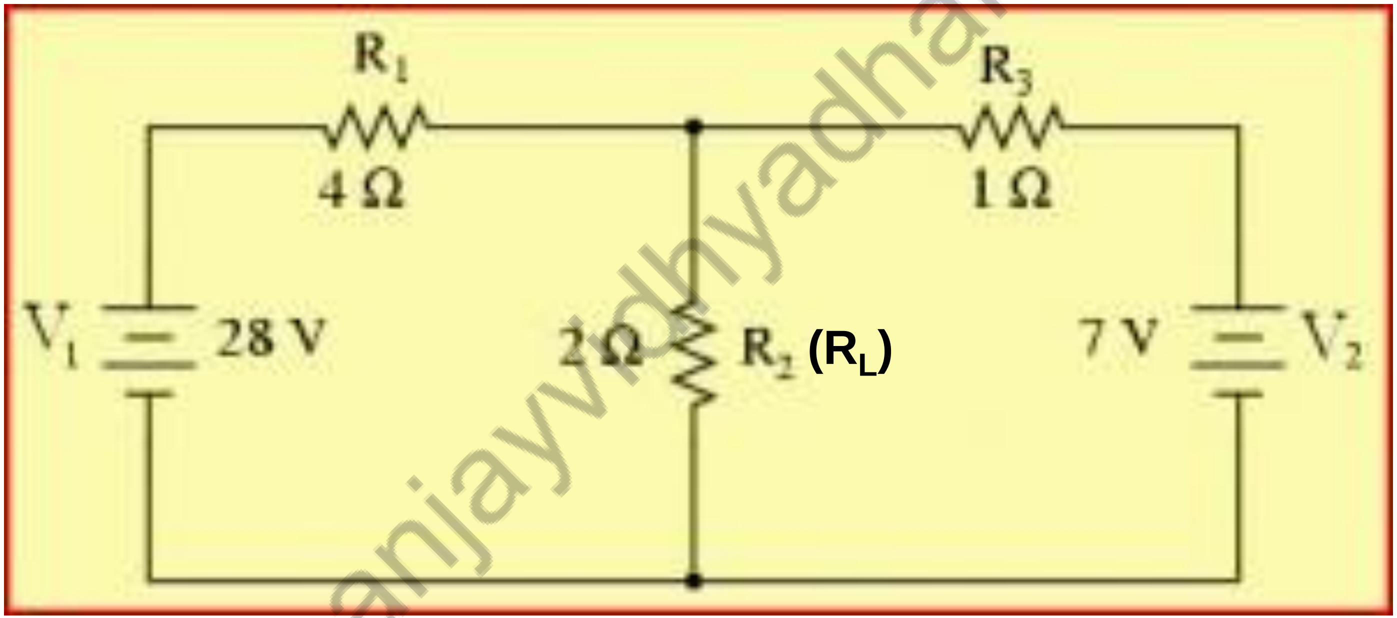
Case 2: When the networks has Dependent Sources

- Turn off all independent sources, apply voltage source V_o across terminals a-b and determine the resulting current I_o. Then $R_{Th} = V_o / I_o$.
- Alternatively, insert a current source i o across terminals a-b and find the terminal voltage V_o . Again $R_{Th} = V_o / I_o$.

Thevenin's Theorem

Example 1: To find Thevenin equivalent between terminals 'a' and 'b'

Case 1: No dependent source



Thevenin's Theorem

Example 1: To find Thevenin equivalent between terminals 'a' and 'b'

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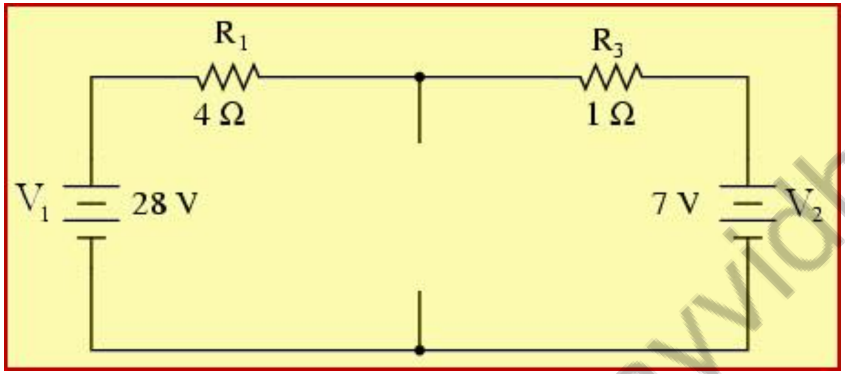

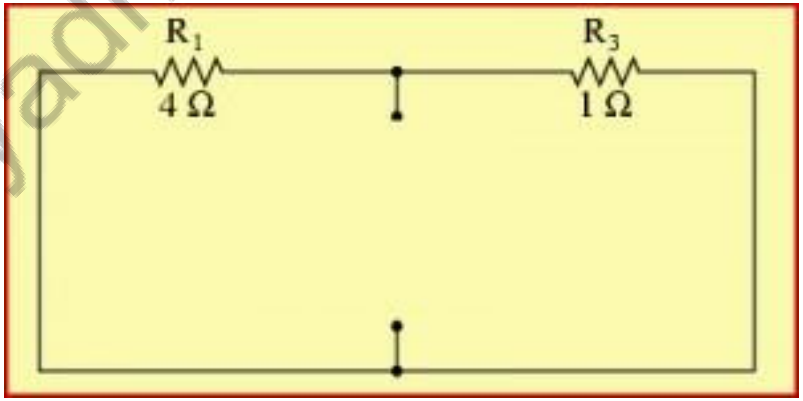

V_{Th} = 7 + 21*(1/5) = 11.2 V

R_{Th} = 0.8 Ohms

Thevenin's Theorem

Example 1: To find Thevenin equivalent between terminals 'a' and 'b'

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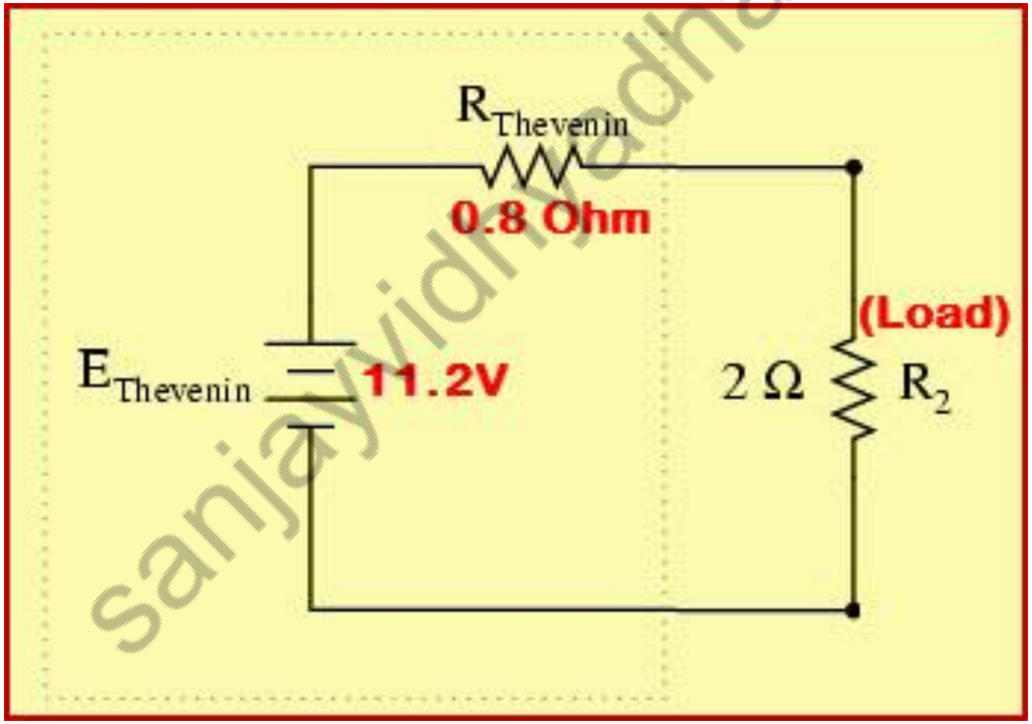
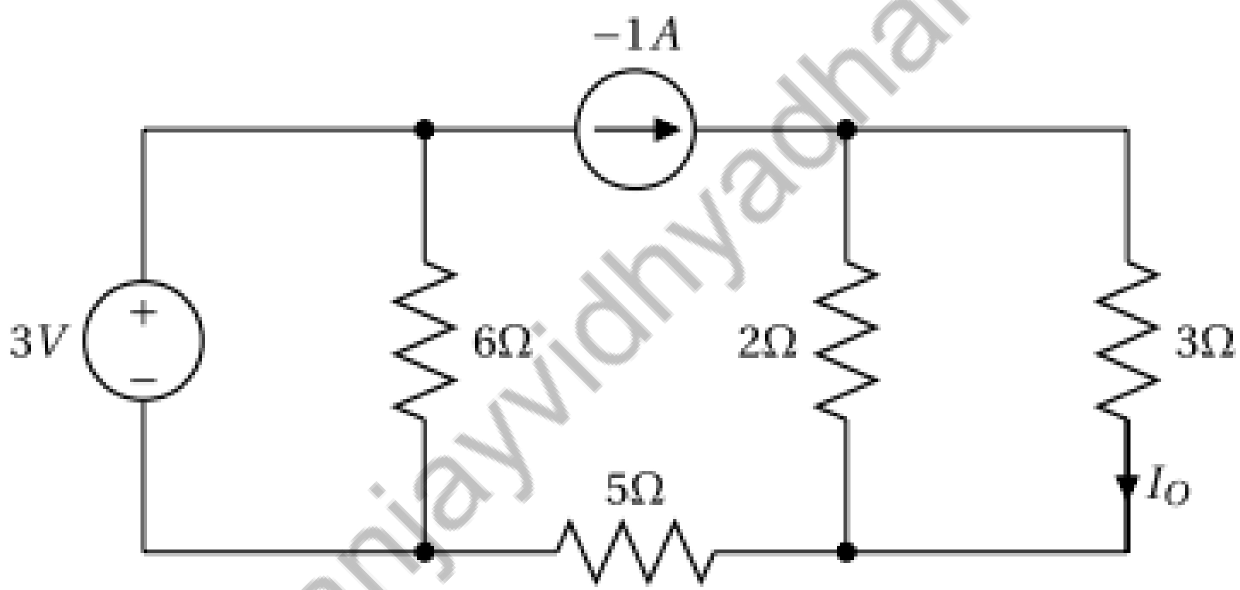


Thevenin's Theorem

Example 2: To find Thevenin equivalent between terminals 'a' and 'b'

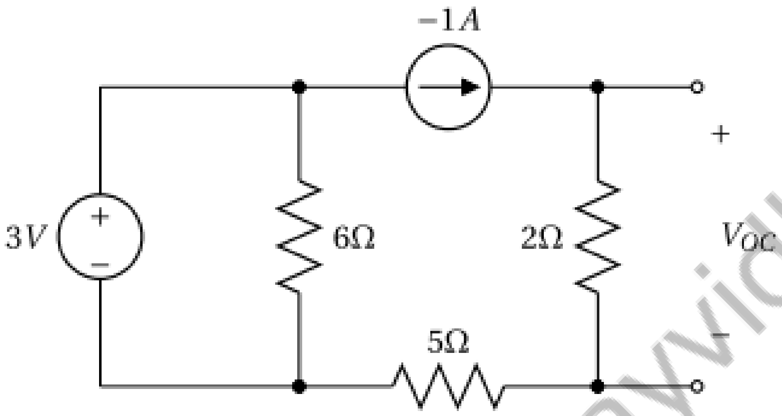
Case 1: No dependent source

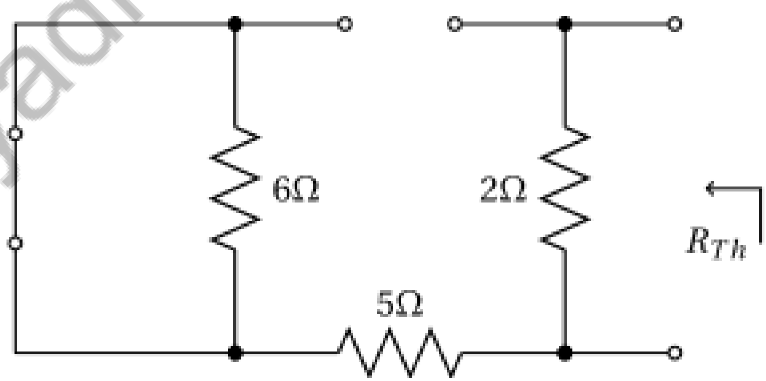


Thevenin's Theorem

Example 2: To find Thevenin equivalent between terminals 'a' and 'b'

Case 1: No dependent source





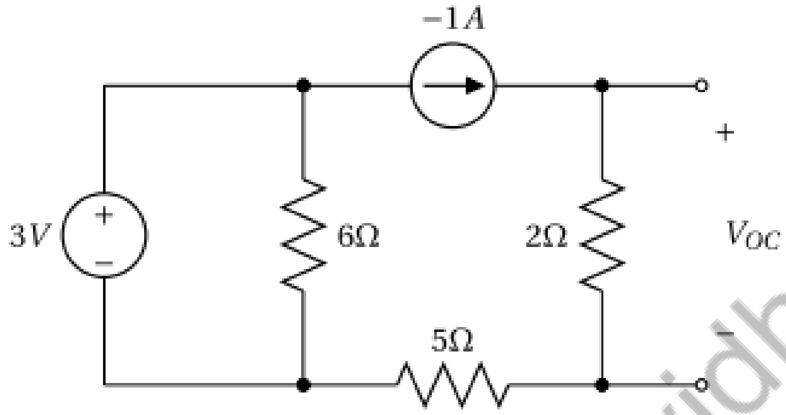
V_{Th} = - 2 V

R_{Th} = 2 Ohms

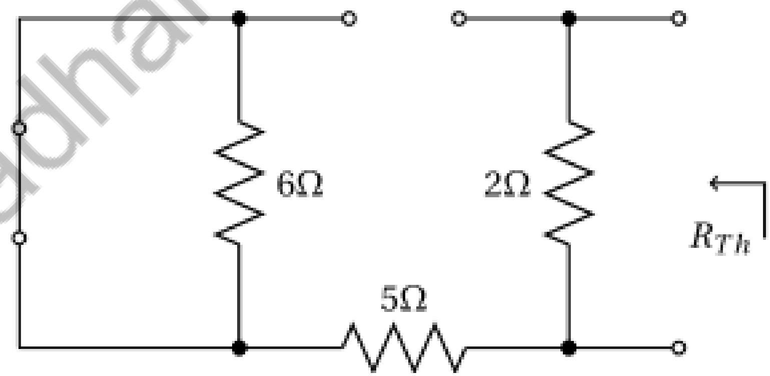
Thevenin's Theorem

Example 2: To find Thevenin equivalent between terminals 'a' and 'b'

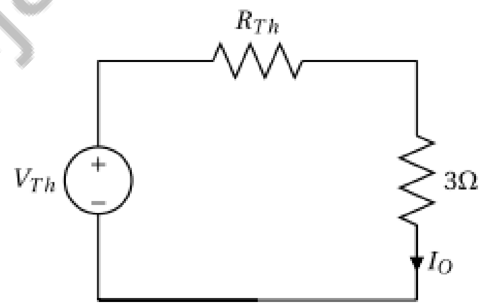
Case 1: No dependent source



V_{Th} = - 2 V



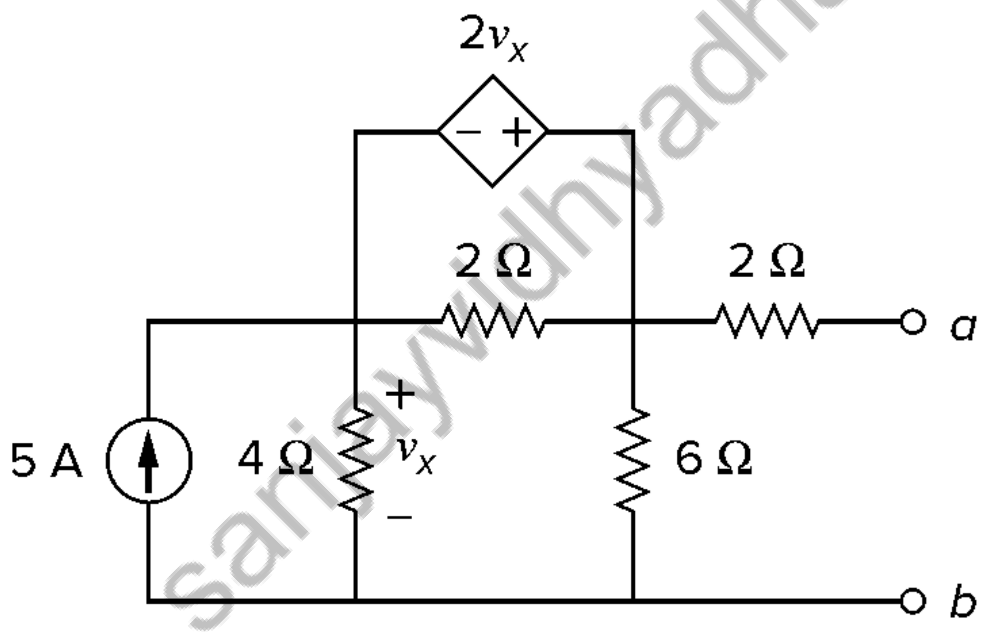
R_{Th} = 2 Ohms



Thevenin's Theorem

Example 3: To find Thevenin equivalent between terminal 'a' and 'b'

Case 2 : With dependent source



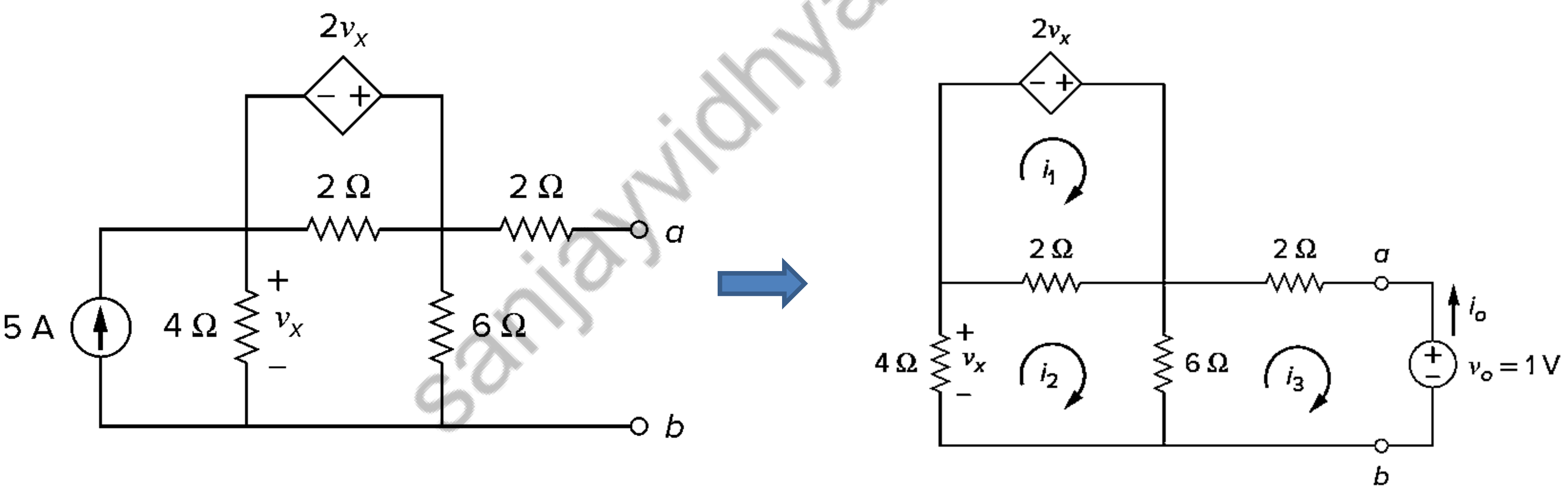
Thevenin's Theorem

Example 3: To find Thevenin equivalent between terminal 'a' and 'b'

Case 2 : With dependent source

Step 1. Remove dependent sources

5A current source is replaced by open circuit and set v 0 = 1V.

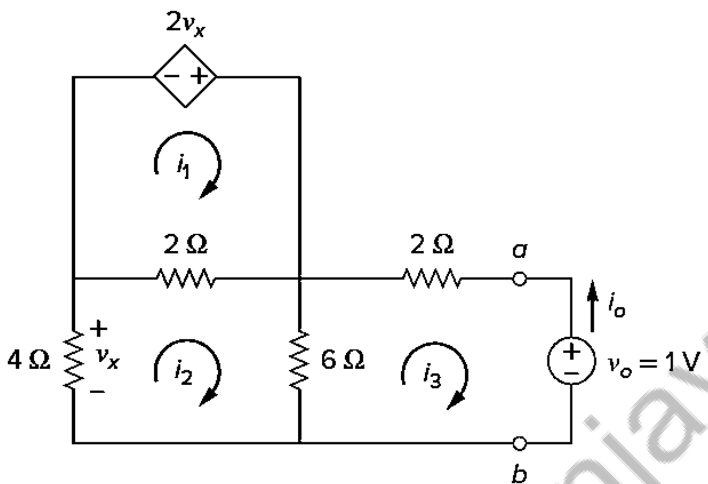


Thevenin's Theorem

Example 3: To find Thevenin equivalent between terminal 'a' and 'b'

Case 2 : With dependent source

Step 2.



Mesh analysis for loop 2 and 3,

$$4i_2 + 2(i_2 - i_1) + 6(i_2 - i_3) = 0$$

$$\text{and } 6(i_3 - i_2) + 2i_3 + 1 = 0$$

KVL for loop 1:

$$-2v_x + 2(i_1 - i_2) = 0$$

$$\Rightarrow v_x = i_1 - i_2$$

Also

$$-4i_2 = v_x = i_1 - i_2$$

$$i_1 = -3i_2$$

On solving we get, $i_0 = -i_3 = 1/6$ A

Therefore,

$$R_{Th} = \frac{v_o}{i_o} = \frac{1}{1/6} = 6\Omega$$

Thevenin's Theorem

Example 3: To find Thevenin equivalent between terminal 'a' and 'b'

Case 2 : With dependent source

Step 3. Find V_{Th}

We have to find v_{oc} for this circuit.

Applying mesh analysis we get,

$i_1 = 5 \quad (1)$

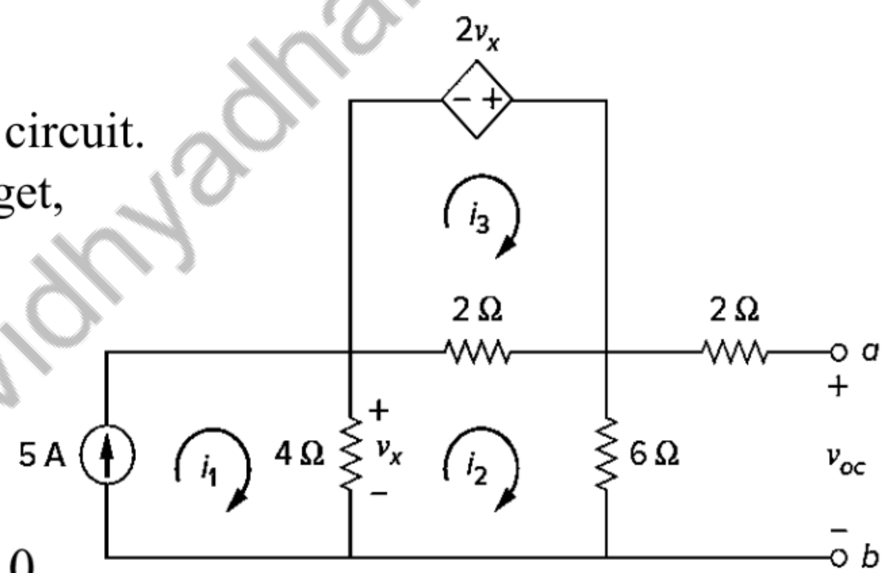
$-2v_x + 2(i_3 - i_2) = 0$

$\Rightarrow v_x = i_3 - i_2 \quad (2)$

and

$4(i_2 - i_1) + 2(i_2 - i_3) + 6i_2 = 0$

$\Rightarrow 12i_2 - 4i_1 - 2i_3 = 0 \quad (3)$



$4(i_1 - i_2) = v_x \quad (4)$

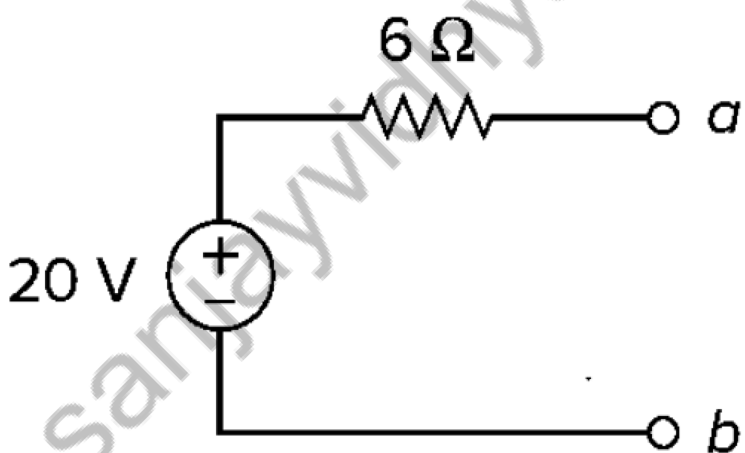
Thevenin's Theorem

Example 3: To find Thevenin equivalent between terminal 'a' and 'b'

Case 2 : With dependent source

On solving (1),(2),(3) and (4), we get, $\boldsymbol{i_2}$ **= 10/3 =>** $V_{Th} = v_{oc} = 6i_2 = 20\text{V}$

The Thevenin equivalent circuit is shown below.



Limitations of Thevenin's Theorem

If the circuit consists of nonlinear elements, this theorem is not applicable.

Thank you