THEVENIN’S THEOREM

NETWORK THEOREMS

1. ***SUPERPOSITION THEOREM***
2. ***THEVENIN'S THEOREM***
3. ***NORTON'S THEOREM***
4. ***MAXIMUM POWER TRANSFER THEOREM***

THEVENIN’S **THEOREM**

APPLICATION OF THEVENIN’S THEOREM

- *Analyze networks with sources that are not in series or parallel.*

- *Reduce the number of components required to establish the same characteristics at the output terminals.*

- *Investigate the effect of changing a particular component on the behaviour of a network without having to analyze the entire network after each change.*

THEVENIN'S THEOREM

STATEMENT OF THEVENIN'S THEOREM

Any two-terminal dc network can be replaced by an equivalent circuit consisting solely of a voltage source and a series resistor as shown in Fig. 9.23

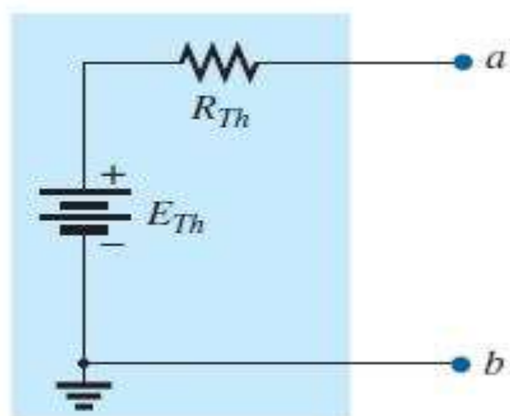

FIG. 9.23
Thévenin equivalent circuit.

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STEPS OF THEVENIN'S THEOREM

To **demonstrate** the **power** of the theorem, consider the fairly complex network of Fig. 9.25(a)

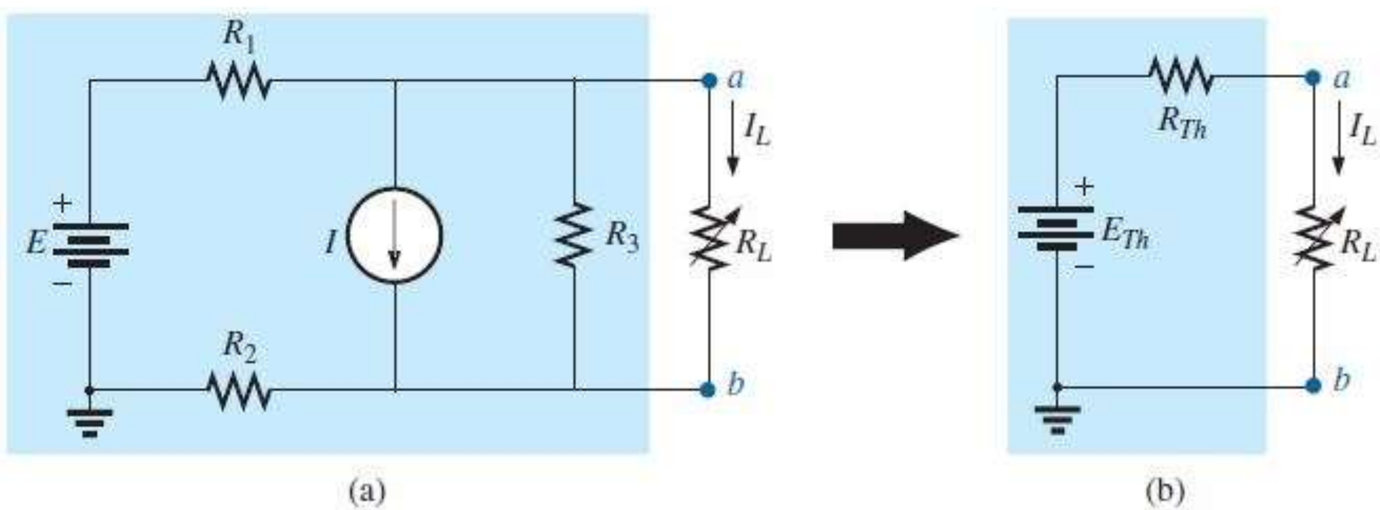

FIG. 9.25
Substituting the Thévenin equivalent circuit for a complex network.

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STEPS OF THEVENIN'S THEOREM

1. Remove that portion of the network where the Thévenin equivalent circuit is found. In Fig. 9.25(a), this requires that the load resistor RL be temporarily removed from the network.

2. Mark the terminals of the remaining two-terminal network. (The importance of this step will become obvious as we progress through some complex networks.)

Determination of RTh:

3. Calculate R_{Th} by first setting all sources to zero (voltage sources are replaced by short circuits, and current sources by open circuits) and then finding the resultant resistance between the two marked terminals. (If the internal resistance of the voltage and/or current sources is included in the original network, it must remain when the sources are set to zero.)

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STEPS OF THEVENIN’S THEOREM

Determination of E_{Th}:

4. Calculate E_{Th} by first returning all sources to their original position and finding the open-circuit voltage between the marked terminals. (This step is invariably the one that causes most confusion and errors. In all cases, keep in mind that it is the opencircuit potential between the two terminals marked in step 2.)

Conclusion:

5. Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit. This step is indicated by the placement of the resistor RL between the terminals of the Thévenin equivalent circuit as shown in Fig. 9.25(b).

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EXAMPLE 9.6 Find the Thévenin equivalent circuit for the network in the shaded area of the network in Fig. 9.26. Then find the current through *RL* for values of 2 Ω, 10 Ω, and 100 Ω.

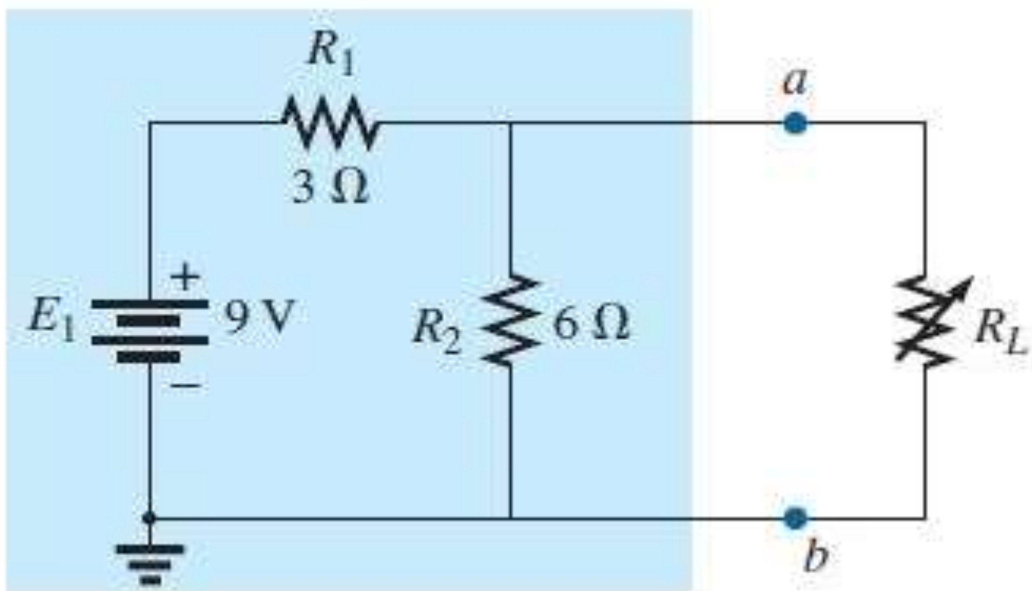

FIG. 9.26
Example 9.6.

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Solution: *Steps 1 and 2:* These produce the network in Fig. 9.27. Note that the load resistor*RL* has been removed and the two "holding" terminals have been defined as *a* and *b.*

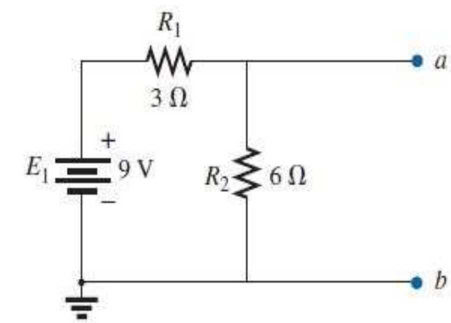

FIG. 9.27
Identifying the terminals of particular importance when applying Thévenin's theorem.

Steps 3: Replacing the voltage source *E1* with a short-circuit equivalent yields the network in Fig. 9.28(a), where

$$R_{Th} = R_1 \| R_2 = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = 2\ \Omega$$

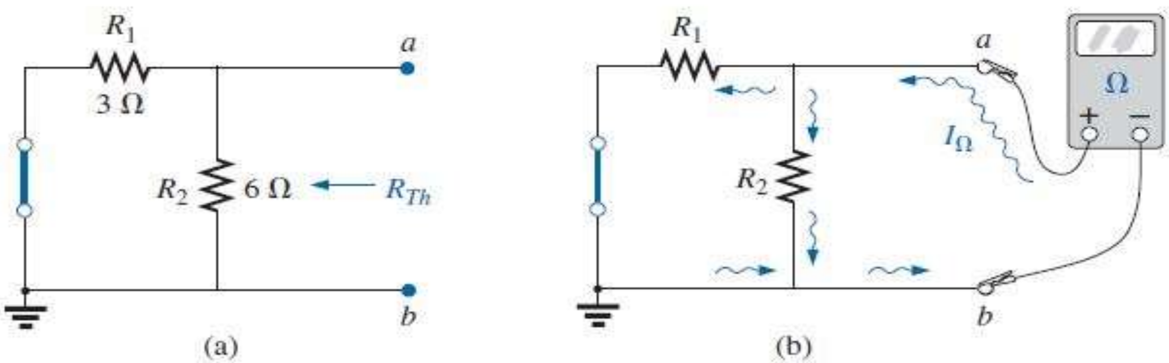

FIG. 9.28
Determining R_{Th} for the network in Fig. 9.27.

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Solution: *Step 4:* Replace the voltage source (Fi 9.29). For this case, the open circuit Voltage *Eth* is the same as the voltage drop across the 6 Ω resistor. Applying the voltage divider rule,

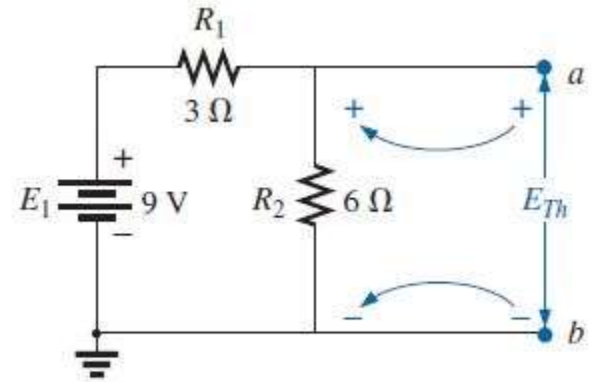

FIG. 9.29
Determining E_{Th} for the network in Fig. 9.27.

$$E_{Th} = \frac{R_2E_1}{R_2 + R_1} = \frac{(6\,\Omega)(9\,\text{V})}{6\,\Omega + 3\,\Omega} = \frac{54\,\text{V}}{9} = \mathbf{6\,V}$$

The use of a voltmeter to measure *Eth* appears in Fig. 9.30. Note that it is placed directly across the resistor *R*2 since *Eth* and V_{R2} are in parallel.

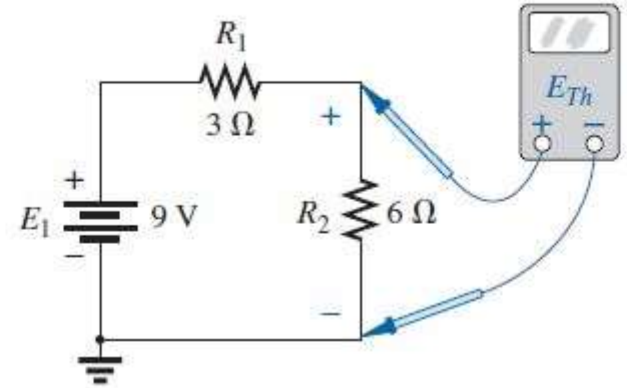

FIG. 9.30
Measuring E_{Th} for the network in Fig. 9.27.

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Solution: *Step 5* (Fig. 9.31):

$$I_L = \frac{E_{Th}}{R_{Th} + R_L}$$

$R_L = 2\ \Omega$: $\quad I_L = \dfrac{6\ \text{V}}{2\ \Omega + 2\ \Omega} = \mathbf{1.5\ A}$

$R_L = 10\ \Omega$: $\quad I_L = \dfrac{6\ \text{V}}{2\ \Omega + 10\ \Omega} = \mathbf{0.5\ A}$

$R_L = 100\ \Omega$: $\quad I_L = \dfrac{6\ \text{V}}{2\ \Omega + 100\ \Omega} = \mathbf{0.06\ A}$

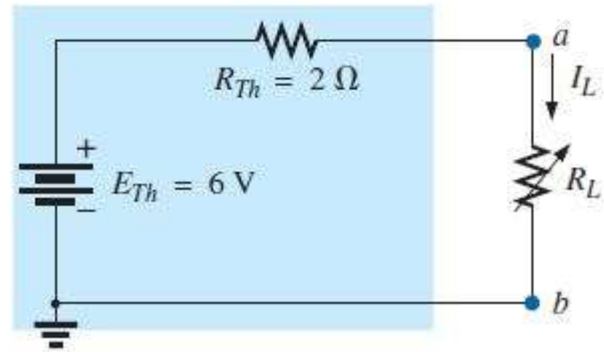

FIG. 9.31
Substituting the Thévenin equivalent circuit for the network external to R_L in Fig. 9.26.

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EXAMPLE 9.7 Find the Thévenin equivalent circuit for the network in the shaded area of the network in Fig. 9.32.

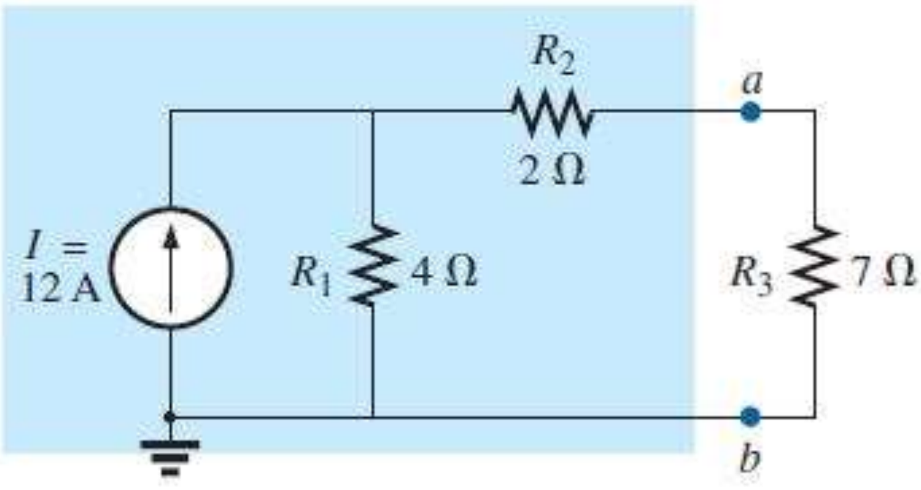

FIG. 9.32
Example 9.7.

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EXAMPLE 9.9 Find the Thévenin equivalent circuit for the network in the shaded area of the bridge network in Fig. 9.43.

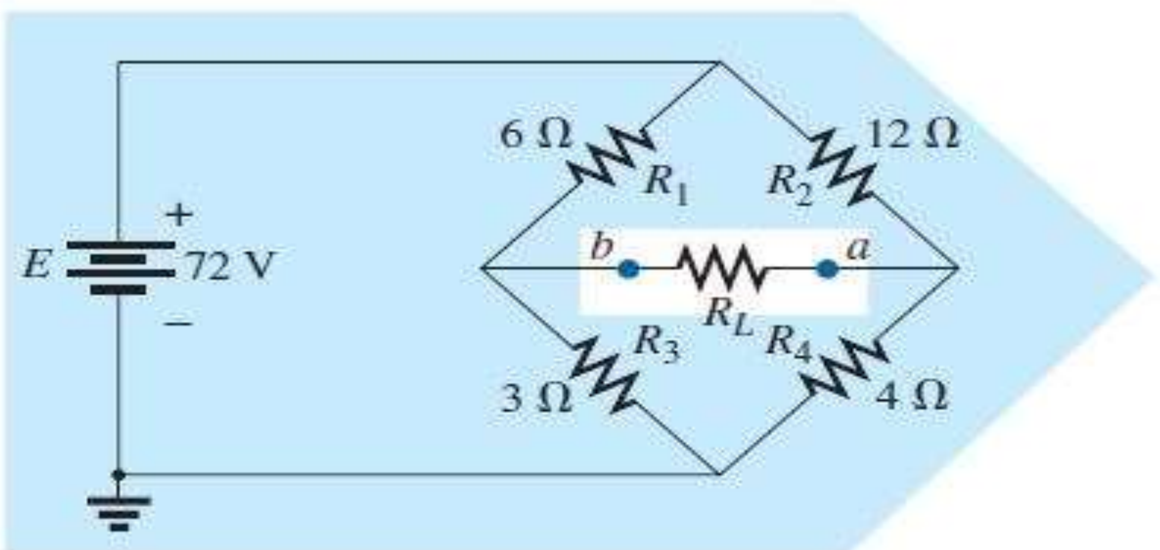

FIG. 9.43
Example 9.9.

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Solution:

Steps 1 and 2: See Fig. 9.44

Step 3: See Fig. 9.45. In this case, the short-circuit replacement of the voltage source *E* provides a direct connection between *c* and *c_* in Fig. 9.45(a), permitting a “folding” of the network around the horizontal line of*a-b* to produce the configuration in Fig. 9.45(b).

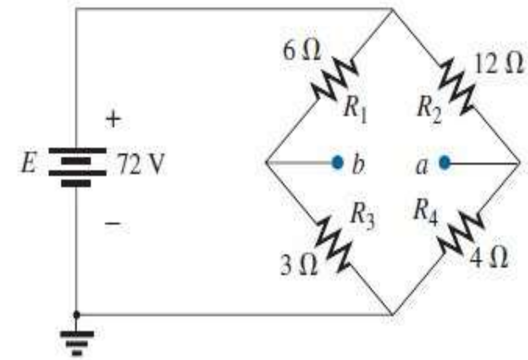

FIG. 9.44
Identifying the terminals of particular interest for the network in Fig. 9.43.

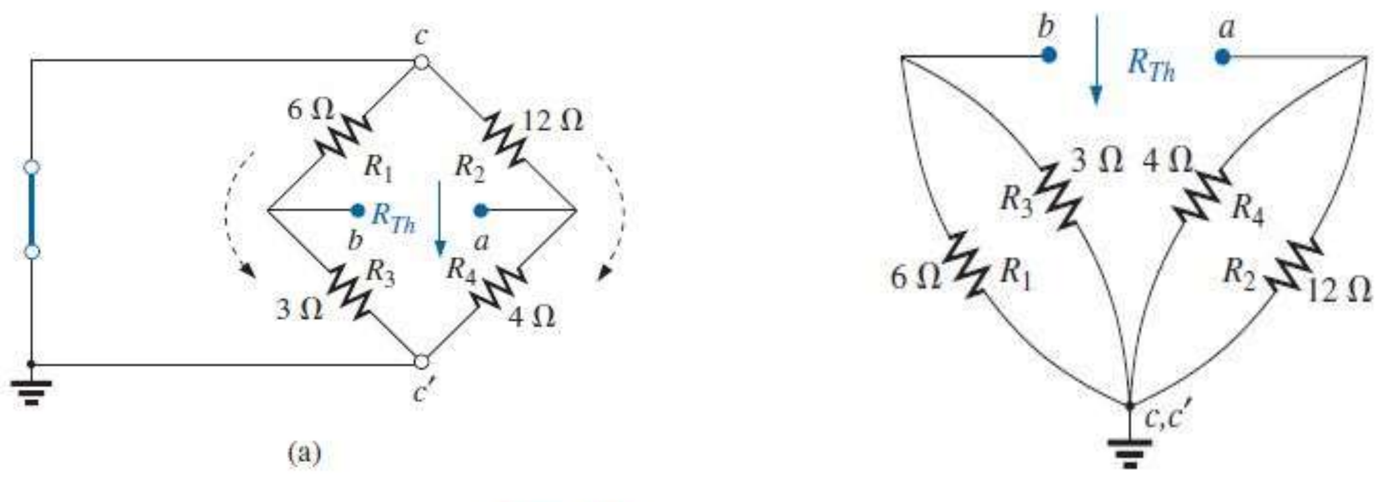

FIG. 9.45

THEVENIN'S THEOREM

Step 4: The circuit is redrawn in Fig. 9.46. The absence of a direct connection between *a* and *b* results in a network with three parallel branches. The voltages *V*1 and *V*2 can therefore be determined using the voltage divider rule:

$$V_1 = \frac{R_1E}{R_1 + R_3} = \frac{(6\ \Omega)(72\ \text{V})}{6\ \Omega + 3\ \Omega} = \frac{432\ \text{V}}{9} = 48\ \text{V}$$

$$V_2 = \frac{R_2E}{R_2 + R_4} = \frac{(12\ \Omega)(72\ \text{V})}{12\ \Omega + 4\ \Omega} = \frac{864\ \text{V}}{16} = 54\ \text{V}$$

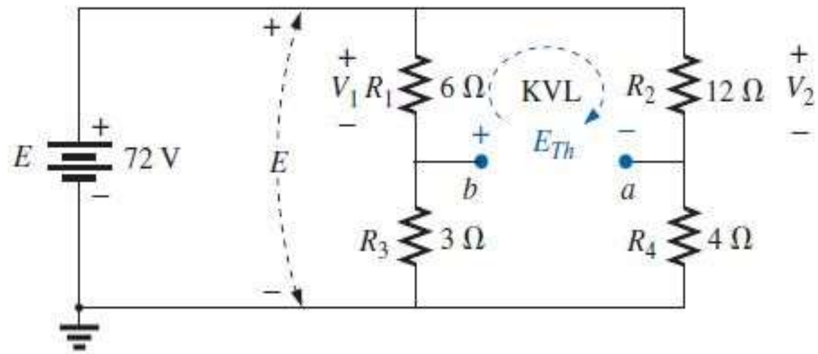

FIG. 9.46
Determining E_{Th} for the network in Fig. 9.44.

Assuming the polarity shown for E_{Th} and applying Kirchhoff's voltage law to the top loop in the clockwise direction results in

$$\Sigma_{\circlearrowright} V = +E_{Th} + V_1 - V_2 = 0$$

and $$E_{Th} = V_2 - V_1 = 54\ \text{V} - 48\ \text{V} = \mathbf{6\ V}$$

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Step 5: See Fig. 9.47

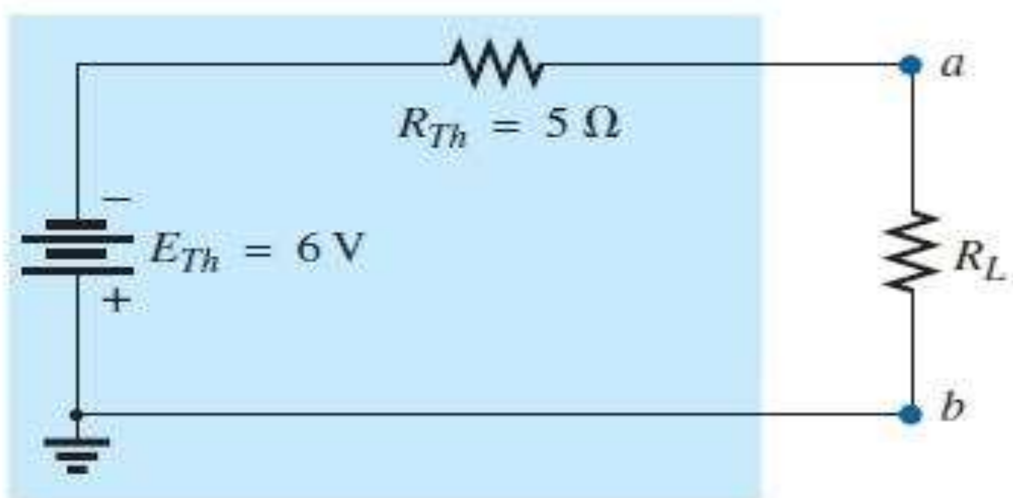

FIG. 9.47
Substituting the Thévenin equivalent circuit for the network external to the resistor R_L in Fig. 9.43.

THEVENIN’S THEOREM

EXAMPLE 9.8: Find the Thévenin equivalent circuit for the network in the shaded area of the network in Fig. 9.37. Note in this example that there is no need for the section of the network to be preserved to be at the “end” of the configuration.

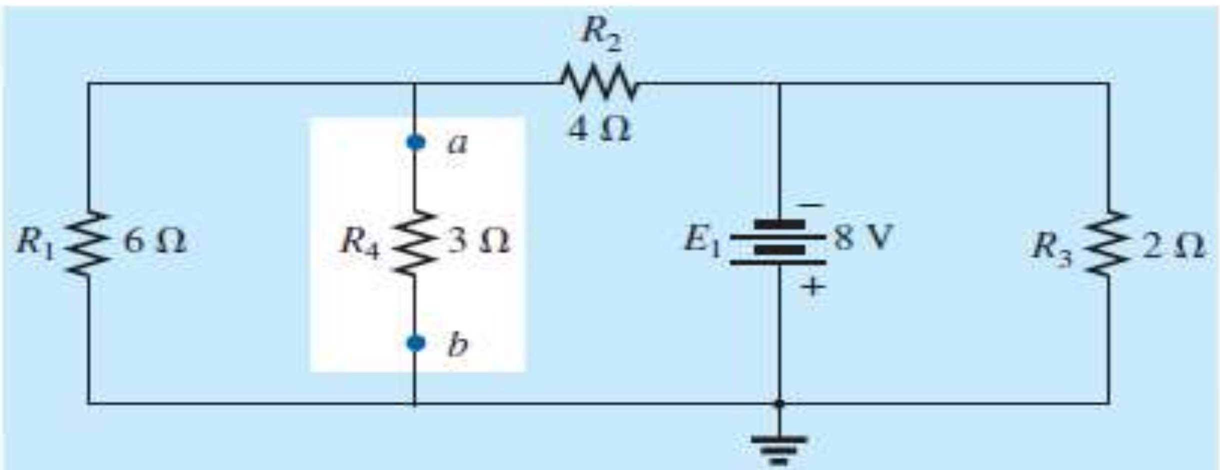

FIG. 9.37
Example 9.8.

THEVENIN'S THEOREM

Steps 1 and 2: See Fig. 9.38

Step 3: See Fig. 9.39. Steps 1 and 2 are relatively easy to apply, but now we must be careful to "hold" onto the terminals *a* and *b* as the Thévenin resistance and voltage are determined. In Fig. 9.39, all the remaining elements turn out to be in parallel, and the network can be redrawn as shown.

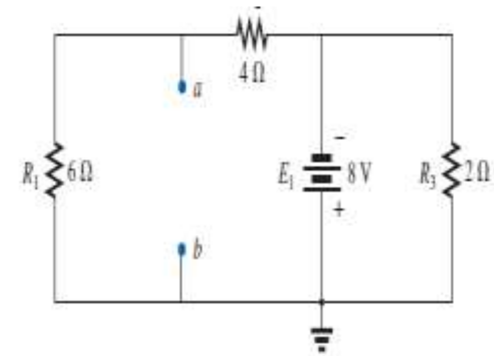

FIG. 9.38
Identifying the terminals of particular interest for the network in Fig. 9.37.

$$R_{Th} = R_1 \parallel R_2 = \frac{(6\ \Omega)(4\ \Omega)}{6\ \Omega + 4\ \Omega} = \frac{24\ \Omega}{10} = \mathbf{2.4\ \Omega}$$

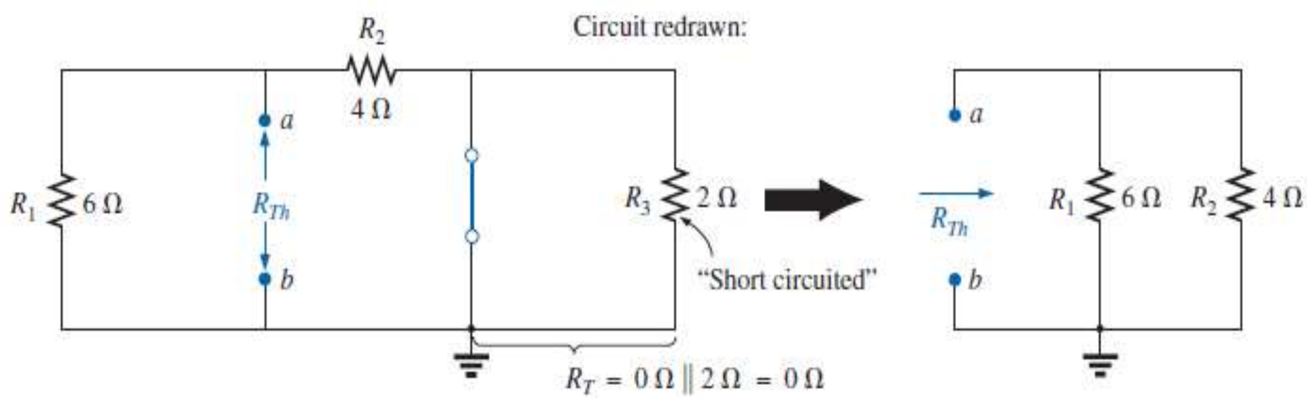

FIG. 9.39
Determining R_{Th} for the network in Fig. 9.38.

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Step 4: See Fig. 9.40. In this case, the network can be redrawn as shown in Fig. 9.41. Since the voltage is the same across parallel elements, the voltage across the series resistors *R*1 and *R*2 is *E*1, or 8 V. Applying the voltage divider rule

$$E_{Th} = \frac{R_1 E_1}{R_1 + R_2} = \frac{(6\ \Omega)(8\ \text{V})}{6\ \Omega + 4\ \Omega} = \frac{48\ \text{V}}{10} = \mathbf{4.8\ V}$$

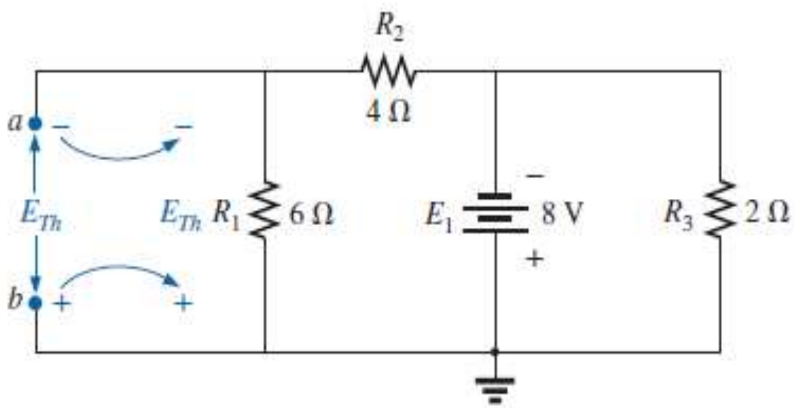

FIG. 9.40
Determining E_{Th} for the network in Fig. 9.38.

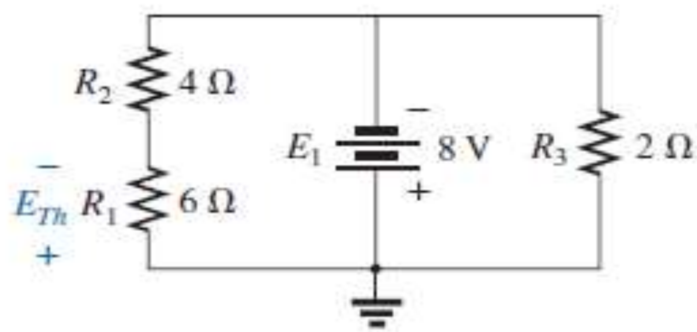

FIG. 9.41
Network of Fig. 9.40 redrawn.

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Step 5: See Fig. 9.42.

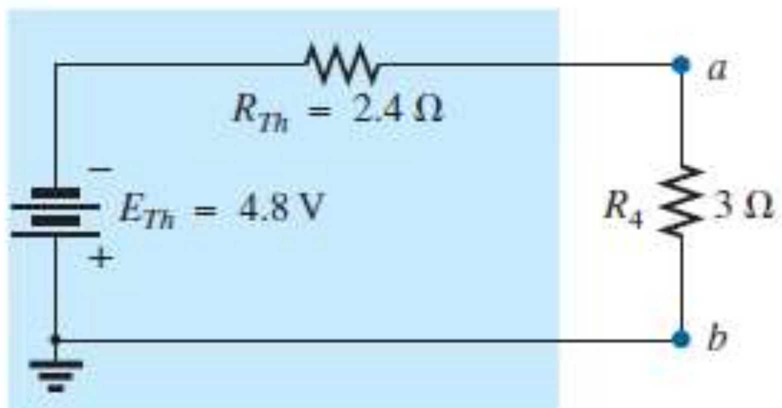

FIG. 9.42

Substituting the Thévenin equivalent circuit for the network external to the resistor R_4 in Fig. 9.37.

QUIZ

1. The Thevenin voltage is the___________

a) Open circuit voltage
b) Short circuit voltage
c) Open circuit and short circuit voltage
d) Neither open circuit nor short circuit voltage

ANS: A. Open circuit voltage

QUIZ

2. Thevenin's theorem is true for ___________

A. Linear networks
B. Non-Linear networks
C. Both linear networks and nonlinear networks
D. Neither linear networks nor non-linear networks

ANS: A. Linear networks

QUIZ

3. Vth is found across the _______________ terminals of the network.

a) Input
b) Output
c) Neither input nor output
d) Either input or output

ANS: B. Output

QUIZ

4. Thevenin's equivalent circuit consists of ---.

a) Voltage source and resistor connected in series
b) Voltage source and resistor connected in Parallel
c) Current source and resistor connected in series
d) Current source and resistor connected in Parallel

ANS: A. Voltage source and resistor connected in series

QUIZ

5. Current in Thevenin’s equivalent circuit can determine using---.

a) Ohm’s law
b) KCL
c) KVL
d) Current divider Law

ANS: A. Ohm’s law

HOME WORK

PRACTICE PROBLEM : Find the Thévenin equivalent circuit for the network external to the resistor *R for the network in the following circuit.*