Chapter 9
Network Theorems

9.2 SUPERPOSITION THEOREM

Statement of Superposition Theorem

The current through, or voltage across, an element in a linear bilateral network is equal to the algebraic sum of the currents or voltages produced independently by each source.

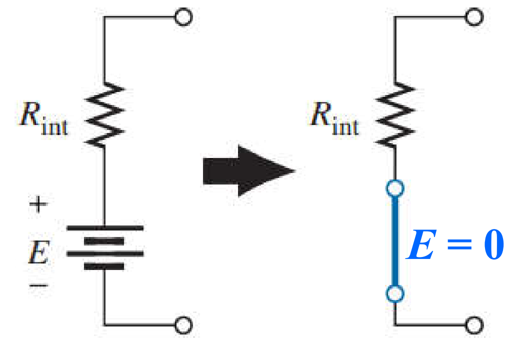
Steps to Apply Superposition Theorem

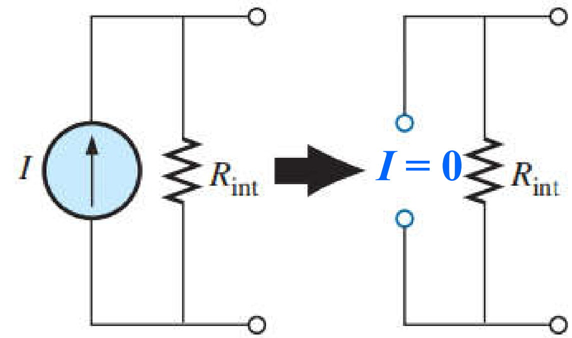
Step 1: Select a single source acting alone. Short the other voltage sources to make voltage is zero and open the current sources to make current is zero, if internal resistance/impedances are not known. If known, replace them by their internal impedances.

Step 2: Find the current through or the voltage across the required element, due to the source under consideration, using a suitable simplification technique.

Step 3: Repeat the above two steps for all the sources.

Step 4: Add all the individual effects produced by individual sources, to obtained the total current in or voltage across the element.





EXAMPLE 9.1 Using the superposition theorem, determine current I_1 for the network in Fig. 9.2.

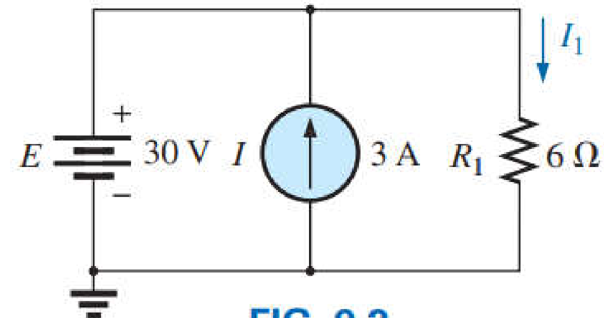
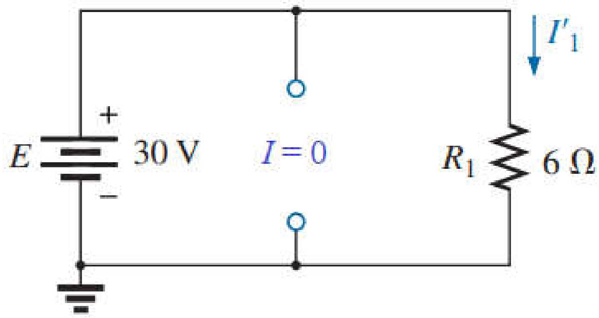


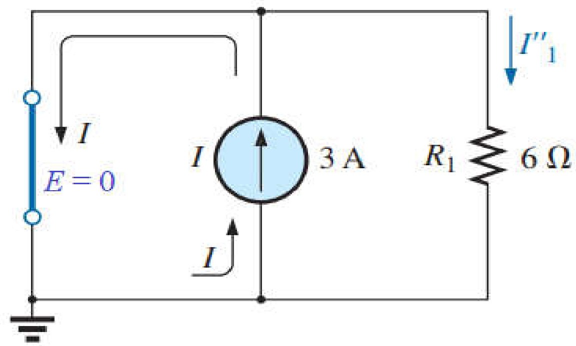
FIG. 9.2

Solution: Consider E then and $I = 0$ A (**open**).



$$I'_1 = \frac{E}{R_1} = \frac{30\text{ V}}{6\ \Omega} = 5\text{ A}$$

Consider I then and $E = 0$ V (**shorted**).



$$I''_1 = \frac{R_{sc}I}{R_{sc} + R_1} = \frac{(0\ \Omega)I}{0\ \Omega + 6\ \Omega} = 0\text{ A}$$

According to Superposition Theorem:

$$I_1 = I'_1 + I''_1 = 5\text{ A} + 0\text{ A} = \mathbf{5\text{ A}}$$

EXAMPLE 9.5 Find the current through the 2 Ω resistor of the network in Fig. 9.18. The presence of three sources results in three different networks to be analyzed.

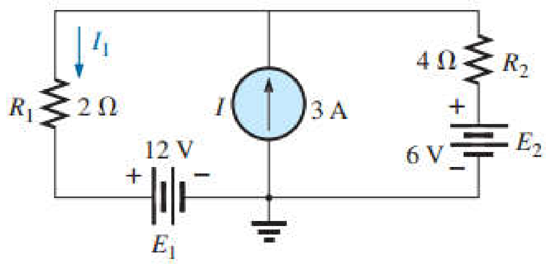


FIG. 9.18 *Example 9.5.*

Solution: Considering the effect of the 12 V source (Fig. 9.19):

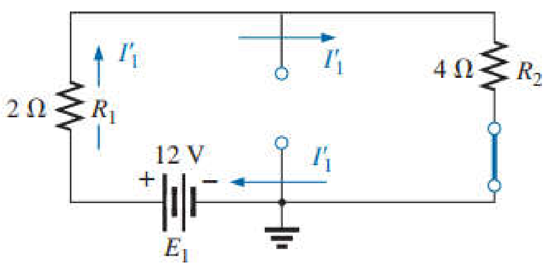


FIG. 9.19
The effect of E_1 on the current I.

$$I'_1 = \frac{E_1}{R_1 + R_2}$$

$$= \frac{12\text{ V}}{2\ \Omega + 4\ \Omega}$$

$$= \frac{12\text{ V}}{6\ \Omega} = 2\text{ A}$$

Considering the effect of the 6 V source (Fig. 9.20):

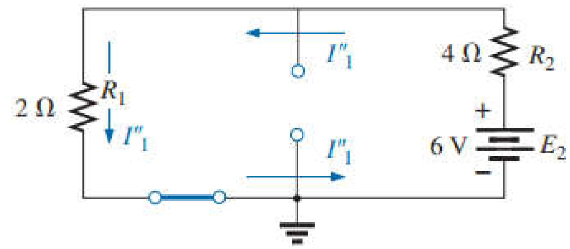


FIG. 9.20
The effect of E_2 on the current I_1.

$$I''_1 = \frac{E_2}{R_1 + R_2}$$

$$= \frac{6\text{ V}}{2\ \Omega + 4\ \Omega}$$

$$= \frac{6\text{ V}}{6\ \Omega} = 1\text{ A}$$

Considering the effect of the 3 A source (Fig. 9.21):

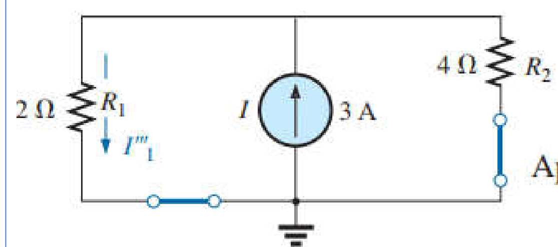


FIG. 9.21
The effect of I on the current I_1.

Applying the current divider rule,

$$I'''_1 = \frac{R_2 I}{R_1 + R_2}$$

$$= \frac{(4\ \Omega)(3\text{ A})}{2\ \Omega + 4\ \Omega}$$

$$= \frac{12\text{ A}}{6} = 2\text{ A}$$

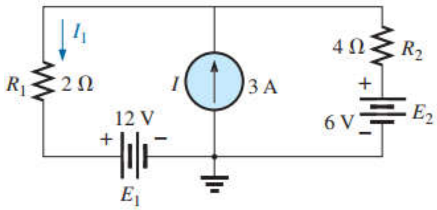


FIG. 9.18 *Example 9.5.*

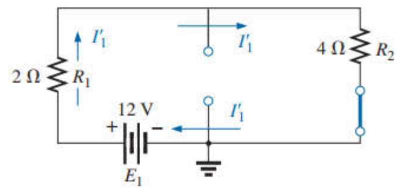


FIG. 9.19
The effect of E_1 on the current I.

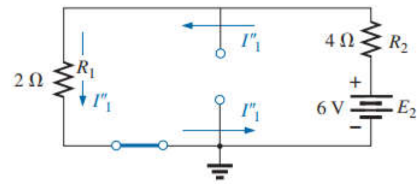


FIG. 9.20
The effect of E_2 on the current I_1.

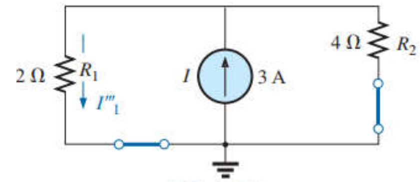


FIG. 9.21
The effect of I on the current I_1.

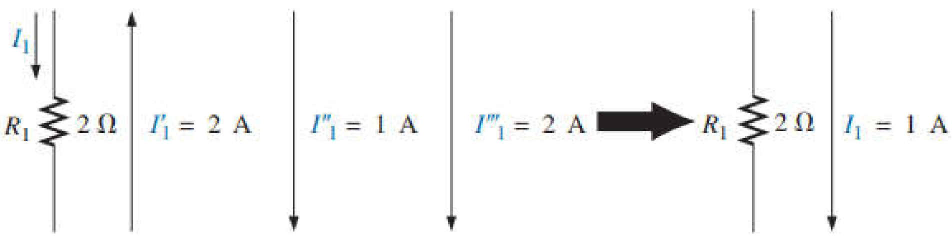


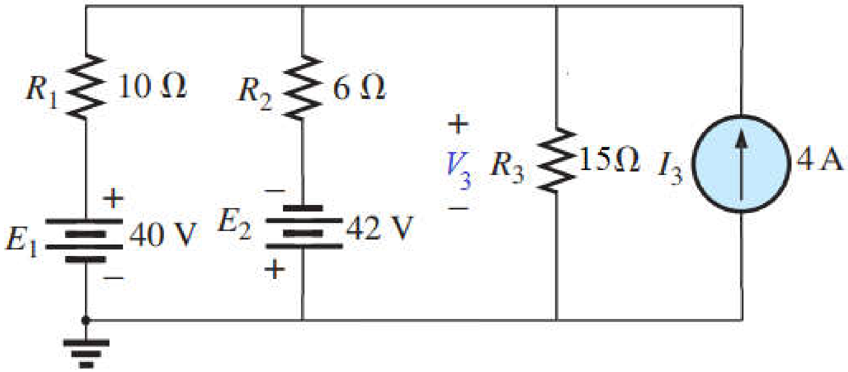
FIG. 9.22 *The resultant current I_1.*

The total current through the 2 Ω resistor appears in Fig. 9.22 and

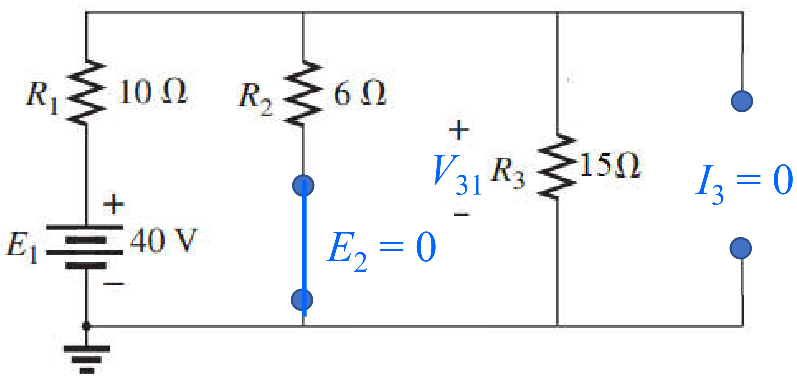
Opposite direction to I_1 in Fig. 9.18

$$I_1 = \overbrace{I''_1 + I'''_1}^{\text{Same direction as } I_1 \text{ in Fig. 9.18}} - I'_1$$
$$= 1\text{ A} + 2\text{ A} - 2\text{ A} = \mathbf{1\ A}$$

Example 9.2.1 Using superposition, find the voltage V_3 for the following network.



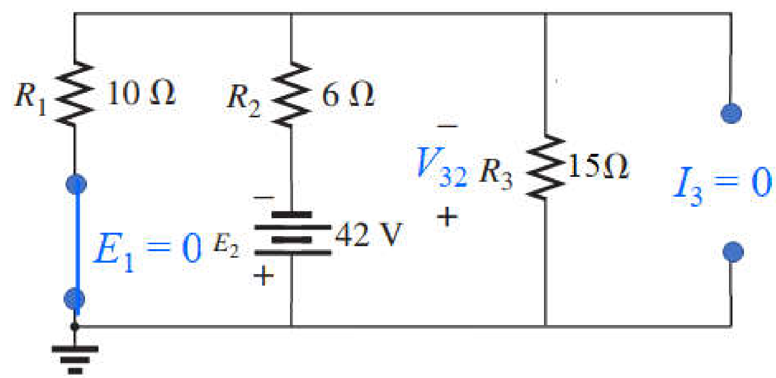
Solution: Consider E_1 then $E_2 = 0$ V (**shorted**) and $I_3 = 0$ A (**open**).



$$R_{p1} = \frac{R_2 R_3}{R_2 + R_3} = 4.29\ \Omega$$

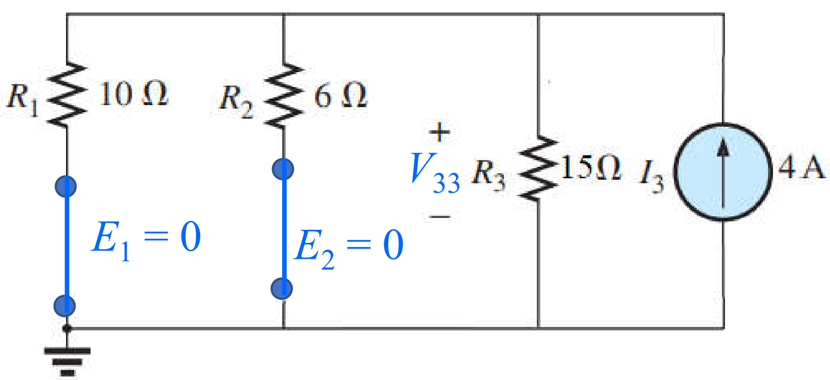
$$V_{31} = \frac{R_{p1}}{R_1 + R_{p1}} E_1 = 12\ \text{V}$$

Consider E_2 then $E_1 = 0$ V (**shorted**) and $I_3 = 0$ A (**open**).



$$R_{p2} = \frac{R_1 R_3}{R_1 + R_3} = 6\ \Omega \qquad V_{32} = \frac{R_{p2}}{R_2 + R_{p2}} E_2 = 21\ \text{V}$$

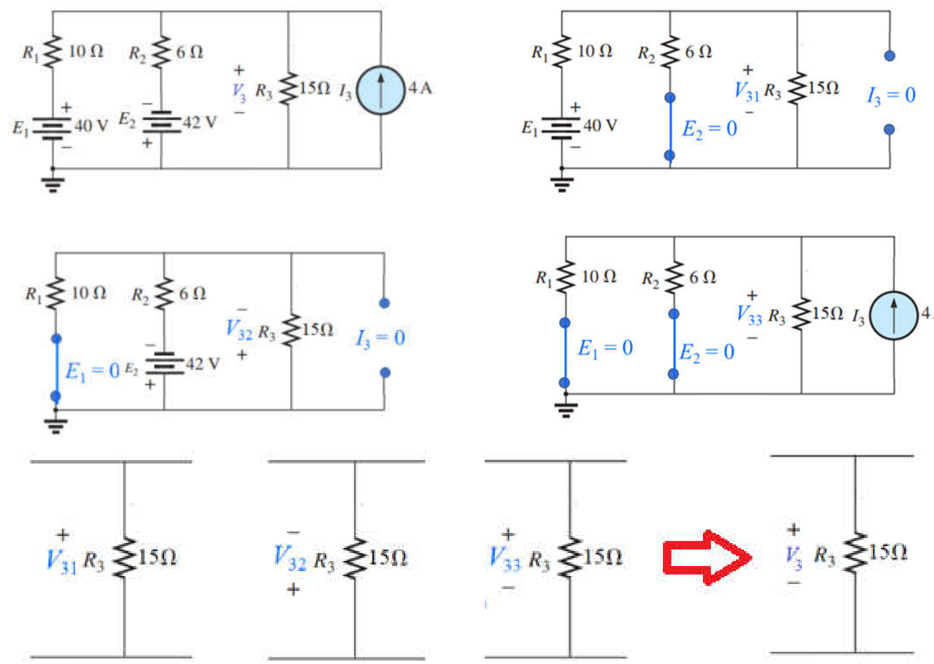
Consider I_3 then $E_1 = 0$ V (**shorted**) and $E_2 = 0$ V (**shorted**).



$$G_{p3} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = 0.333 \text{ S}$$

$$R_{p3} = \frac{1}{G_{p3}} = 3 \ \Omega$$

$$V_{33} = R_{p3} I_3 = 12 \text{ V}$$



According to Superposition Theorem:

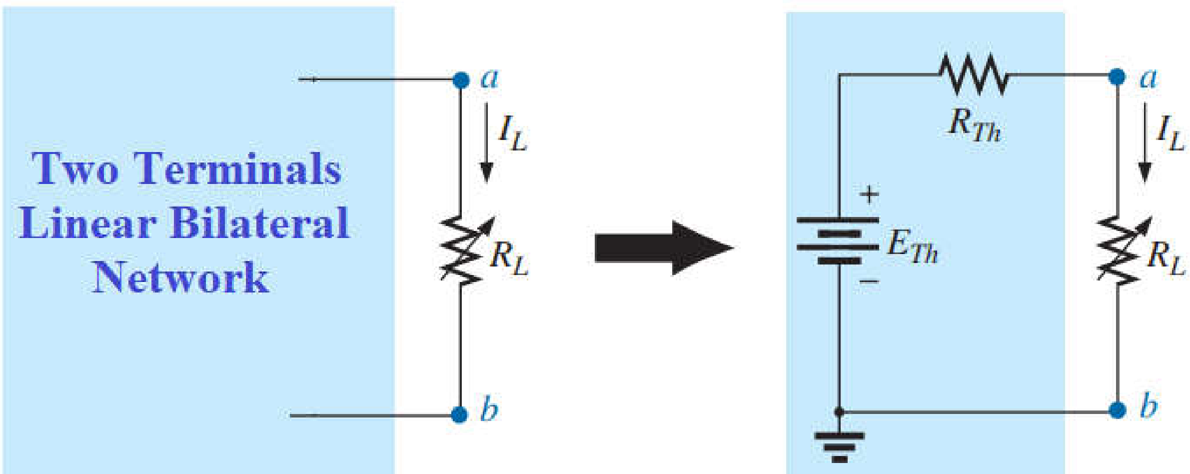
$$V_3 = V_{31} - V_{32} + V_{33} = 12 \text{ V} - 21 \text{ V} + 12 \text{ V} = \mathbf{-21 \text{ V}}$$

Practice Book [Ch 9] Problem: 1 ~ 6

9.3 THÉVENIN’S THEOREM

Statement of Thevenin’s Theorem

Any two-terminal, linear bilateral network can be replaced by an equivalent circuit consisting of a voltage source and a series resistance, as shown in the following figure.



R_{Th}: Thevenin’s equivalent resistance
E_{Th}: Thevenin’s equivalent voltage

Steps to Apply Thevenin's Theorem

Step 1: Remove that portion of the network where the Thévenin equivalent circuit is found.

Step 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.)

Step 3: Calculate R_{Th}/Z_{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/impedance between the two marked terminals. (If the internal resistance/impedance of the voltage and/or current sources is included in the original network, it must remain when the sources are set to zero.)

Step 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 open circuit potential between the two terminals marked in step 2.)

Step 5: Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.

Step 6: Do the remaining required calculation

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 R_L for values of 2 Ω, 10 Ω, and 100 Ω.

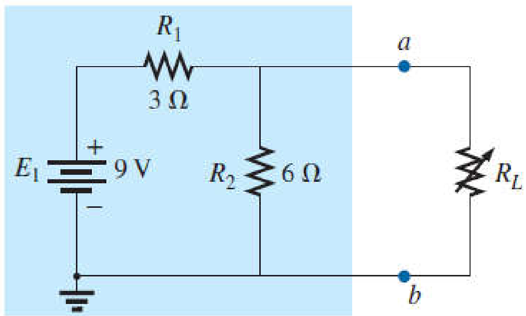
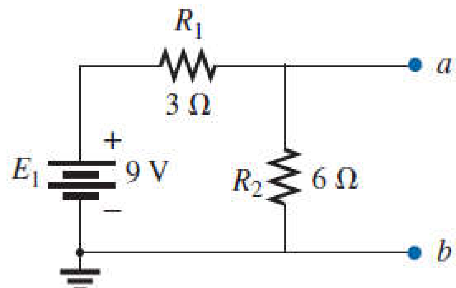


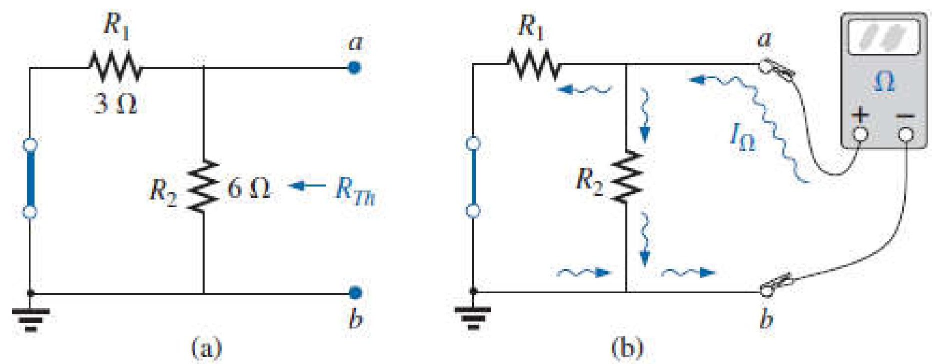
FIG. 9.26 *Example 9.6.*

Step 1: Remove that portion of the network where the Thévenin equivalent circuit is found.

Step 2: Mark the terminals (such as *a* and *b*) of the remaining two-terminal network.

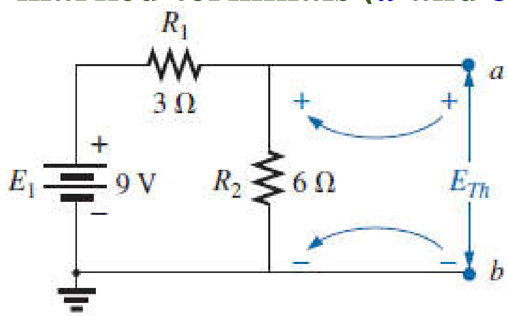


Step 3: Calculate R_{Th} by first setting all sources to zero (voltage sources are replaced by short circuits, and current sources by open circuits) and then finding the resultant resistance between the two marked terminals (*a* and *b*).



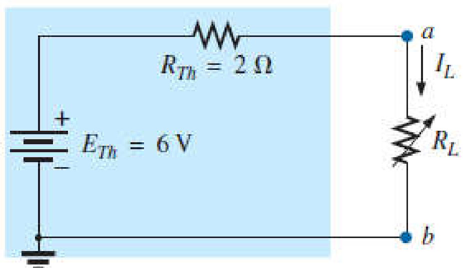
$$R_{Th} = R_1 \| R_2 = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = 2\ \Omega$$

Step 4: Calculate E_{Th} **by first returning all sources to their original position and finding the open-circuit voltage between the marked terminals (*a* and *b*).**



$$E_{Th} = \frac{R_2 E_1}{R_2 + R_1} = \frac{(6\ \Omega)(9\ \text{V})}{6\ \Omega + 3\ \Omega} = \frac{54\ \text{V}}{9} = \mathbf{6\ V}$$

Step 5: Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.



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

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

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

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

Example 9.8 Using Thevenin's Theorem calculate the current passing through the resistor R_4.

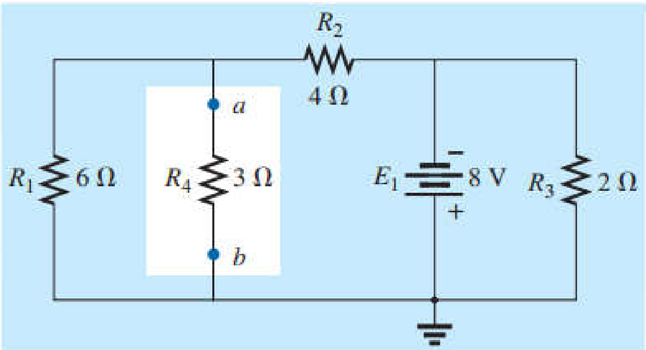
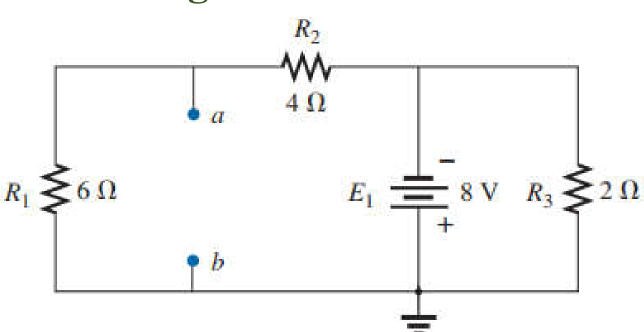


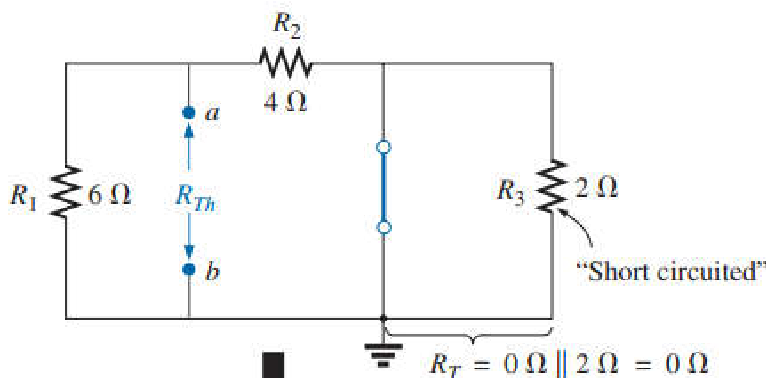
FIG. 9.37 *Example 9.8.*

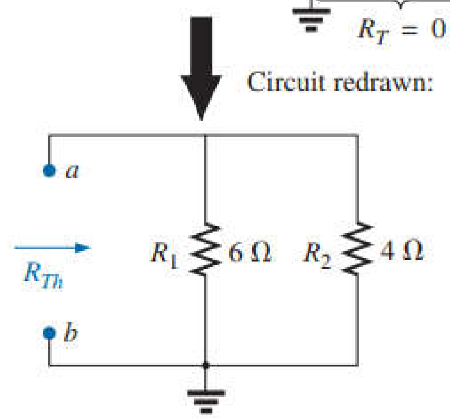
Step 1: Remove that portion of the network where the Thévenin equivalent circuit is found.

Step 2: Mark the terminals (such as *a* and *b*) of the remaining two-terminal network.



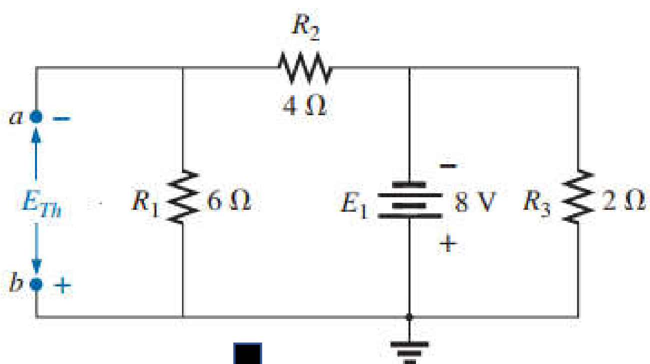
Step 3: Calculate R_{Th} by first setting all sources to zero (voltage sources are replaced by short circuits, and current sources by open circuits) and then finding the resultant resistance between the two marked terminals (*a* and *b*).

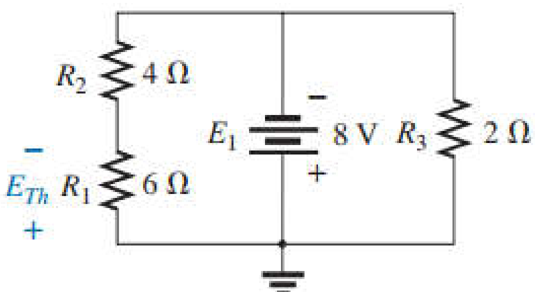




$$R_{Th} = R_1 \parallel R_2 = \frac{(6\,\Omega)(4\,\Omega)}{6\,\Omega + 4\,\Omega} = \frac{24\,\Omega}{10} = \mathbf{2.4\,\Omega}$$

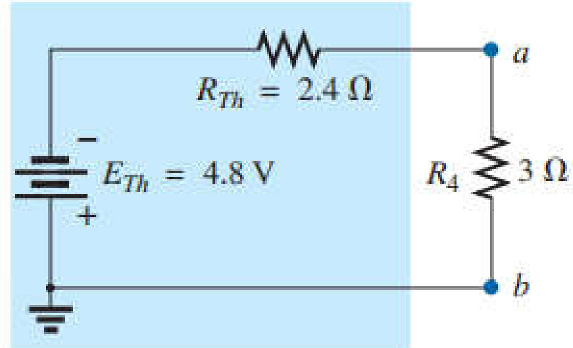
Step 4: Calculate E_{Th} by first returning all sources to their original position and finding the open-circuit voltage between the marked terminals (*a* and *b*).





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

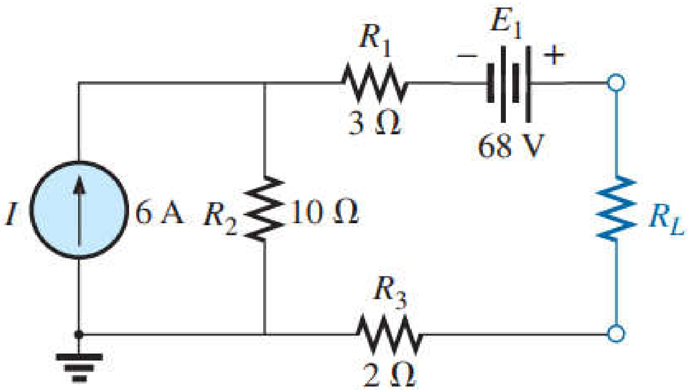
Step 5: Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.



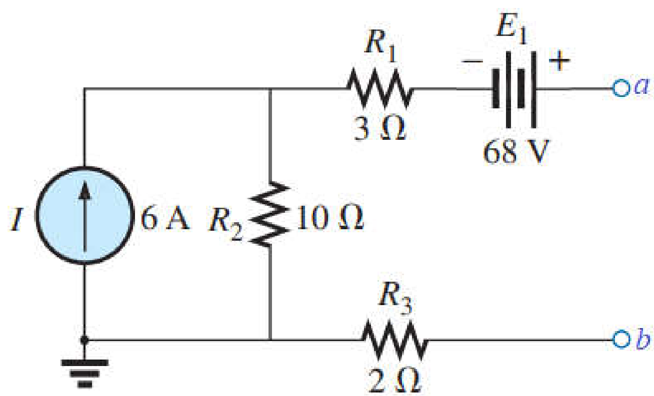
Step 6: Calculate the current passing through the resistor R_4.

$$I_{R4} = \frac{E_{Th}}{R_{Th} + R_4} = \frac{4.8\ \text{V}}{2.4\ \Omega + 3\ \ \Omega} = \mathbf{0.89\ A}$$

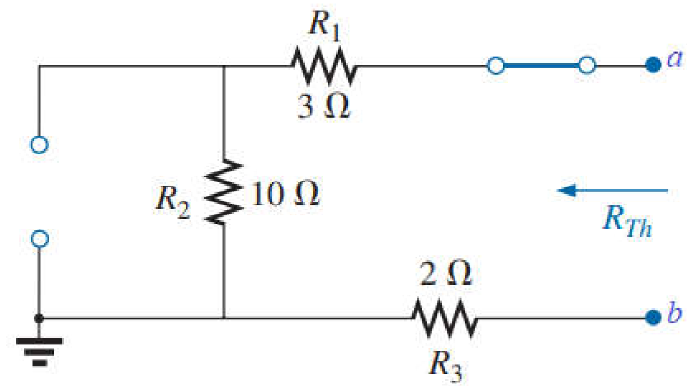
Example 9.3.1: Find the Thévenin equivalent circuit for the portions of the following network to points *a* and *b*.



Step 1 and Step 2:

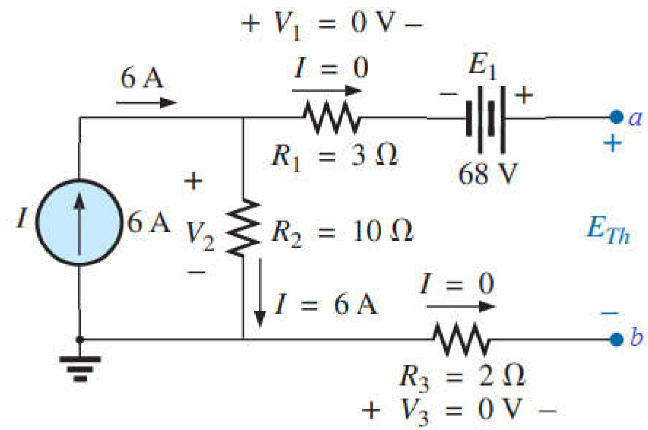


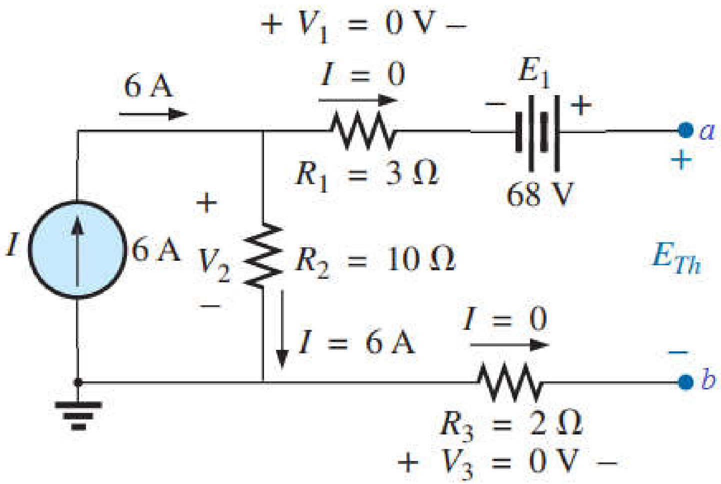
Step 3: R_{Th} calculation



$$R_{Th} = R_1 + R_2 + R_3 = 3\ \Omega + 10\ \Omega + 2\ \Omega = 15\ \Omega$$

Step 4: E_{TH} calculation





$$V_1 = V_3 = 0\text{ V}$$

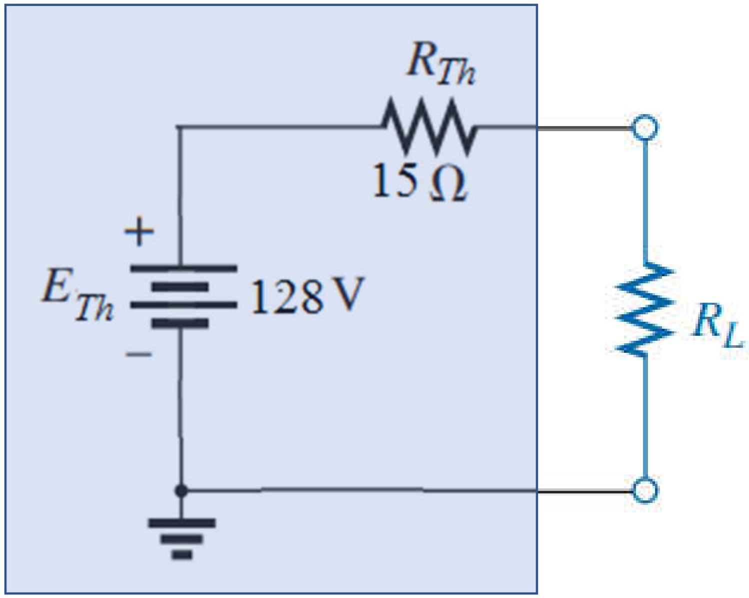
$$V_2 = I_2R_2 = IR_2$$

$$= (6\text{ A})(10\ \Omega) = 60\text{ V}$$

Applying Kirchhoff's voltage law:

$$E_{Th} = V_2 + E_1 = 60\text{ V} + 68\text{ V} = \mathbf{128\ V}$$

Step 5: Draw the Thévenin equivalent circuit

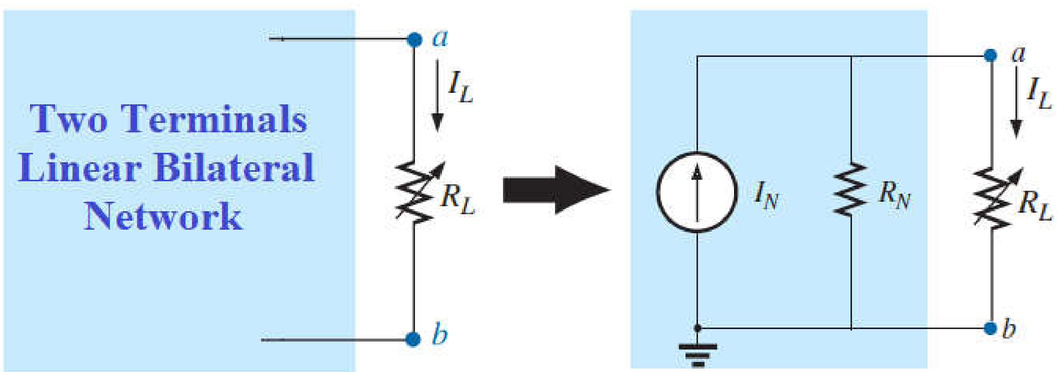


Practice Book [Ch 9] Problem: 7 ~ 15

9.4 NORTON'S THEOREM

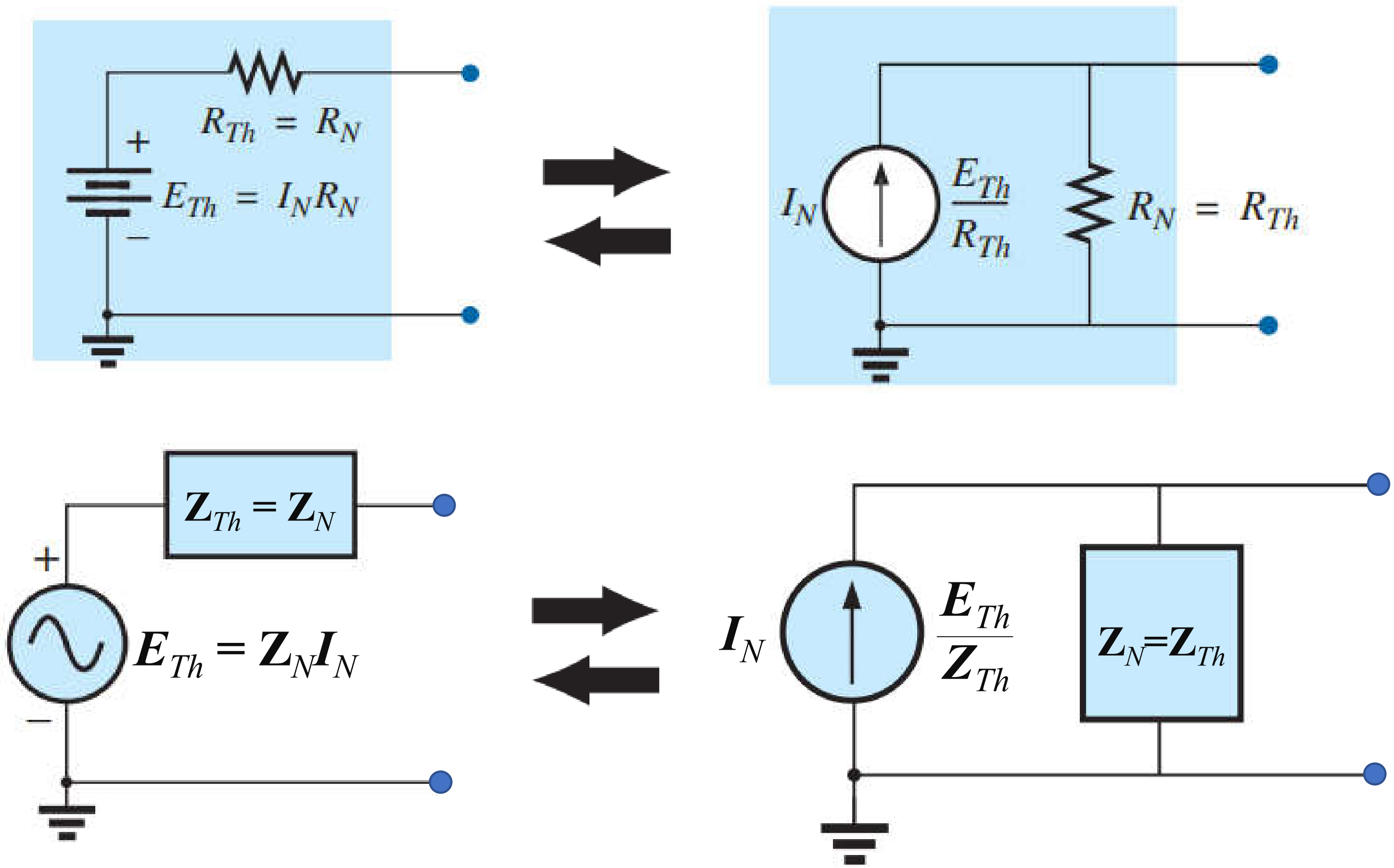
Statement of Norton's Theorem

Any two-terminal, linear bilateral network can be replaced by an equivalent circuit consisting of a current source and a parallel resistance, as shown in the following figure.



R_N: Norton's equivalent resistance
I_N: Norton's equivalent current

Conversion Between Thevenin and Norton's Equivalent Circuit



Steps to Apply Norton's Theorem

Step 1: Remove that portion of the network where the Thévenin equivalent circuit is found.

Step 2: Mark the terminals of the remaining two-terminal network.

Step 3: Calculate R_N/Z_N 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/impedance between the two marked terminals. (If the internal resistance/impedance of the voltage and/or current sources is included in the original network, it must remain when the sources are set to zero.)

Step 4: Calculate I_N by first returning all sources to their original position and then finding the short-circuit current between the marked terminals. It is the same current that would be measured by an ammeter placed between the marked terminals.

Step 5: Draw the Norton's equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.

Step 6: Do the remaining required calculation

Example 9.11 [P364] Find the Norton equivalent circuit for the network in the shaded area in Fig. 9.61.

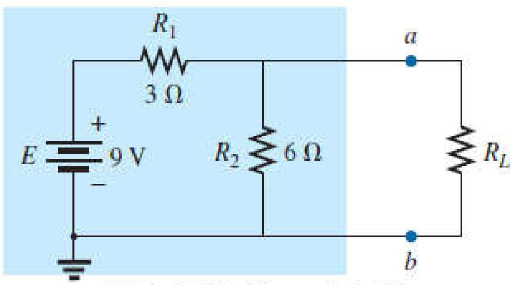
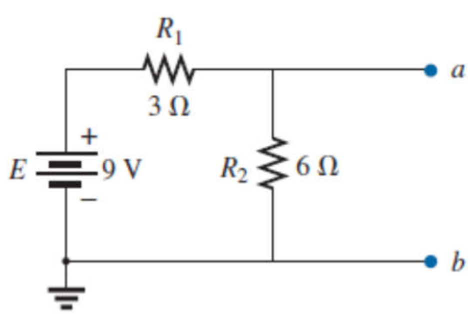
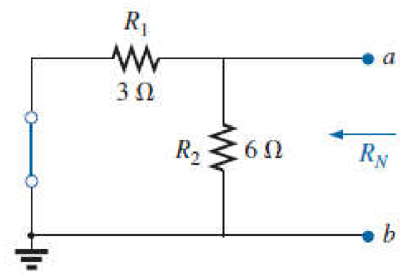


FIG. 9.61 *Example 9.11.*

Step 1: Remove that portion of the network where the Norton equivalent circuit is found.
Step 2: Mark the terminals (such as *a* and *b*).



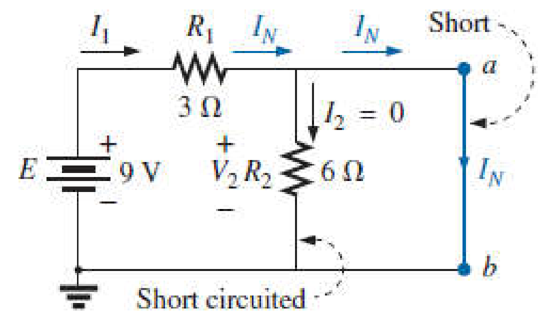
Step 3: Calculate R_N by first setting all sources to zero and then finding the resultant resistance between the two marked terminals (*a* and *b*).



$$R_N = R_1 \| R_2 = 3\ \Omega \| 6\ \Omega$$

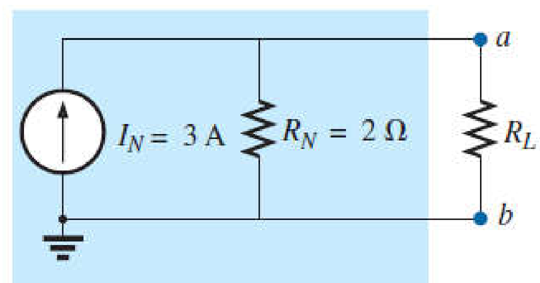
$$= \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = \frac{18\ \Omega}{9} = 2\ \Omega$$

Step 4: Calculate I_N by first returning all sources to their original position then finding the short-circuit current between the marked terminals. (*a* and *b*).



$$I_N = \frac{E}{R_1} = \frac{9\ \text{V}}{3\ \Omega} = 3\ \text{A}$$

Step 5: Draw the Norton equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.



EXAMPLE 9.13 (Two sources) Find the Norton equivalent circuit for the portion of the network to the left of *a-b* in Fig. 9.72.

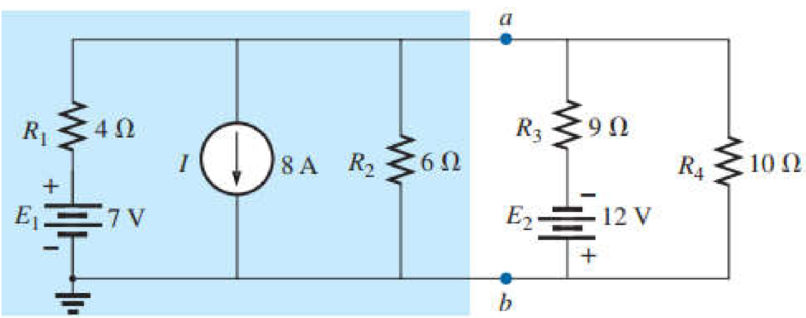
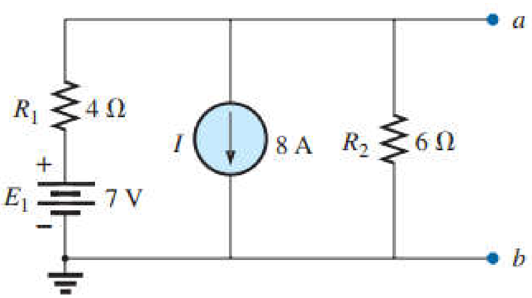
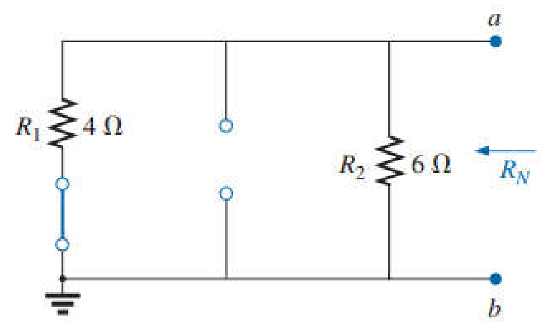


FIG. 9.72 *Example 9.13.*

Step 1 and Step 2:



Step 3: Calculate R_N:

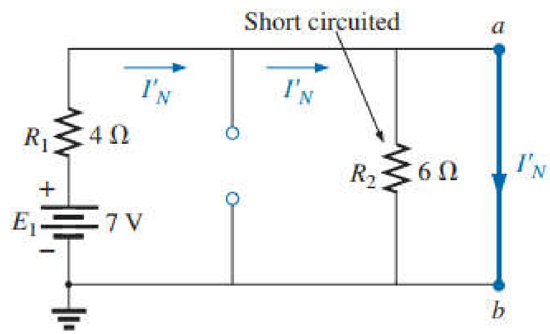


$$R_N = R_1 \parallel R_2 = 4\ \Omega \parallel 6\ \Omega$$

$$= \frac{(4\ \Omega)(6\ \Omega)}{4\ \Omega + 6\ \Omega} = \frac{24\ \Omega}{10}$$

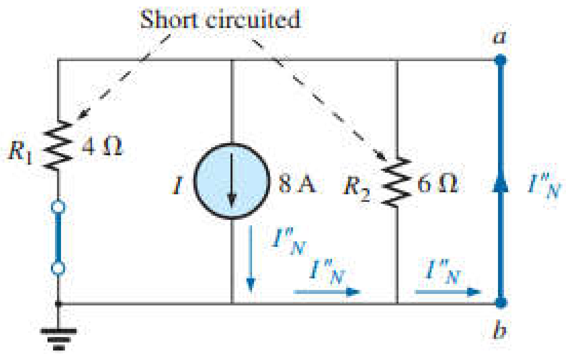
$$= \mathbf{2.4\ \Omega}$$

Step 4: Calculate I_N: Since there are two sources Superposition theorem has to be applied. **Consider 7 V:**



$$I'_N = \frac{E_1}{R_1} = \frac{7\ \text{V}}{4\ \Omega} = 1.75\ \text{A}$$

Consider 8 A:

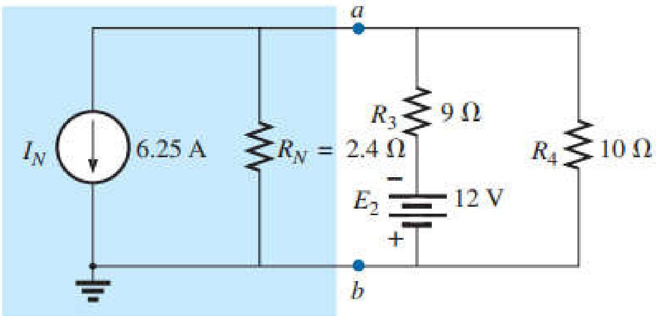


$$I''_N = I = 8 \text{ A}$$

According to Superposition Theorem

$$\begin{aligned} I_N &= I''_N - I'_N \\ &= 8 \text{ A} - 1.75 \text{ A} \\ &= \mathbf{6.25 \text{ A}} \end{aligned}$$

Step 5: Draw the Norton equivalent circuit:



Example 9.12 [P365] Using the Norton Theorem to terminal *a* and *b* of Fig. 9.67, find the value of current which is passing through 9 Ω resistor.

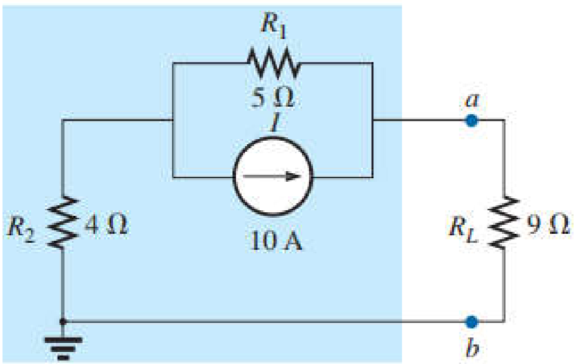
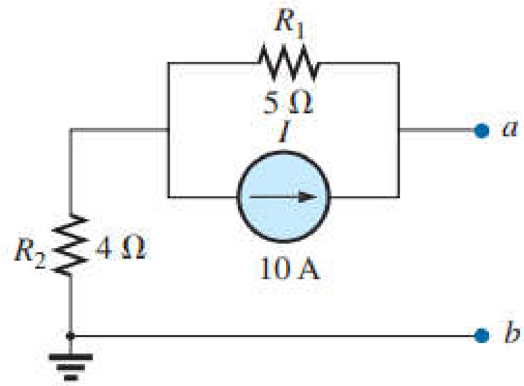
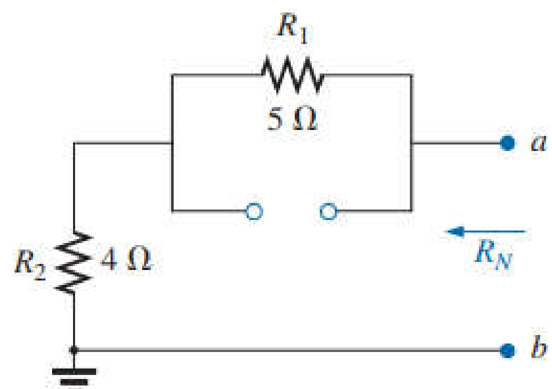


FIG. 9.67 *Example 9.12.*

Step 1: Remove that portion of the network where the Norton equivalent circuit is found.
Step 2: Mark the terminals (such as *a* and *b*).

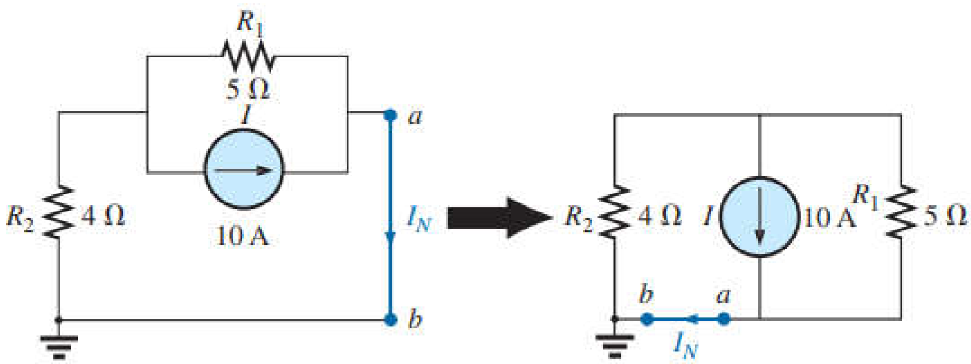


Step 3: Calculate R_N by first setting all sources to zero and then finding the resultant resistance between the two marked terminals (*a* and *b*).



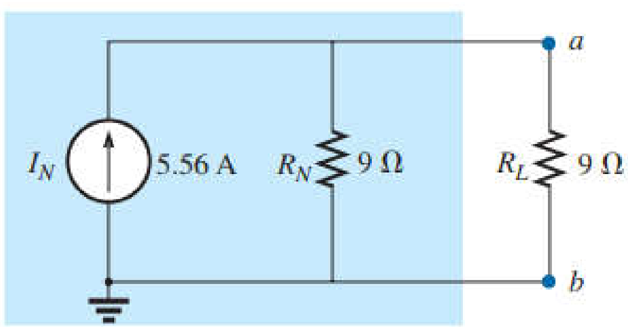
$$R_N = R_1 + R_2 = 5\ \Omega + 4\ \Omega = \mathbf{9\ \Omega}$$

Step 4: Calculate I_N by first returning all sources to their original position then finding the short-circuit current between the marked terminals. (*a* and *b*).



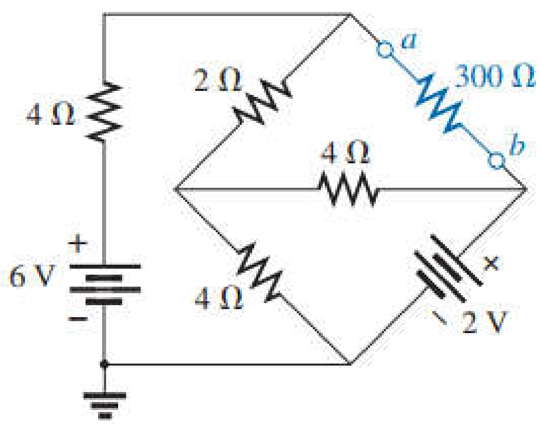
$$I_N = \frac{R_1 I}{R_1 + R_2} = \frac{(5\ \Omega)(10\ \text{A})}{5\ \Omega + 4\ \Omega} = \frac{50\ \text{A}}{9} = \mathbf{5.56\ A}$$

Step 5: Draw the Norton equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.

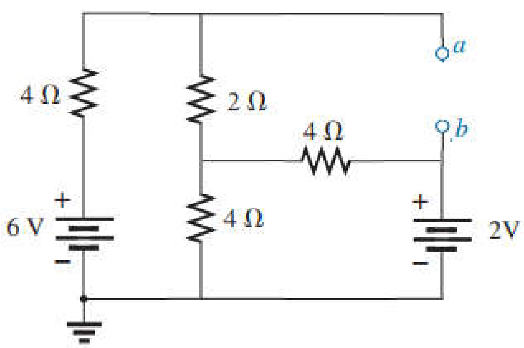


$$I_{RL} = \frac{R_N}{R_N + R_L} I_N = \mathbf{2.78\ \ A}$$

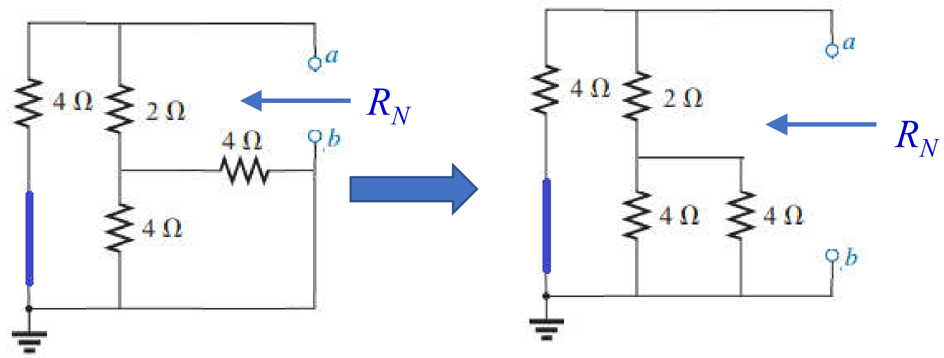
Problem 23 [P392] Find the Norton equivalent circuit for the portions of the networks in Fig. 9.136(b) external to branch *a*-*b*.



Step 1 and Step 2:

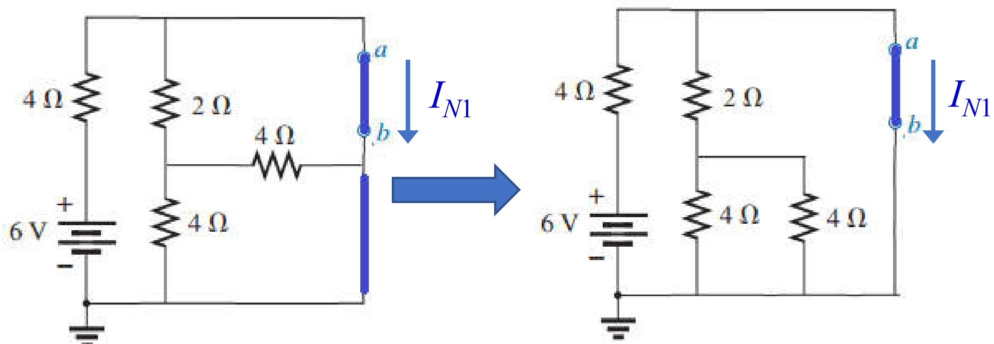


Step 3: Calculate R_N:



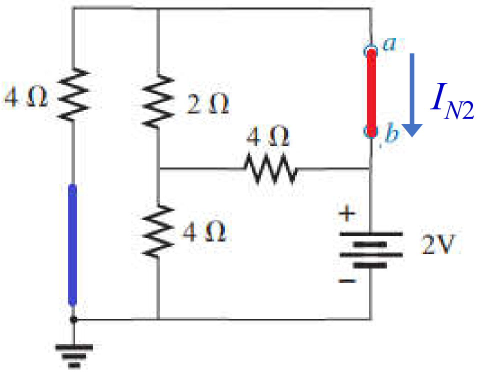
$$R_N = 4\Omega // [2\Omega + 4\Omega // 4\Omega] = \mathbf{2\,\Omega}$$

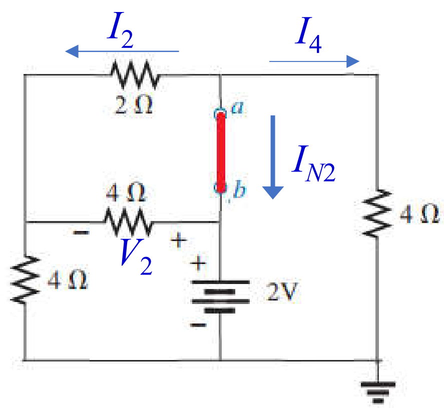
Step 4: Calculate I_N: Since there are two sources Superposition theorem has to be applied. Consider 6 V:



$$I_{N1} = \frac{6\,\text{V}}{4\Omega} = 1.5\ \text{A}$$

Consider 2 V:





$$I_4 = \frac{2\,\text{V}}{4\Omega} = 0.5\ \text{A}$$

$$V_2 = \frac{(2\Omega // 4\Omega)}{(2\Omega // 4\Omega) + 4\Omega} 2\,\text{V} = 0.5\ \text{V}$$

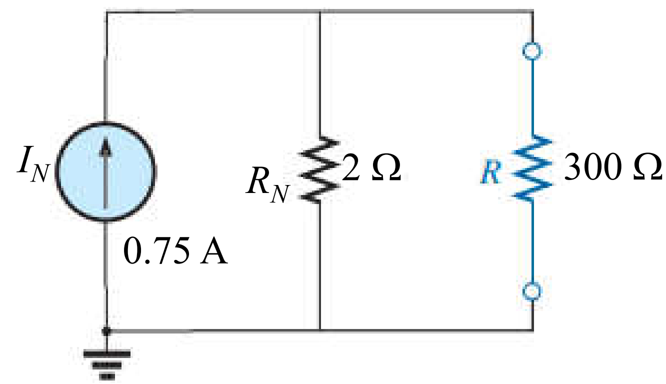
$$I_2 = \frac{0.5\,\text{V}}{2\Omega} = 0.25\ \text{A}$$

$$I_{N2} = -I_4 - I_2 = -0.75\ \text{A}$$

According to Superposition Theorem

$$I_N = I_{N1} + I_{N2} = \mathbf{0.75\ A}$$

Step 5: Draw the Norton equivalent circuit:



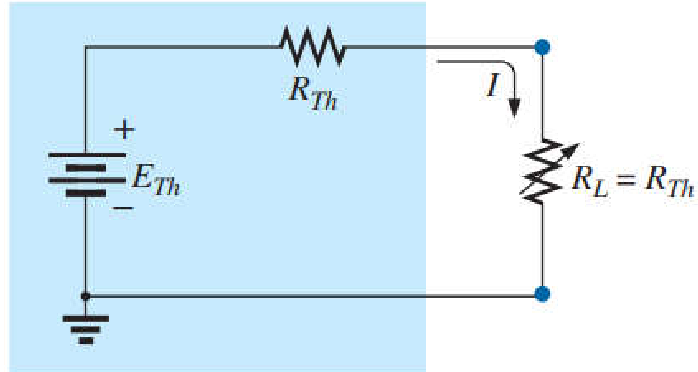
Practice Book [Ch 9] Problem: 18 ~ 23

9.5 MAXIMUM POWER TRANSFER THEOREM

Statement of Maximum Power Transfer Theorem

A load will receive/consume/absorb maximum power from a network when *its resistance is exactly equal to the Thévenin resistance* of the network applied to the load. That is:

$$\boxed{R_L = R_{Th}} \qquad \textbf{(9.2)}$$



When $R_L = R_{Th}$, the maximum power delivered to the load can be determined by first finding the current:

$$I_L = \frac{E_{Th}}{R_{Th} + R_L} = \frac{E_{Th}}{R_{Th} + R_{Th}} = \frac{E_{Th}}{2R_{Th}}$$

Power can be calculated as follows: $$P_L = I_L^2 R_L = \left(\frac{E_{Th}}{2R_{Th}}\right)^2 (R_{Th}) = \frac{E_{Th}^2 R_{Th}}{4R_{Th}^2}$$

$$\boxed{P_{L_{max}} = \frac{E_{Th}^2}{4R_{Th}}} \qquad \textbf{(9.3)}$$

For the Norton equivalent circuit in Fig. 9.84, maximum power will be delivered to the load when

$$\boxed{R_L = R_N} \qquad \textbf{(9.5)}$$

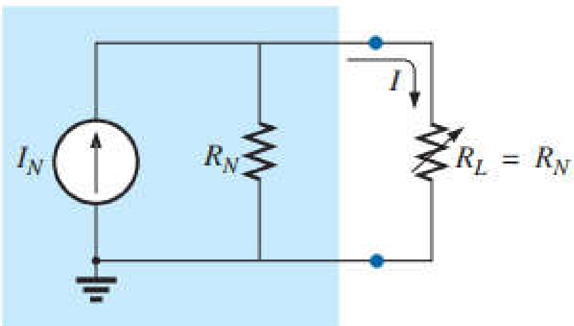
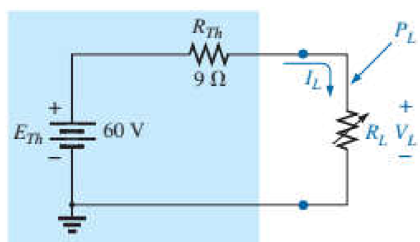
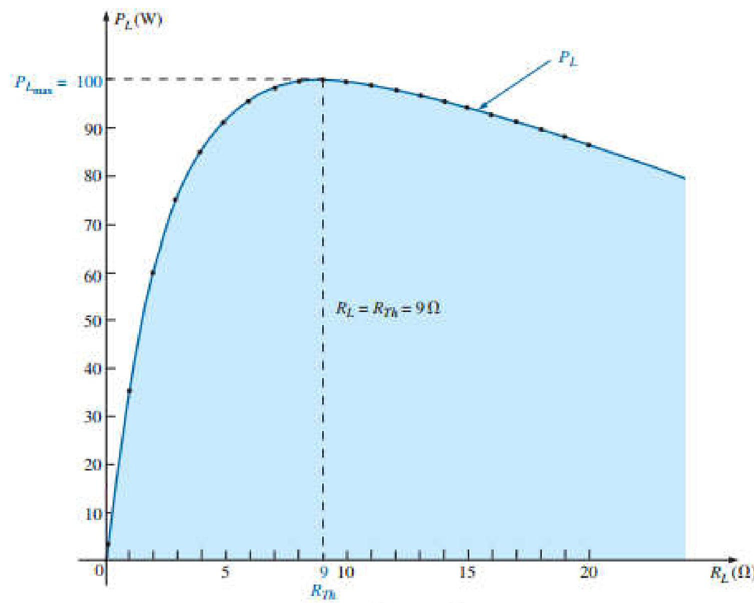


FIG. 9.84

Power can be calculated as follows:
$$\boxed{P_{L_{max}} = \frac{I_N^2 R_N}{4}} \quad \text{(W)} \quad \textbf{(9.6)}$$





P_L versus R_L

Example 9.5.1 For the following network , find the value of R_L for maximum power to RL and determine the maximum power to R_L.

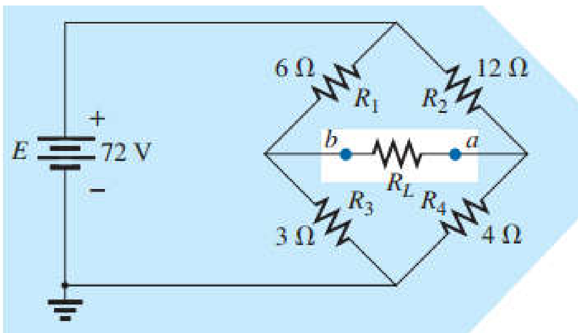
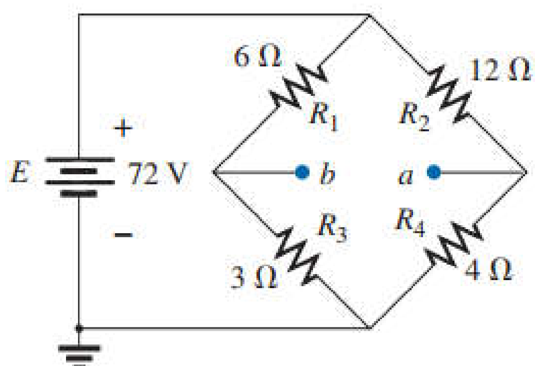


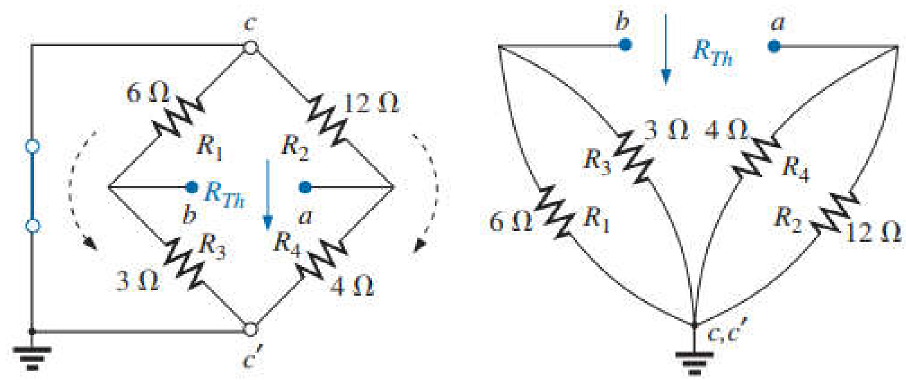
FIG. 9.43 *Example 9.9.*

Step 1: Remove that portion of the network where the Thévenin equivalent circuit is found.

Step 2: Mark the terminals (such as *a* and *b*) of the remaining two-terminal network.



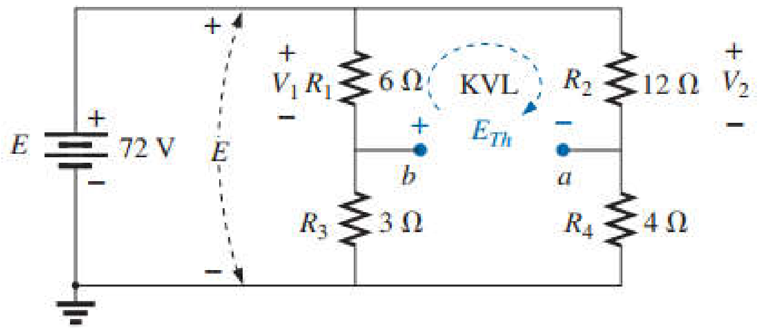
Step 3: Calculate R_{Th} by first setting all sources to zero (voltage sources are replaced by short circuits, and current sources by open circuits) and then finding the resultant resistance between the two marked terminals (*a* and *b*).



(a) (b)

$$R_{Th} = R_{a-b} = R_1 \parallel R_3 + R_2 \parallel R_4$$
$$= 6\ \Omega \parallel 3\ \Omega + 4\ \Omega \parallel 12\ \Omega$$
$$= 2\ \Omega + 3\ \Omega = \mathbf{5\ \Omega}$$

Step 4: Calculate E_{Th} by first returning all sources to their original position and finding the open-circuit voltage between the marked terminals (*a* and *b*).

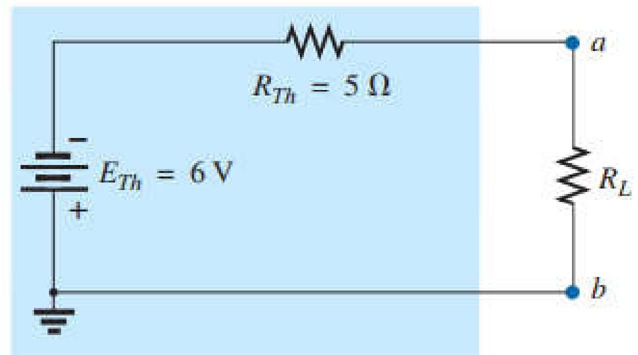


$$V_1 = \frac{R_1 E}{R_1 + R_3} = \frac{(6\ \Omega)(72\ \text{V})}{6\ \Omega + 3\ \Omega} = \frac{432\ \text{V}}{9} = 48\ \text{V}$$

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

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

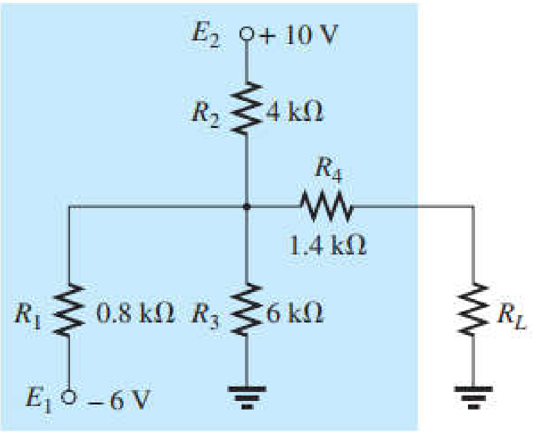
Step 5: Draw the Thévenin equivalent circuit with the portion of the circuit previously removed replaced between the terminals of the equivalent circuit.



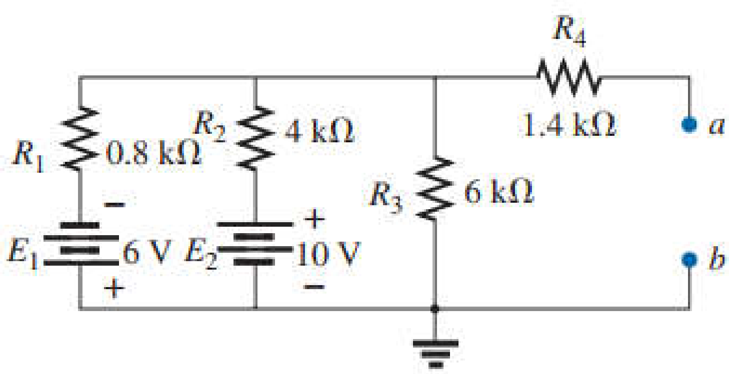
$$R_L = R_{Th} = \mathbf{5\ \Omega}$$

$$P_{\max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(6\text{V})^2}{4 \times 5\Omega} = \mathbf{1.8\ W}$$

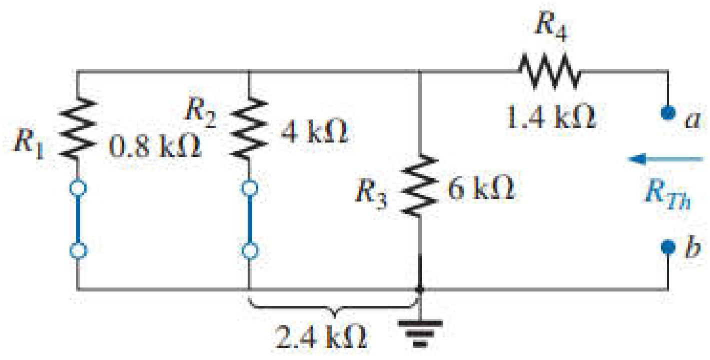
Example 9.5.2 For the following network , find the value of R_L for maximum power to R_L and determine the maximum power to R_L.



Step 1 and Step 2: for Thévenin equivalent circuit



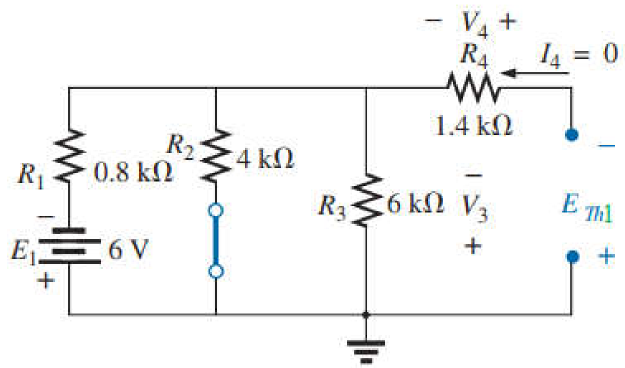
Step 3: Calculate R_{Th}



$$
\begin{aligned}
R_{Th} &= R_4 + R_1 \| R_2 \| R_3 \\
&= 1.4\ \text{k}\Omega + 0.8\ \text{k}\Omega \| 4\ \text{k}\Omega \| 6\ \text{k}\Omega \\
&= 1.4\ \text{k}\Omega + 0.8\ \text{k}\Omega \| 2.4\ \text{k}\Omega \\
&= 1.4\ \text{k}\Omega + 0.6\ \text{k}\Omega \\
&= \mathbf{2\ k\Omega}
\end{aligned}
$$

Step 4: Calculate E_{Th}

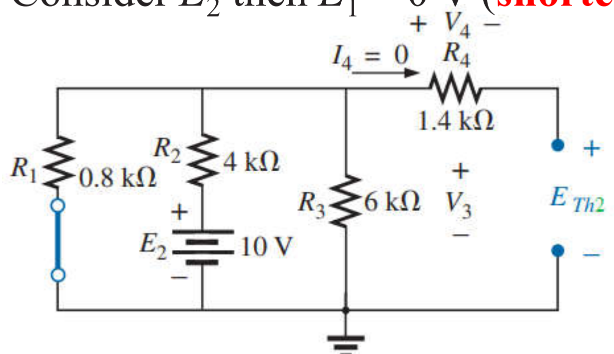
Since there are two sources Superposition theorem has to be applied. Consider E_1 then $E_2 = 0$ V (**shorted**).



$$R_{p1} = R_2 \,//\, R_3 = 2.4\text{ k}\Omega$$

$$E_{Th1} = \frac{R_{p1}}{R_{p1} + R_1} E_1 = 4.5\text{ V}$$

Consider E_2 then $E_1 = 0$ V (**shorted**).



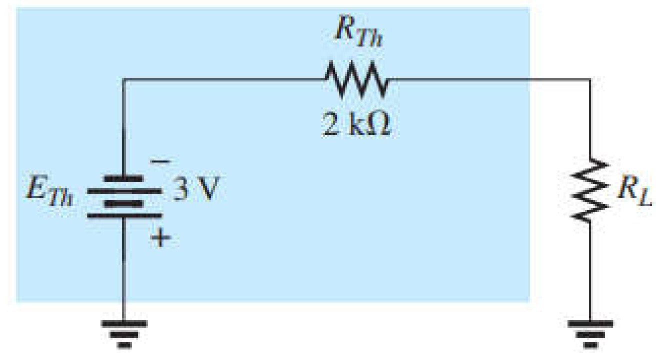
$$R_{p2} = R_1 \,//\, R_3 = 0.706\text{ k}\Omega$$

$$E_{Th2} = \frac{R_{p2}}{R_{p2} + R_4} E_2 = 1.5\text{ V}$$

Since E_{Th1} and E_{Th2} have opposite polarities,

$$\begin{aligned} E_{Th} &= E_{Th1} - E_{Th2} \\ &= 4.5\text{ V} - 1.5\text{ V} \\ &= \mathbf{3\ V} \qquad \text{(polarity of } E'_{Th}\text{)} \end{aligned}$$

Step 5: Draw the Thévenin equivalent circuit



$$R_L = R_{Th} = \mathbf{2\ k\Omega}$$

$$P_{max} = \frac{E_{Th}^2}{4R_{Th}} = \frac{(3\text{V})^2}{4 \times (2 \times 10^3\,\Omega)} = \mathbf{1.125\ mW}$$

Example 9.5.2

(*a*) Find the Norton equivalent circuit for the network external to the resistor R for the network in Fig. 9.127.

(*b*) find the value of R for maximum power to R and determine the maximum power to R.

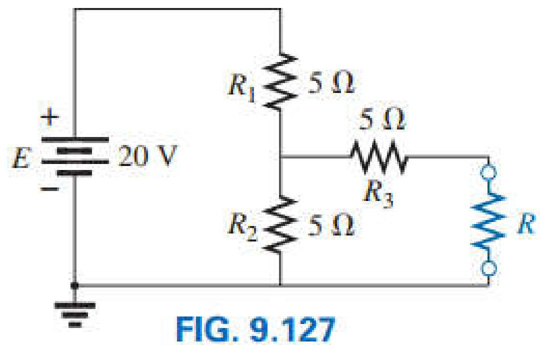
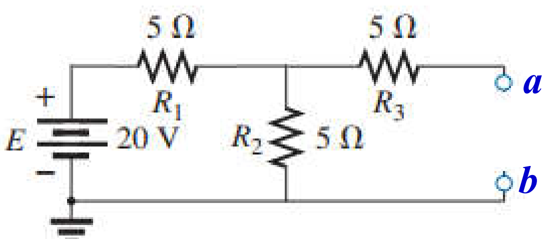
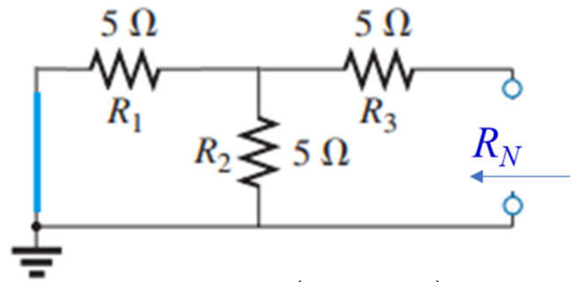


FIG. 9.127

Step 1: and Step 2 for the Norton equivalent circuit.

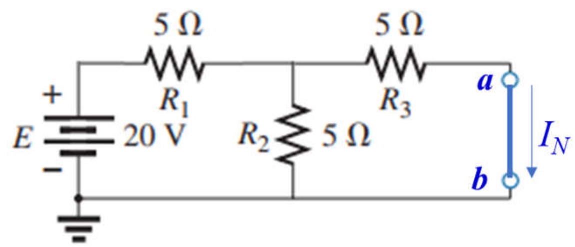


Step 3: Calculate R_N



$$R_N = R_3 + (R_1 // R_2) = 7.5\ \Omega$$

Step 4: Calculate I_N

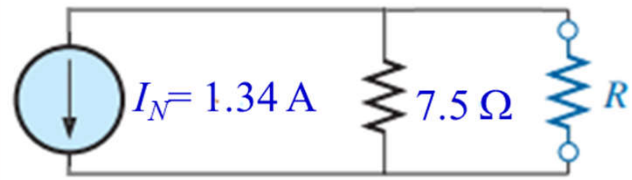


$$R_T = R_1 + (R_2 // R_3) = 7.5\ \Omega$$

$$I_T = \frac{E}{R_T} = 2.67\ \text{A}$$

$$I_N = \frac{I_T}{2} = 1.34\ \text{A}$$

Step 5: Draw the Norton equivalent circuit:



$$R_L = R_N = \mathbf{7.5\ \Omega}$$

$$P_{max} = \frac{I_N^2 R_N}{4}$$

$$= \frac{(1.34\text{A})^2 \times 7.5\Omega}{4}$$

$$= \mathbf{3.367\ W}$$

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