Ministry of Higher Education and Scientific Research
Tikrit University
Engineering Collage –Al shirqat

FUNDAMENTALS OF ELECTRICAL ENGINEERING
LECTURE 7

THEVENIN’S THEOREM

PREPARED BY
TEACHING ASSISTANT

ABDULLAH AHMED ALWAN

الصباحي Classroom: xtofyek4

المسائي Classroom: cftcvpvp

General Objectives:

- Simplifying the analysis of complex electrical circuits into an equivalent simple circuit.
- Enhancing students' understanding of electrical network principles and fundamental laws.
- Developing students' skills in solving electrical circuits efficiently and quickly.
- Enabling learners to apply Thevenin's theorem in practical applications such as circuit design and analysis.
- Facilitating the study of the impact of changes in electrical components on the system as a whole.

Specific objectives:

- Enabling students to determine the equivalent resistance of the voltage source (Thevenin Resistance).
- Introducing students to the calculation of Thevenin Voltage through voltage analysis across open terminals.
- Enabling students to construct the Thevenin equivalent circuit and replace complex parts with it.
- Improving skills in using measuring instruments such as the voltmeter and ohmmeter for practical verification of the theory.
- Enhancing the ability to evaluate the efficiency of electrical design using the Thevenin equivalent circuit.
- Developing analytical thinking and practical skills in dealing with real electrical systems.

Introduction

- **Thevenin's Theorem** is one of the fundamental theorems in electrical circuit analysis. It aims to simplify complex circuits into an equivalent simple circuit, making them easier to understand and analyze.
- **The Concept of the Theorem:**

Thevenin's Theorem states that any electrical network containing voltage or current sources and resistors between two terminals (A and B) can be replaced by an equivalent circuit consisting of:

- **A single voltage source (V_th):** This represents the open-circuit voltage between the two terminals (the voltage measured when no load is connected between them).
- **A single resistance (R_th):** This represents the equivalent resistance of the network when all voltage and current sources are deactivated (voltage sources are replaced with short circuits, and current sources are replaced with open circuits).

Thevenin’s Theorem

Solution method:

- **Finding the Thevenin Voltage (V_th):**
  Calculate the voltage between terminals A and B with the load disconnected.
- **Finding the Thevenin Resistance (R_th):**
  Deactivate the power sources in the circuit and calculate the equivalent resistance between terminals A and B.
- **Drawing the Thevenin Equivalent Circuit:**
  Draw the voltage source (V_th) in series with the equivalent resistance (R_th), then connect the load between the terminals.

Thevenin's Theorem

Exampel1: Find the Thevenin equivalent circuit of the circuit shown in Fig. 5.1, to the left of the terminals a-b . Then find the current through R_L(6,16 and 36)Ω.

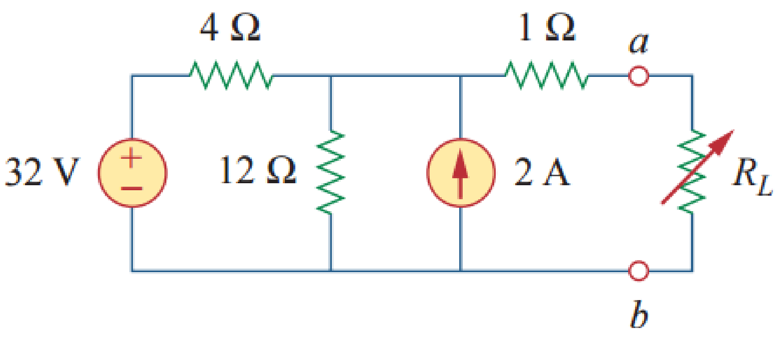
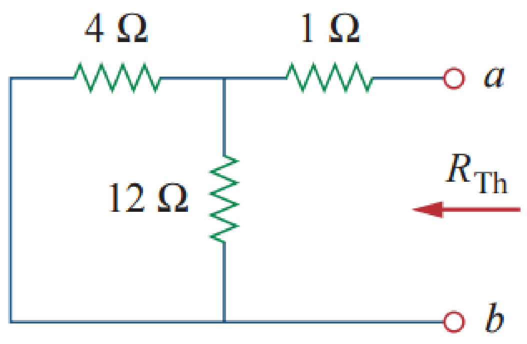


Figure 5-1 Equivalent Circuit for Example 1

Solution: We find by turning off the 32-V voltage source (replacing it with a short circuit) and the 2-A current source (replacing it with an open circuit).The circuit becomes what is shown in Fig. 5.2 (a).Thus,

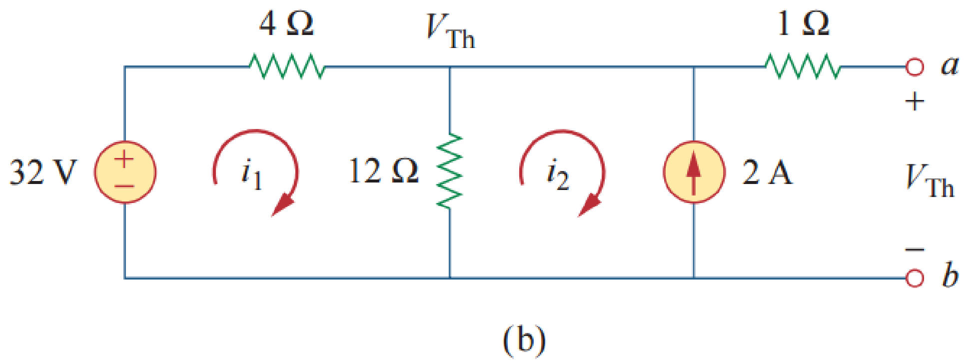
$$R_{TH} = 4\|12 + 1 = \frac{4\times12}{4+12} + 1 = 4\ \Omega$$



(a)

Figure 5-2 (a) finding R_{th}

Thevenin’s Theorem



(b) calculating v_{TH}

To find consider the circuit in Fig. 5.3 (b). Applying mesh analysis to the two loops, we obtain (For loop 1)

$$-32 + (4 + 12)i_1 - 12i_2 = 0$$
$$-32 + 16\, i_1 - 12i_2 = 0$$
$$16\, i_1 - 12i_2 = 32 \quad \dots \dots \text{Eq}(1)$$

For Loop 2

$$i_2 = -2\text{A} \quad \text{Sub in Eq(1)}$$

$$16\, i_1 - 12 \times (-2) = 32 \Rightarrow 16\, i_1 = 32 - 24 \Rightarrow i_1 = \frac{8}{16} = 0.5 \text{ A}$$

$$v_{Th} = 12(i_1 - i_2) = 12[0.5 - (-2)] = 12(2.5) = 30 \text{ V}$$

or

$$\frac{32 - v_{Th}}{4} + 2 = \frac{v_{Th}}{12} \qquad \text{multblied by 12}$$

$$3(32 - v_{Th}) + 24 = v_{Th} \Rightarrow 96 - 3v_{Th} + 24 = v_{Th} \Rightarrow 4v_{Th} = 120$$

$$v_{Th} = \frac{120}{4} = 30 \text{ V}$$

Alternatively, it is even easier to use nodal analysis. We ignore the 1Ω resistor since no current flows through it. At the top node, KCL gives

Thevenin’s Theorem

as obtained before. We could also use source transformation to find v_{Th}.The Thevenin equivalent circuit is shown in Fig. 4.29. The current through R_L is

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

When $R_L = 6\ \Omega$

$$I_L = \frac{30}{4+6} = \frac{30}{10} = 3\ \mathrm{A}$$

When $R_L = 16\ \Omega$

$$I_L = \frac{30}{4+16} = \frac{30}{20} = 1.5\ \mathrm{A}$$

When $R_L = 36\ \Omega$

$$I_L = \frac{30}{4+36} = \frac{30}{40} = 0.75\ \mathrm{A}$$

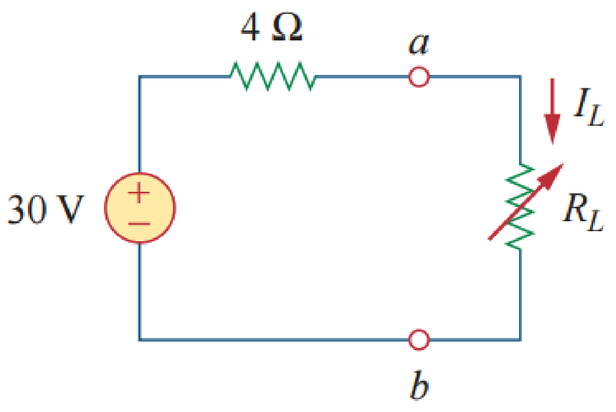


Figure 5-4 The Thevenin equivalent circuit for Example 1

Thevenin's Theorem

Example 2: Find the Thévenin equivalent circuit for the network in the shaded area of the network of Fig.7.1. Then find the current through R_L(2,10 and 100)Ω.

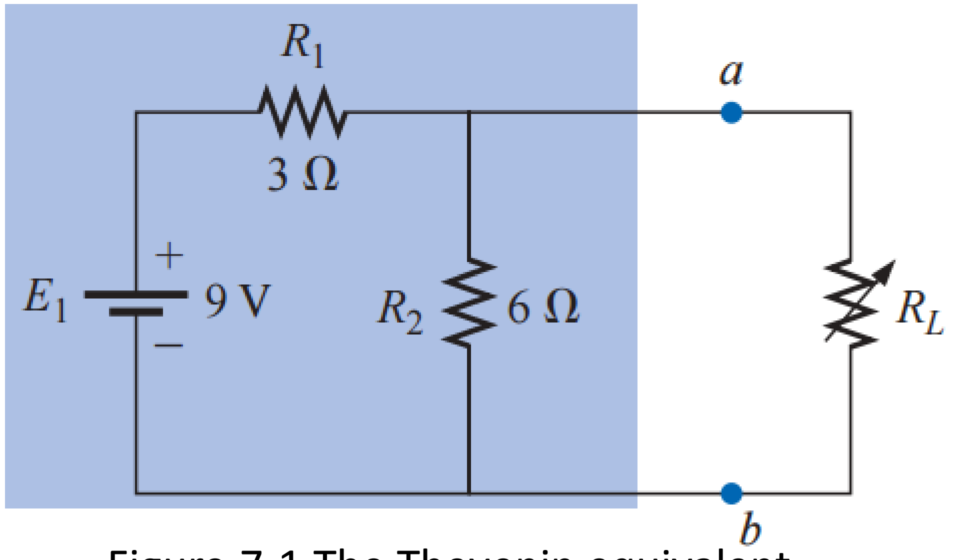
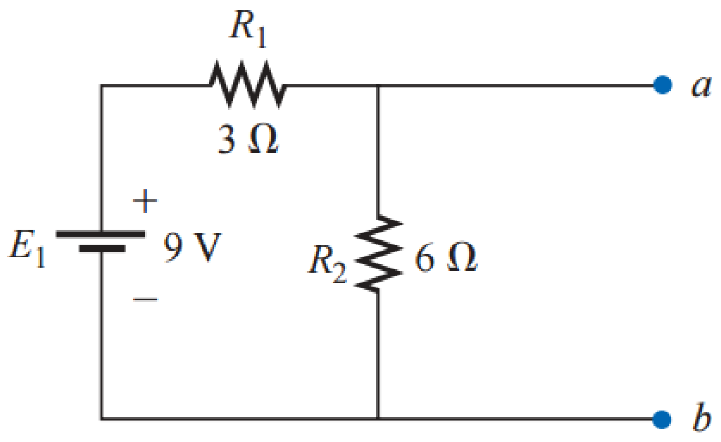


Figure 7-1 The Thevenin equivalent circuit for Example 2

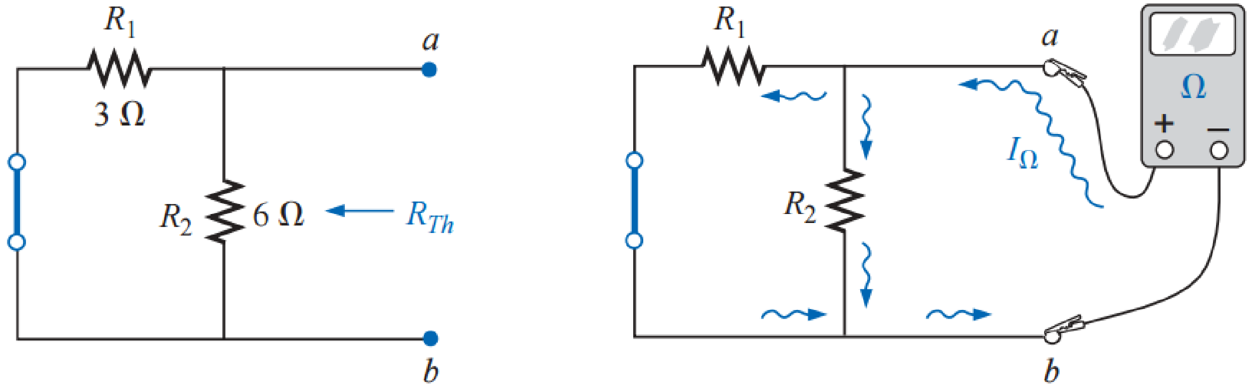
Solution:

Steps 1 and 2 produce the network of Fig. 9.28. Note that the load resistor R_L has been removed and the two "holding" terminals have been defined as a and b.



Step 3: Replacing the voltage source E_1 with a short-circuit equivalent yields the network of Fig. 9.29(a), where

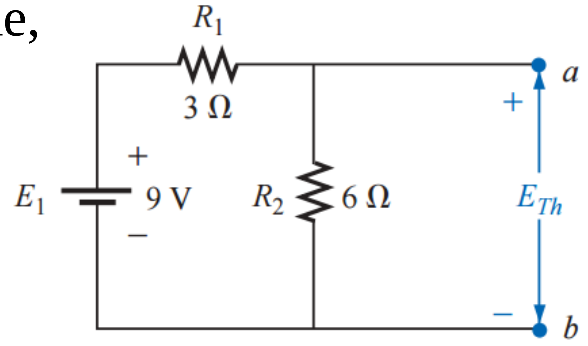
$$R_{Th} = R_1 \parallel R_2 = \frac{(3\ \Omega)(6\ \Omega)}{3\ \Omega + 6\ \Omega} = \mathbf{2\ \Omega}$$

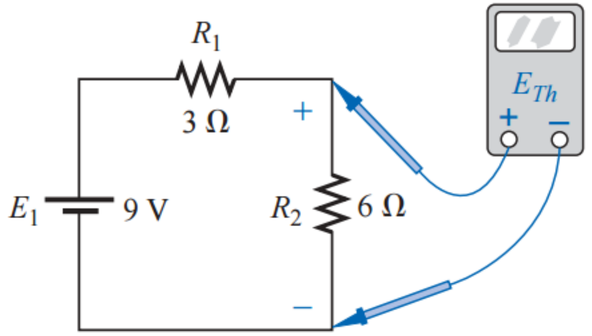


(a) (b)

Step 4: Replace the voltage source (Fig. 9.30). For this case, the open-circuit voltage E_{TH} is the same as the voltage drop across the 6Ω resistor. Applying the voltage divider rule,

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



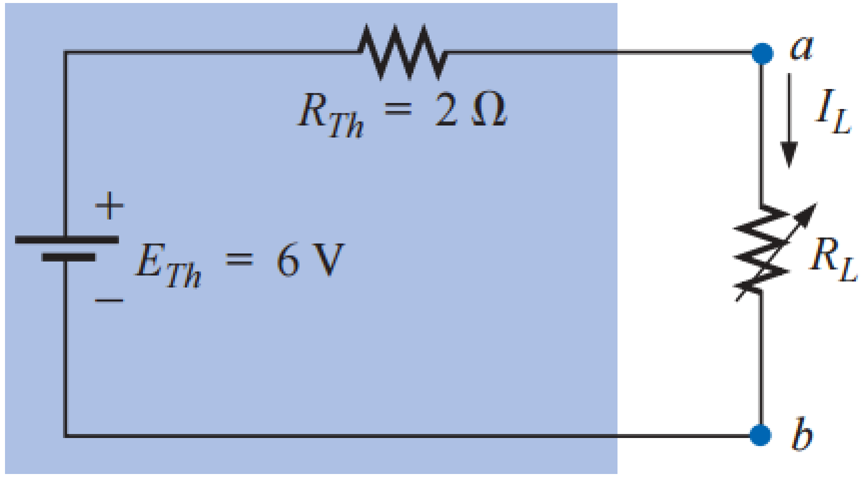


$$I_L = \frac{E_{Th}}{R_{Th} + R_L}$$

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

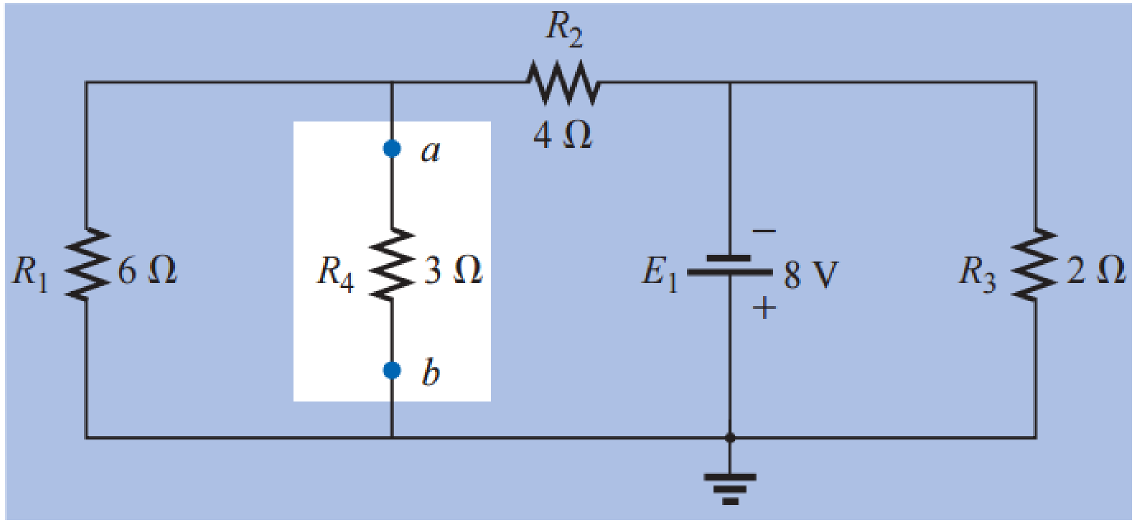
$$R_L = 10\ \Omega: \quad I_L = \frac{6\ \text{V}}{2\ \Omega + 10\ \Omega} = \mathbf{0.5\ A}$$

$$R_L = 100\ \Omega: \quad I_L = \frac{6\ \text{V}}{2\ \Omega + 100\ \Omega} = \mathbf{0.059\ A}$$

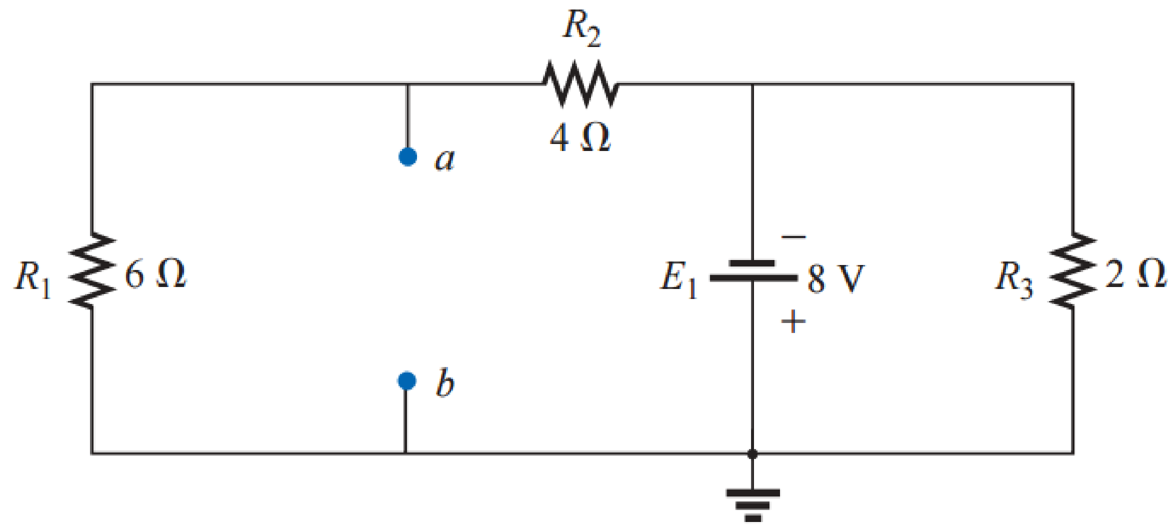


EX3: Find the Thévenin equivalent circuit for the network in the shaded area of the network of the figure below.

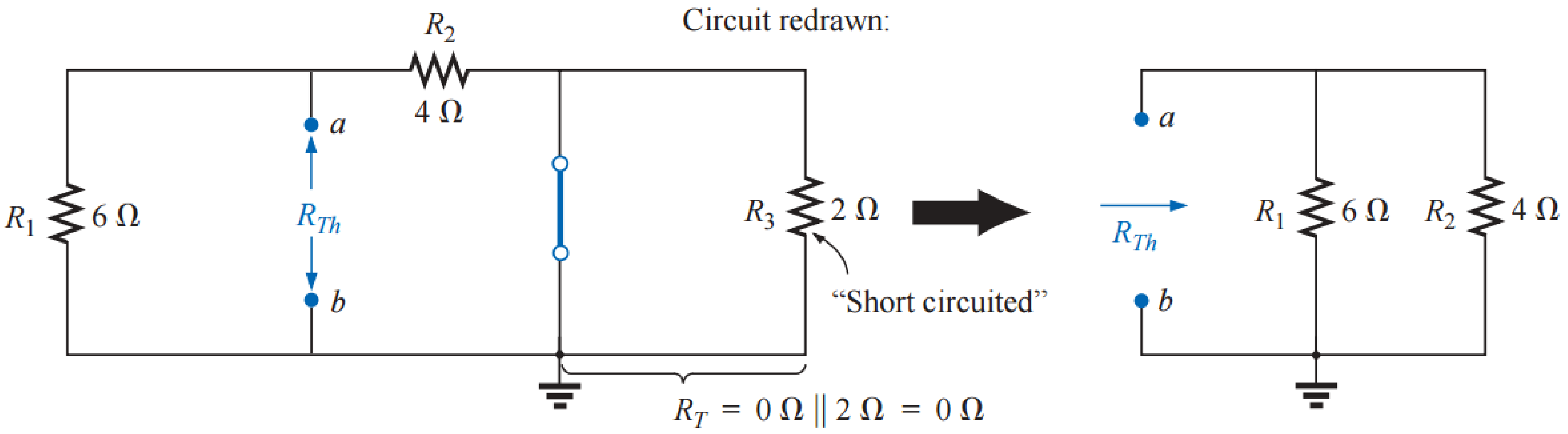
Solution:



Steps 1 and 2: See Fig.

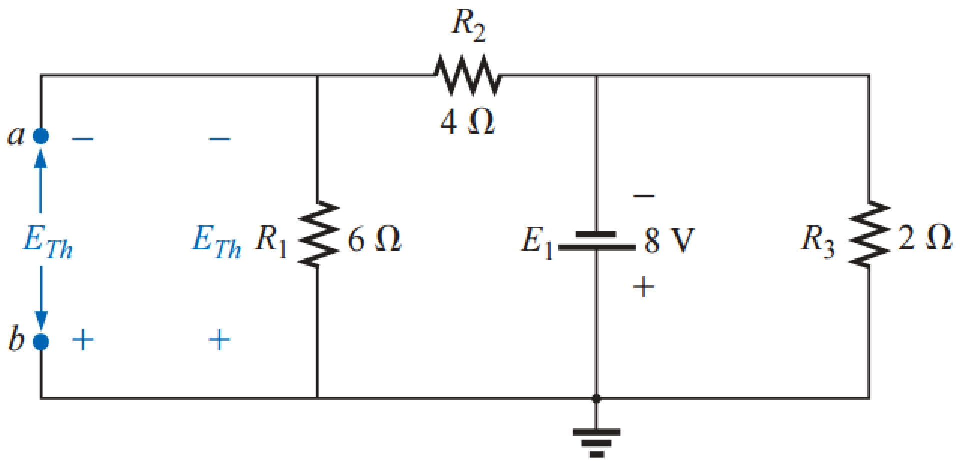


Step 3: See the figure below. Steps 1 and 2 are relatively easy to apply, but now we must be careful to "hold" onto the terminals a and b as the Thévenin resistance and voltage are determined. In the figure below, all the remaining elements turn out to be in parallel, and the network can be redrawn as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

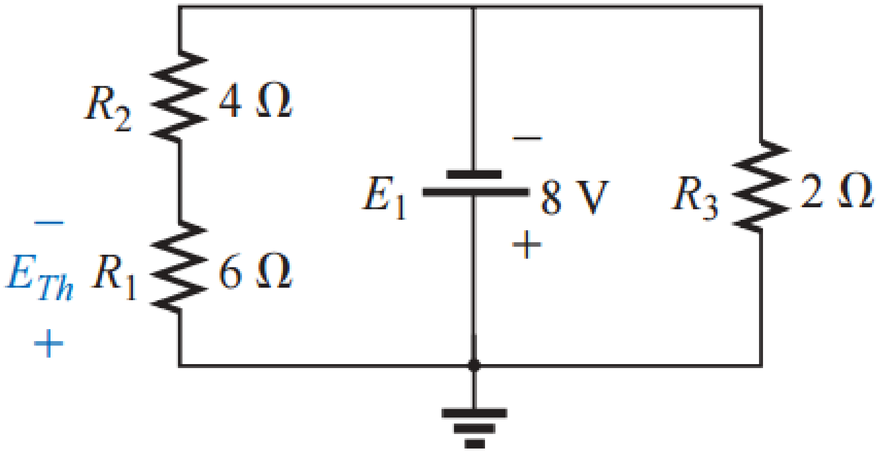


$$R_{Th} = R_1 \parallel R_2 = \frac{(6\ \Omega)(4\ \Omega)}{6\ \Omega + 4\ \Omega} = \frac{24\ \Omega}{10} = \mathbf{2.4\ \Omega}$$

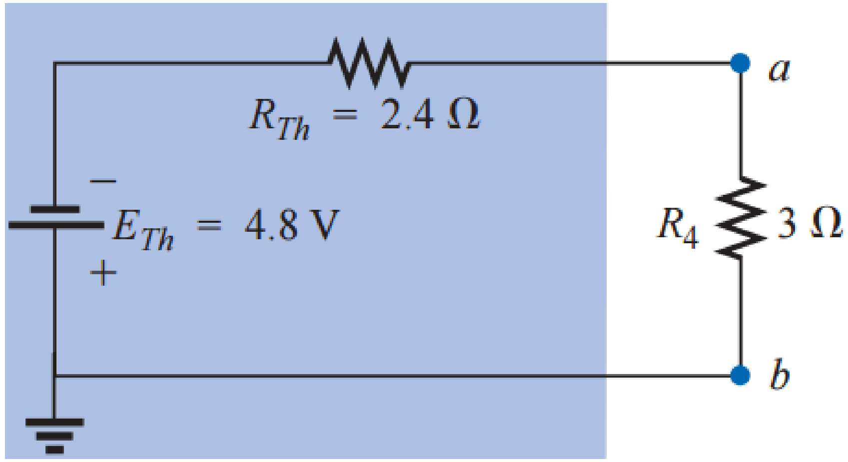
Step 4: See figure below. In this case, the network can be redrawn as shown in the figure below, and since the voltage is the same across parallel elements, the voltage across the series resistors R1 and R_2 is E_1, or 8 V. Applying the voltage divider rule



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



Step 5: See figure below.



Thank you for listening