Methods of Analysis for DC Networks

By Ariful Islam
Dept. of EEE

University of Dhaka

MESH ANALYSIS (GENERAL APPROACH)
Supermesh Currents

- Occasionally, you will find current sources in a network without a parallel resistance.
- This removes the possibility of converting the source to a voltage source as required by the given procedure.

MESH ANALYSIS (GENERAL APPROACH)
Supermesh Currents

- In such cases, you have a choice of two approaches.
  - The simplest and most direct approach is to place a resistor in parallel with the current source that has a much higher value than the other resistors of the network.
  - The other choice is to use the **supermesh approach.**

MESH ANALYSIS (GENERAL APPROACH)

Supermesh Currents

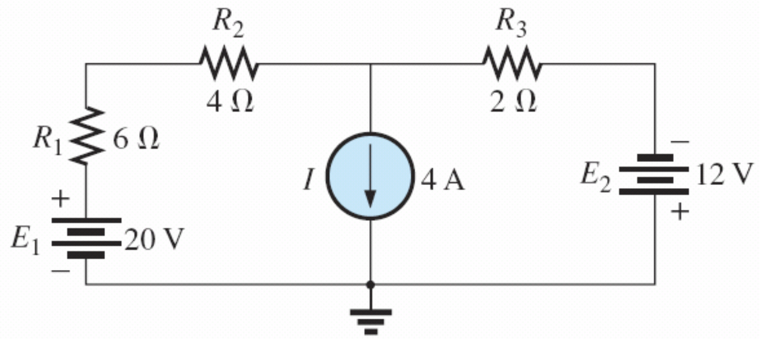

FIG. 8.31 *Example 8.14.*

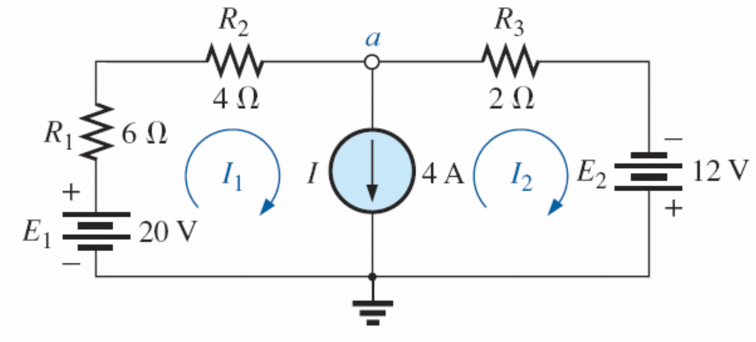

FIG. 8.32 *Defining the mesh currents for the network in Fig. 8.31.*

MESH ANALYSIS (GENERAL APPROACH)

Supermesh Currents

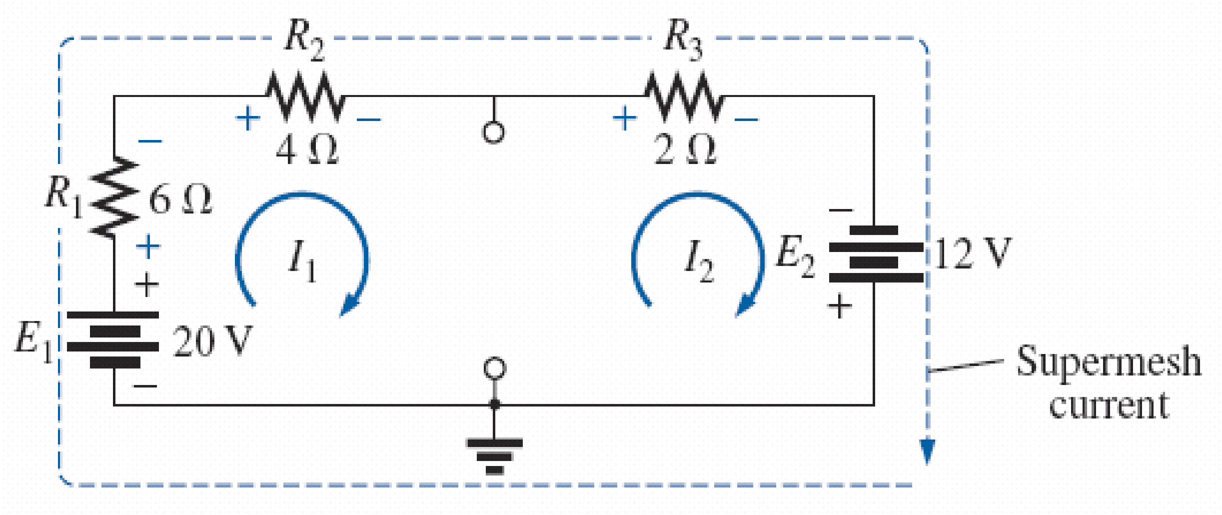

FIG. 8.33 *Defining the supermesh current.*

MESH ANALYSIS (GENERAL APPROACH)
Supermesh Currents

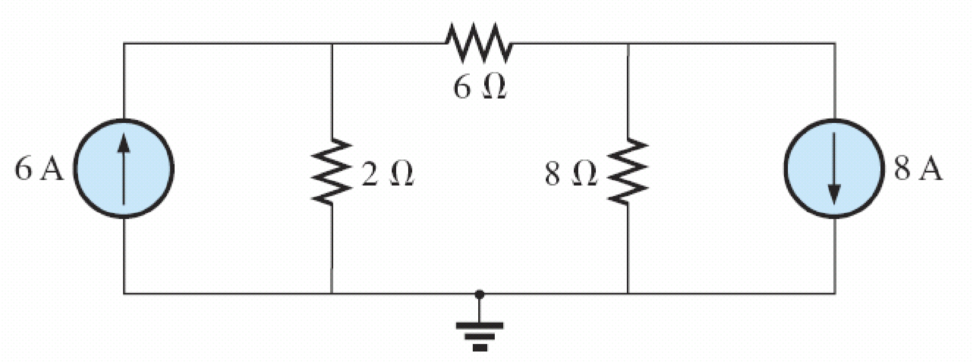

FIG. 8.34 *Example 8.15.*

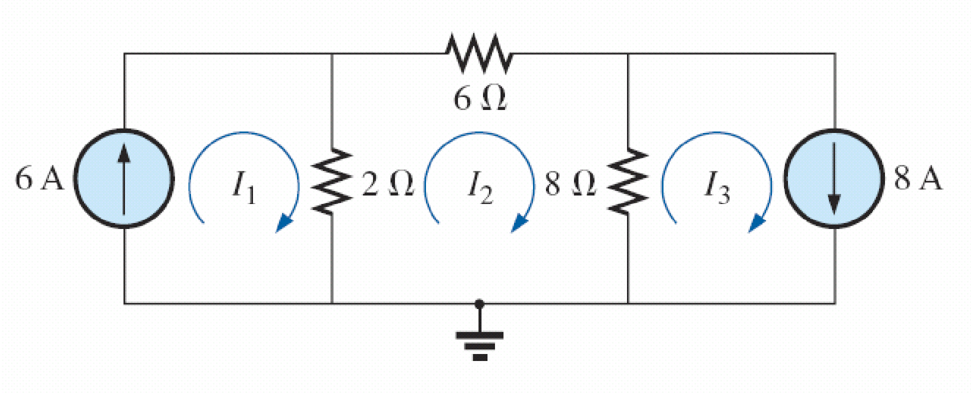

FIG. 8.35 *Defining the mesh currents for the network in Fig. 8.34.*

MESH ANALYSIS (GENERAL APPROACH)
Supermesh Currents

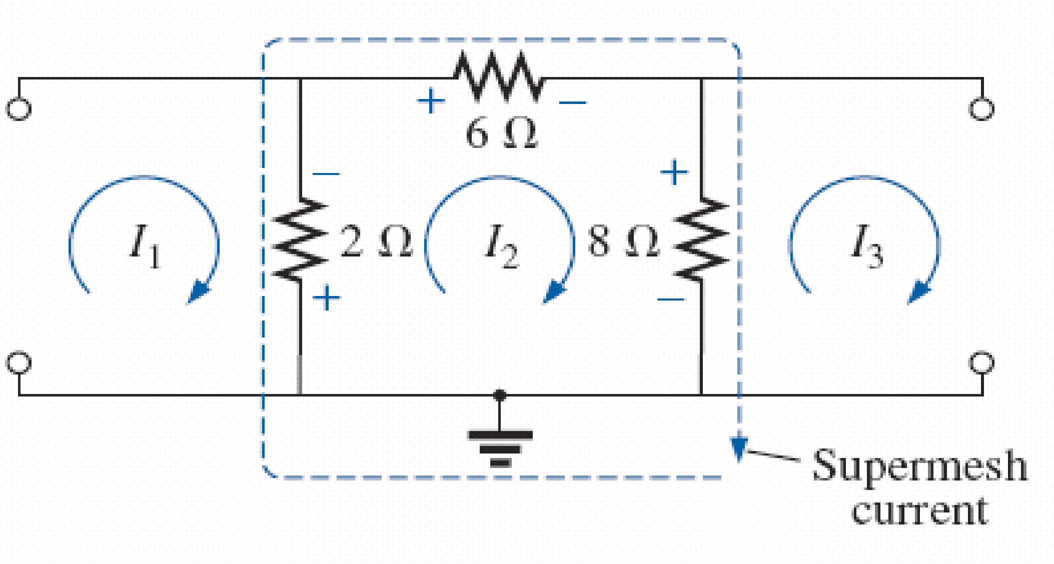

FIG. 8.36 *Defining the supermesh current for the network in Fig. 8.34.*

NODAL ANALYSIS (GENERAL APPROACH)

- The methods introduced thus far have all been to find the currents of the network.
- We now turn our attention to **nodal analysis**—a method that provides the nodal voltages of a network, that is, the voltage from the various **nodes** (junction points) of the network to ground.
- The method is developed through the use of Kirchhoff’s current law in much the same manner as Kirchhoff’s voltage law was used to develop the mesh analysis approach.

NODAL ANALYSIS (GENERAL APPROACH)

- ***The number of nodes for which the voltage must be determined using nodal analysis is 1 less than the total number of nodes.***
- ***The number of equations required to solve for all the nodal voltages of a network is 1 less than the total number of independent nodes.***

NODAL ANALYSIS (GENERAL APPROACH)

Nodal Analysis Procedure

1. ***Determine the number of nodes within the network.***
2. ***Pick a reference node, and label each remaining node with a subscripted value of voltage: V1, V2, and so on.***

NODAL ANALYSIS (GENERAL APPROACH)

Nodal Analysis Procedure

3. ***Apply Kirchhoff's current law at each node except the reference. Assume that all unknown currents leave the node for each application of Kirchhoff's current law. In other words, for each node, don't be influenced by the direction that an unknown current for another node may have had. Each node is to be treated as a separate entity, independent of the application of Kirchhoff's current law to the other nodes.***
4. ***Solve the resulting equations for the nodal voltages.***

NODAL ANALYSIS (GENERAL APPROACH)
Nodal Analysis Procedure

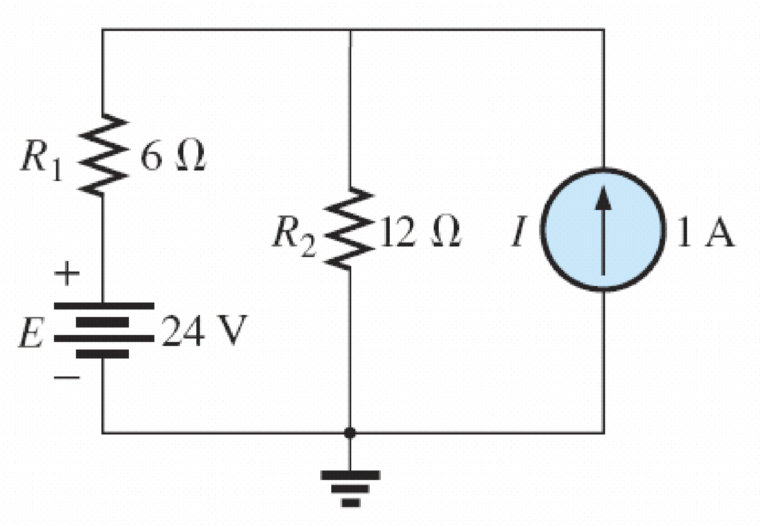

FIG. 8.43 *Example 8.19.*

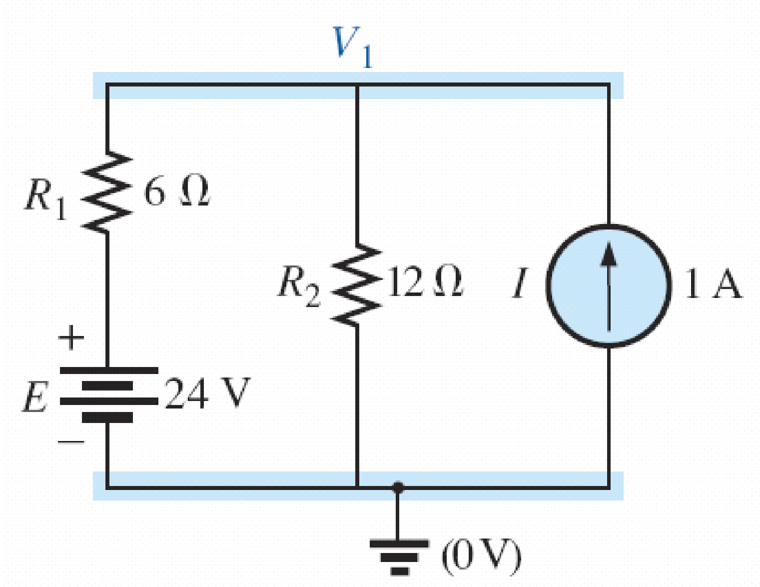

FIG. 8.44 *Network in Fig. 8.43 with assigned nodes.*

NODAL ANALYSIS (GENERAL APPROACH)
Nodal Analysis Procedure

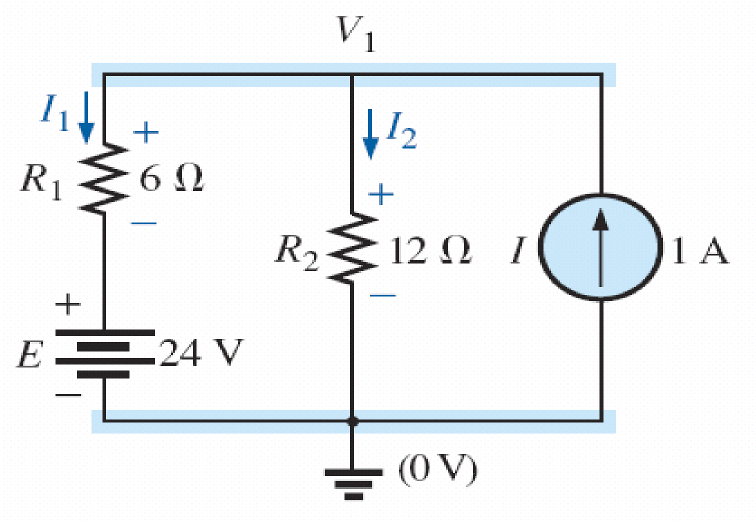

FIG. 8.45 *Applying Kirchhoff 's current law to the node V_1.*

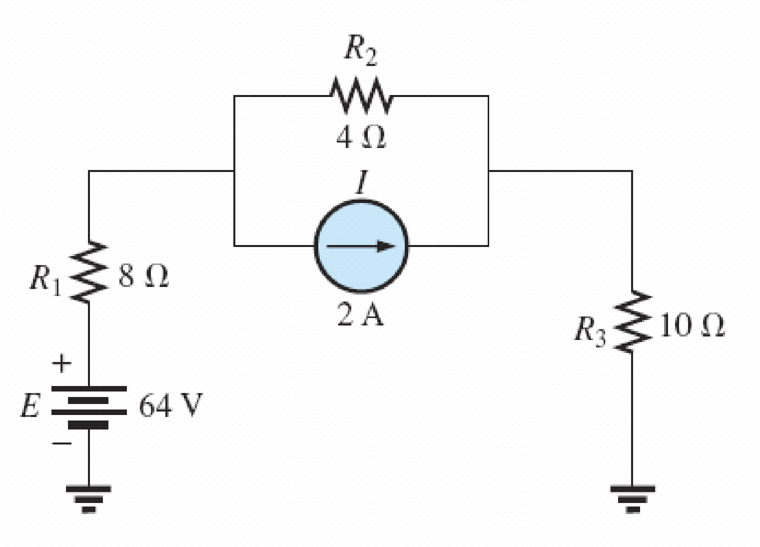

FIG. 8.46 *Example 8.20.*

NODAL ANALYSIS (GENERAL APPROACH)
Nodal Analysis Procedure

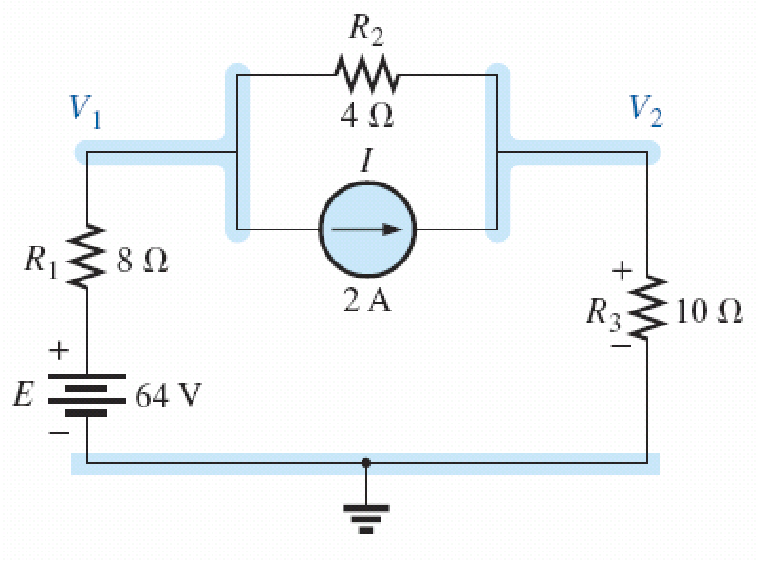

FIG. 8.47 *Defining the nodes for the network in Fig. 8.46.*

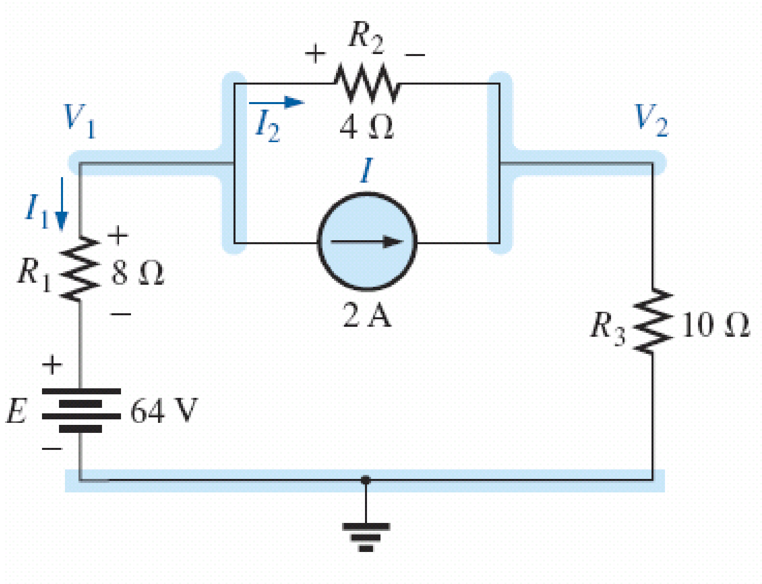

FIG. 8.48 *Applying Kirchhoff 's current law to node V1.*

NODAL ANALYSIS (GENERAL APPROACH)
Nodal Analysis Procedure

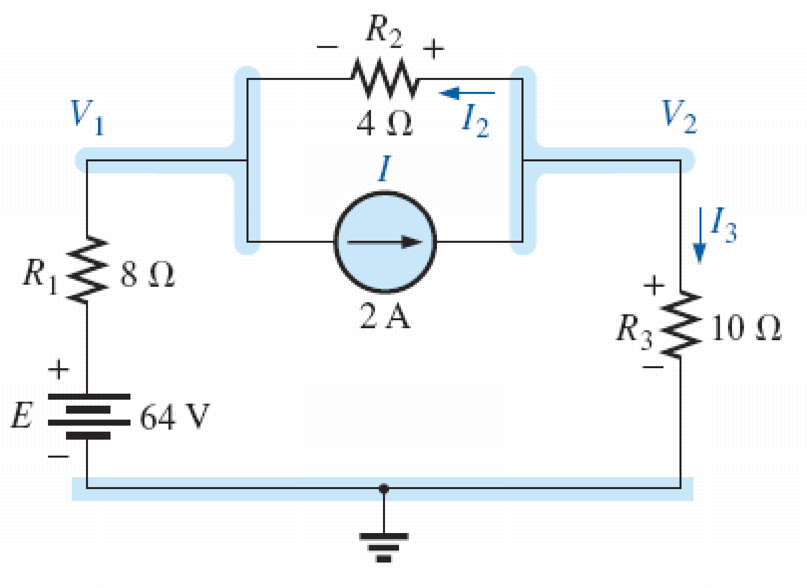

FIG. 8.49 *Applying Kirchhoff 's current law to node V_2.*

NODAL ANALYSIS (GENERAL APPROACH)

Nodal Analysis Procedure

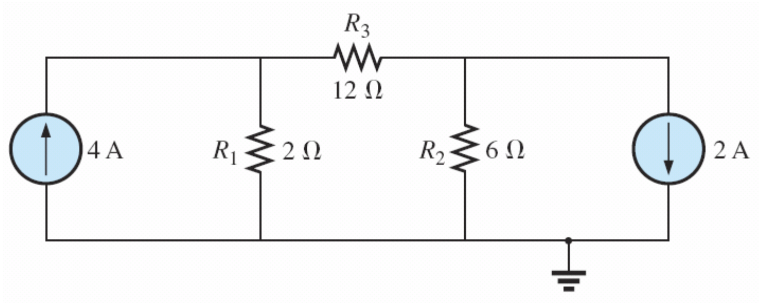

FIG. 8.50 *Example 8.21.*

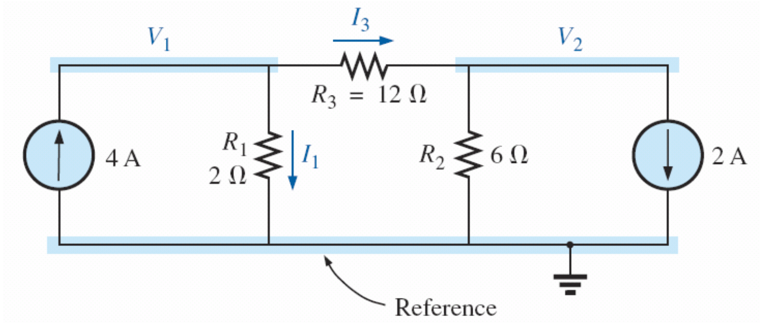

FIG. 8.51 *Defining the nodes and applying Kirchhoff 's current law to the node V_1.*

NODAL ANALYSIS (GENERAL APPROACH)

Nodal Analysis Procedure

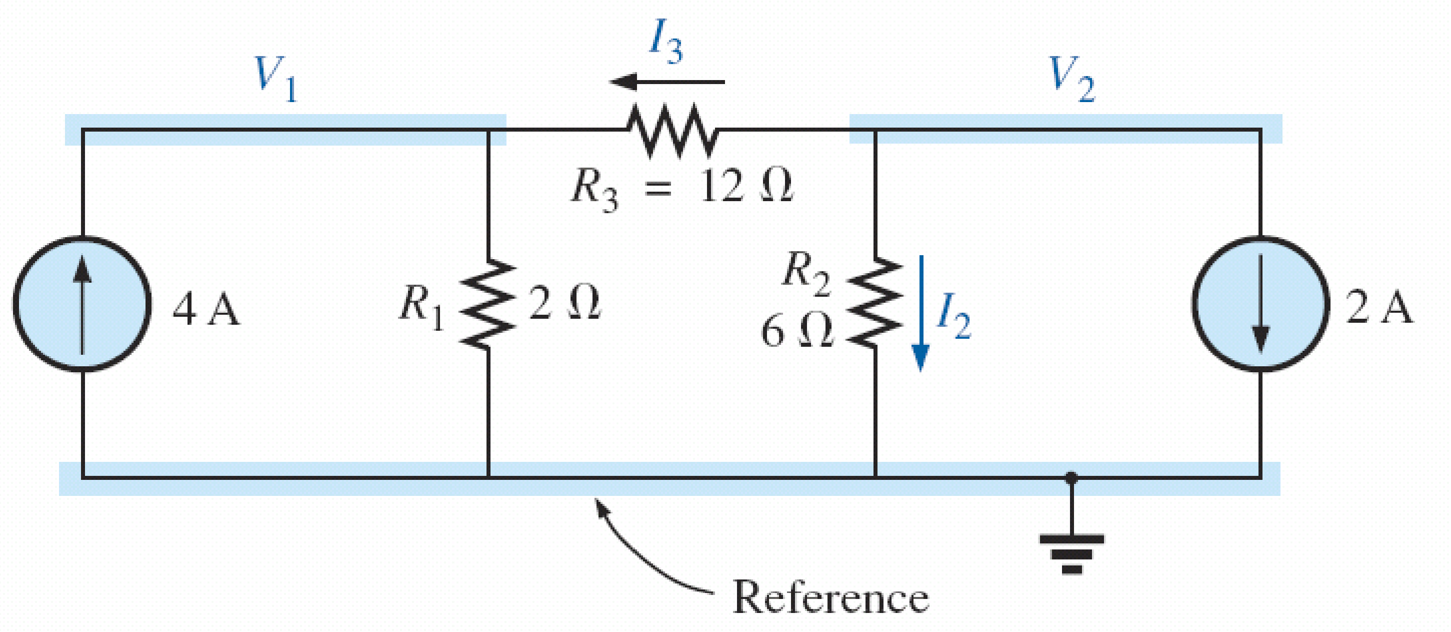

FIG. 8.52 *Applying Kirchhoff 's current law to the node V_2.*

NODAL ANALYSIS (GENERAL APPROACH)
Supernode

- Occasionally, you may encounter voltage sources in a network that do not have a series internal resistance that would permit a conversion to a current source.
- In such cases, you have two options.
  - The simplest and most direct approach is to *place a resistor in series with the source of a very small value compared to the other resistive elements of the network.*
  - The other approach is to use the **supernode approach**

NODAL ANALYSIS (GENERAL APPROACH)

Supernode

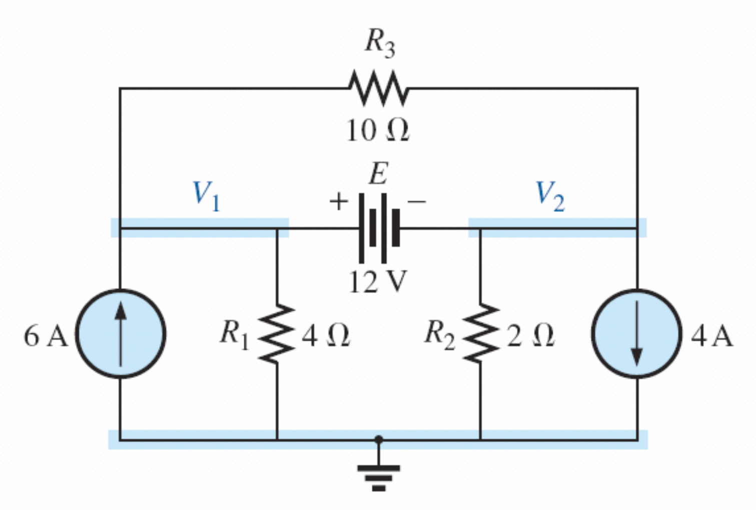

FIG. 8.53 *Example 8.22.*

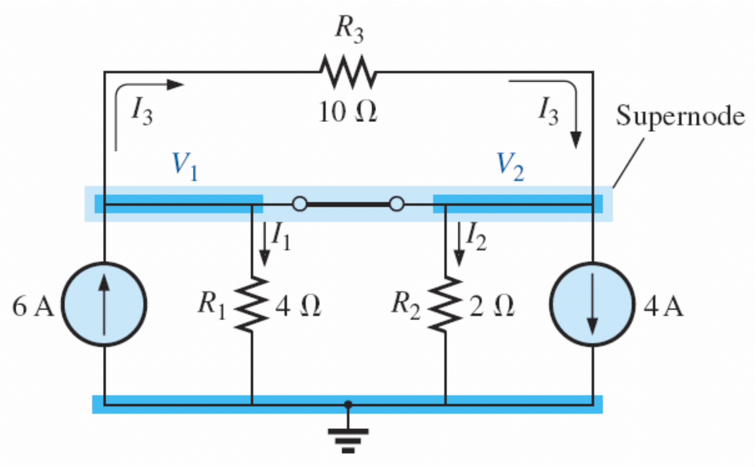

FIG. 8.54 *Defining the supernode for the network in Fig. 8.53.*

NODAL ANALYSIS (FORMAT APPROACH)

Nodal Analysis Procedure

1. ***Choose a reference node, and assign a subscripted voltage label to the (N - 1) remaining nodes of the network.***
2. ***The number of equations required for a complete solution is equal to the number of subscripted voltages (N - 1). Column 1 of each equation is formed by summing the conductances tied to the node of interest and multiplying the result by that subscripted nodal voltage.***

NODAL ANALYSIS (FORMAT APPROACH)

Nodal Analysis Procedure

3. ***We must now consider the mutual terms, which, as noted in the preceding example, are always subtracted from the first column. It is possible to have more than one mutual term if the nodal voltage of current interest has an element in common with more than one other nodal voltage. This is demonstrated in an example to follow. Each mutual term is the product of the mutual conductance and the other nodal voltage, tied to that conductance.***

NODAL ANALYSIS (FORMAT APPROACH)

Nodal Analysis Procedure

4. ***The column to the right of the equality sign is the algebraic sum of the current sources tied to the node of interest. A current source is assigned a positive sign if it supplies current to a node and a negative sign if it draws current from the node.***
5. ***Solve the resulting simultaneous equations for the desired voltages.***

NODAL ANALYSIS (FORMAT APPROACH)
Nodal Analysis Procedure

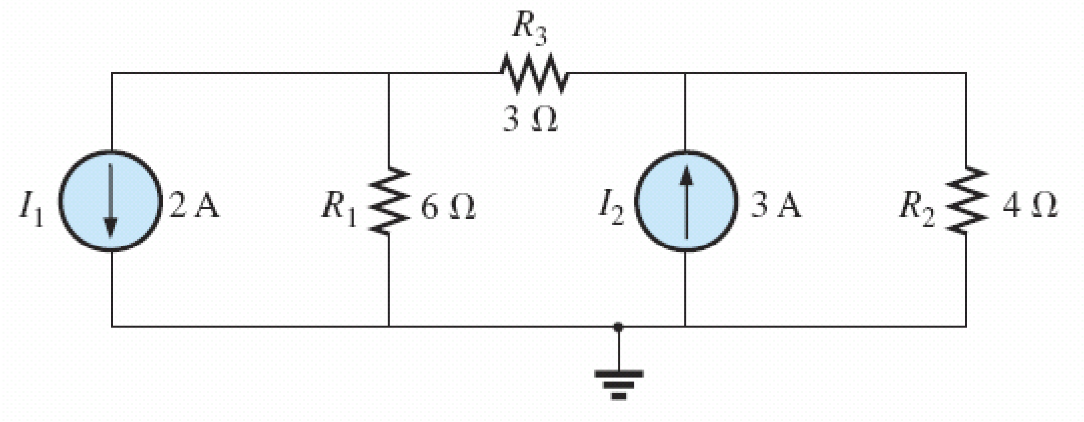

FIG. 8.55 *Example 8.23.*

NODAL ANALYSIS (FORMAT APPROACH)

Nodal Analysis Procedure

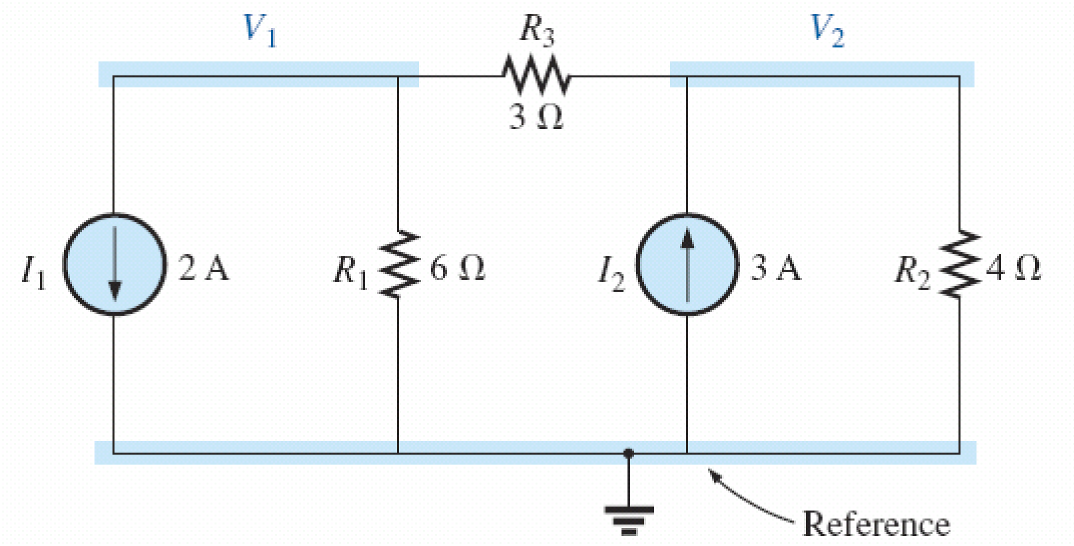

FIG. 8.56 *Defining the nodes for the network in Fig. 8.55.*

NODAL ANALYSIS (FORMAT APPROACH)
Nodal Analysis Procedure

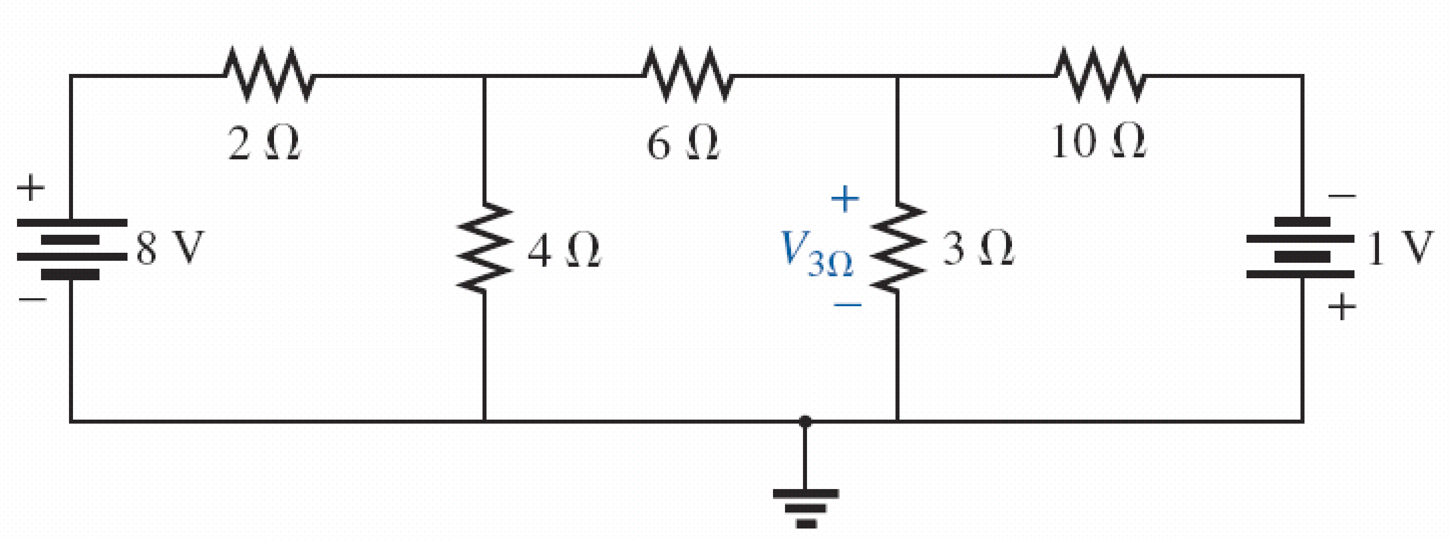

FIG. 8.57 *Example 8.24.*

NODAL ANALYSIS (FORMAT APPROACH)
Nodal Analysis Procedure

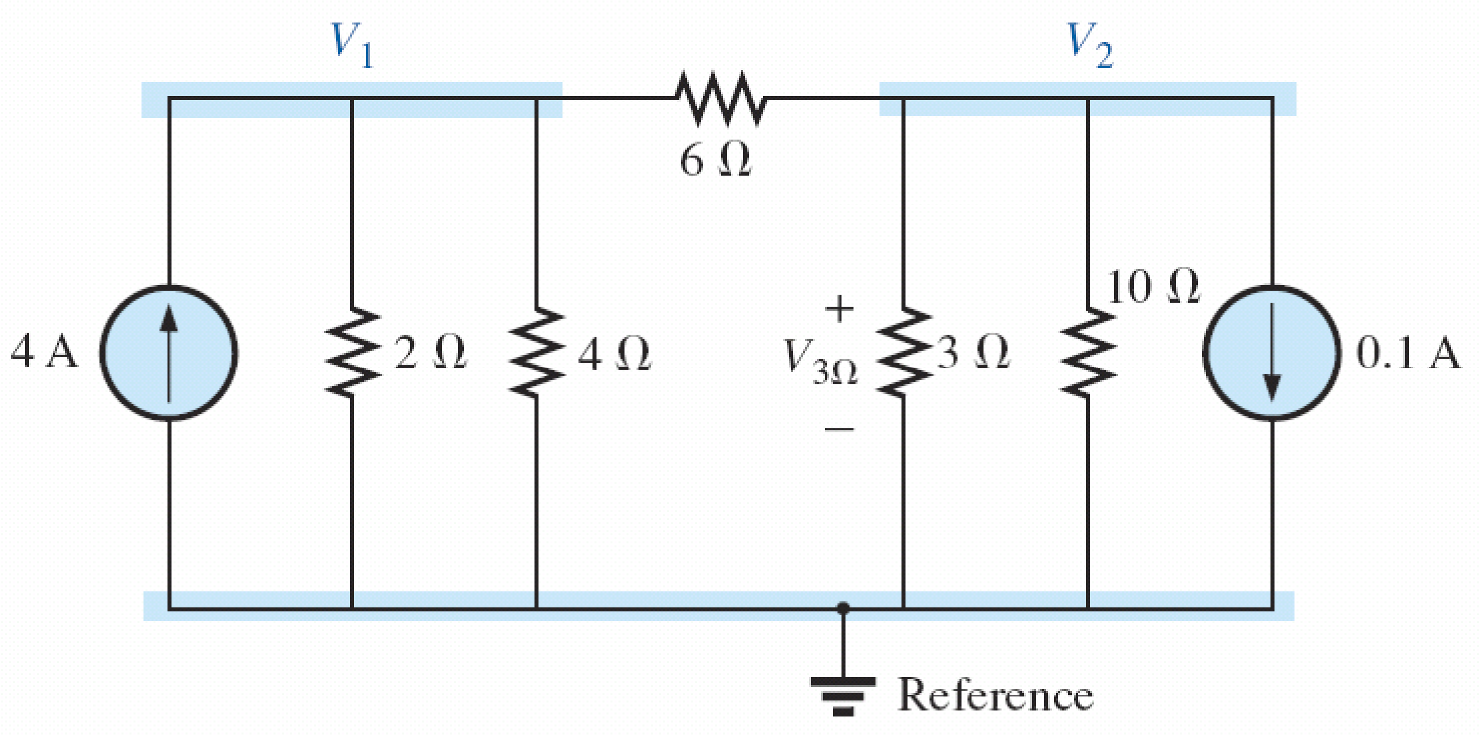

FIG. 8.58 *Defining the nodes for the network in Fig. 8.57.*

NODAL ANALYSIS (FORMAT APPROACH)
Nodal Analysis Procedure

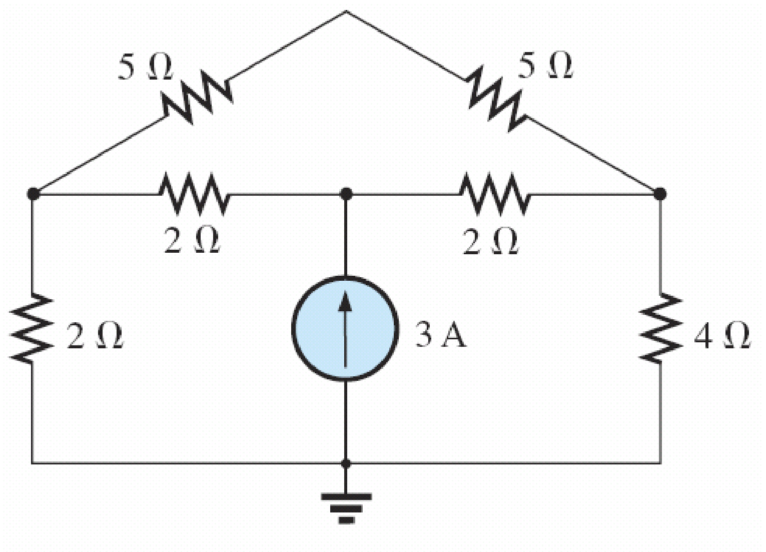

FIG. 8.59 *Example 8.25.*

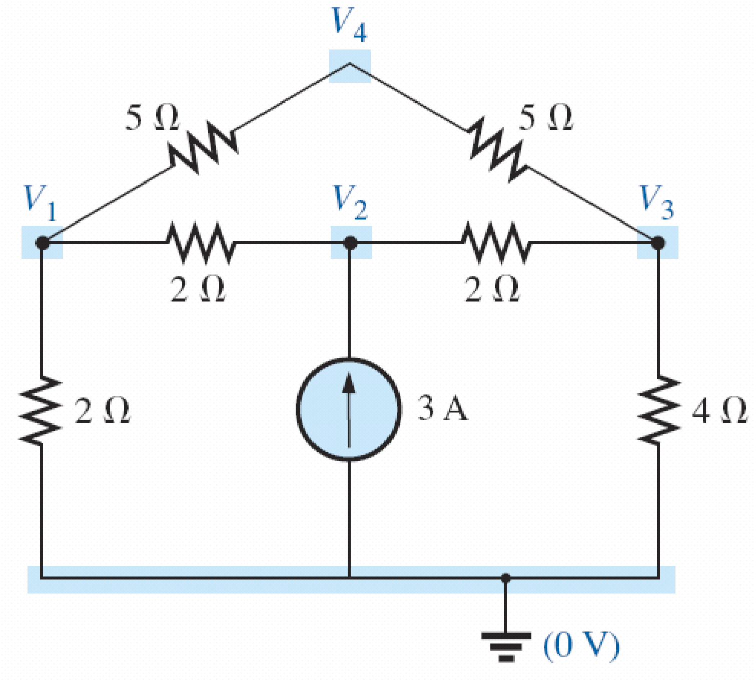

FIG. 8.60 *Defining the nodes for the network in Fig. 8.59.*

NODAL ANALYSIS (FORMAT APPROACH)

Nodal Analysis Procedure

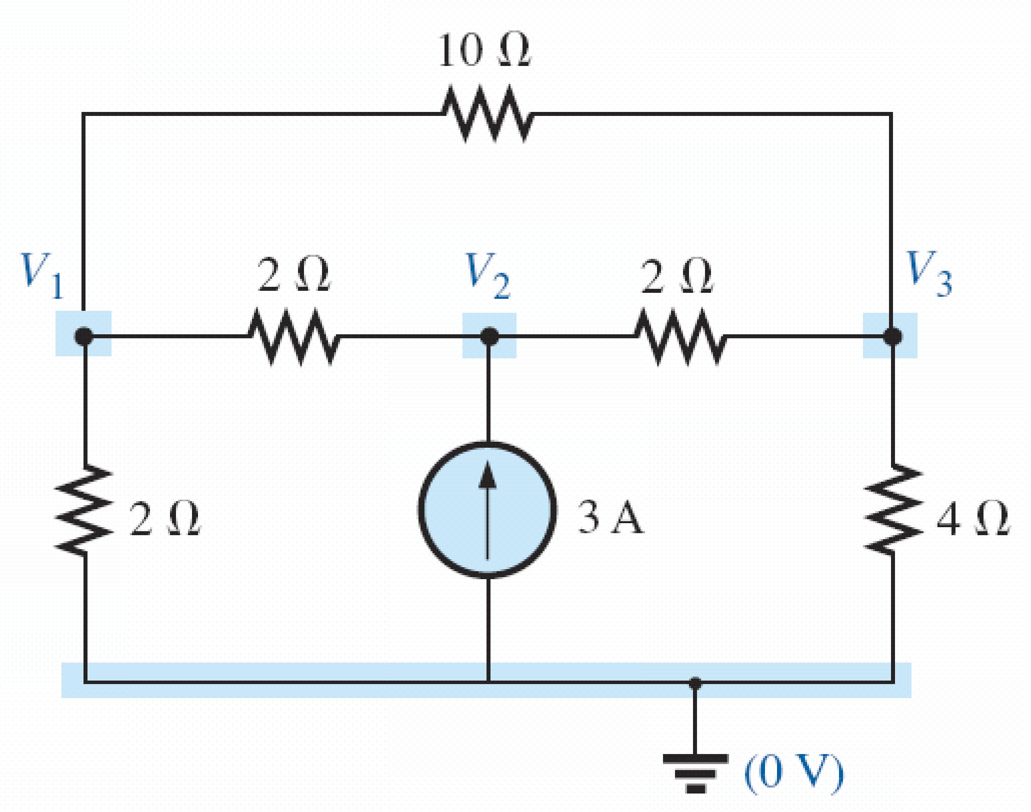

FIG. 8.61 *Reducing the number of nodes for the network in Fig. 8.59 by combining the two 5Ω resistors.*

NODAL ANALYSIS (FORMAT APPROACH)
Nodal Analysis Procedure

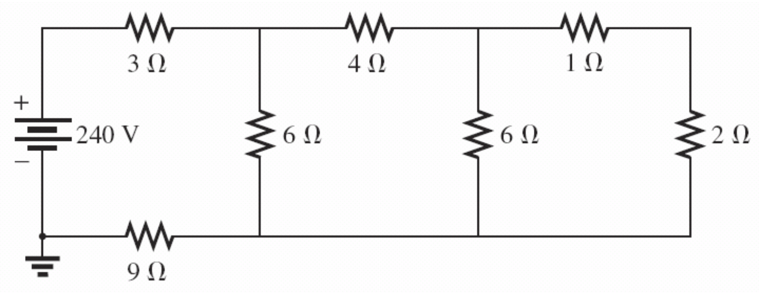

FIG. 8.62 *Example 8.26.*

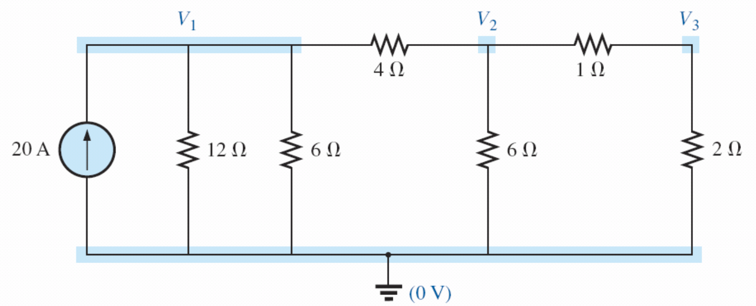

FIG. 8.63 *Converting the voltage source to a current source and defining the nodes for the network in Fig. 8.62.*

BRIDGE NETWORKS

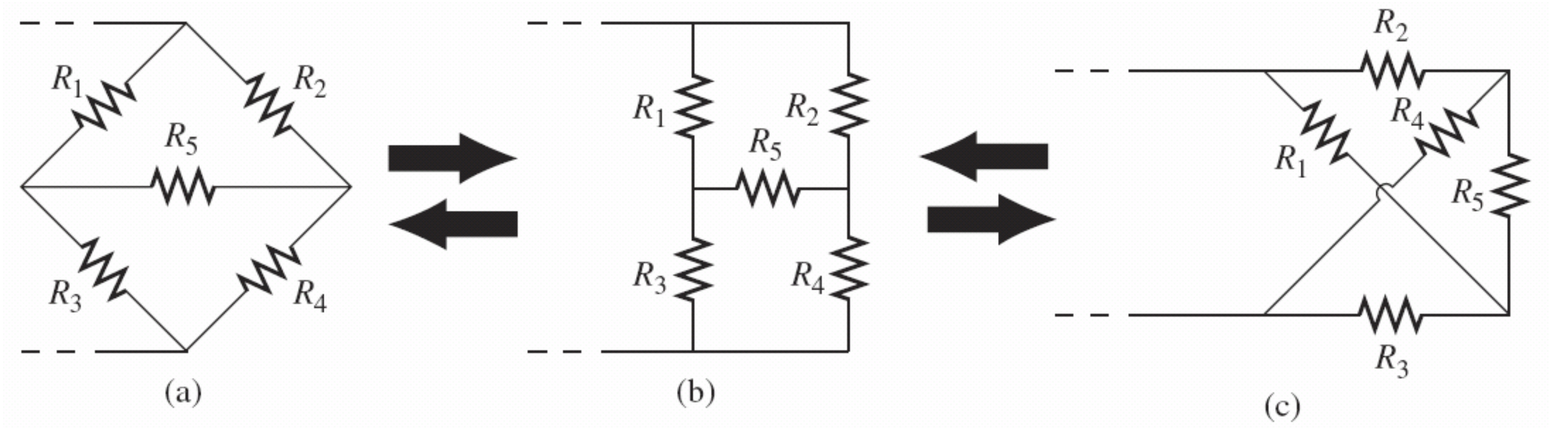

FIG. 8.64 *Various formats for a bridge network.*

BRIDGE NETWORKS

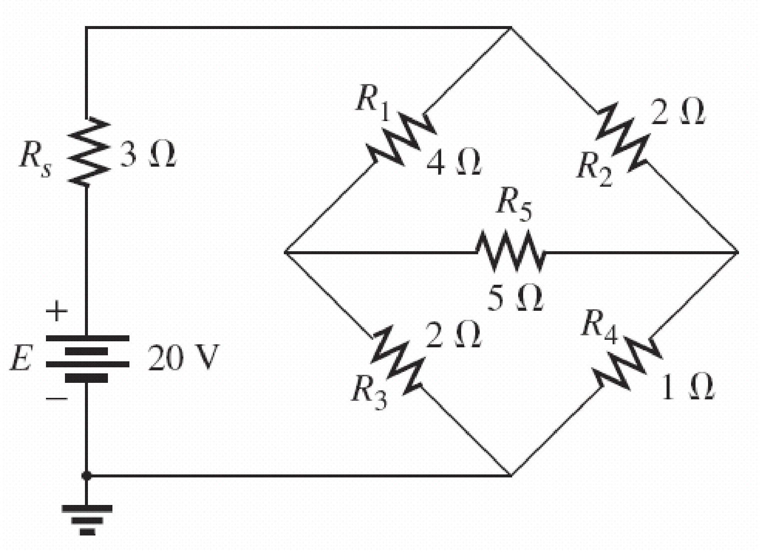

FIG. 8.65 *Standard bridge configuration.*

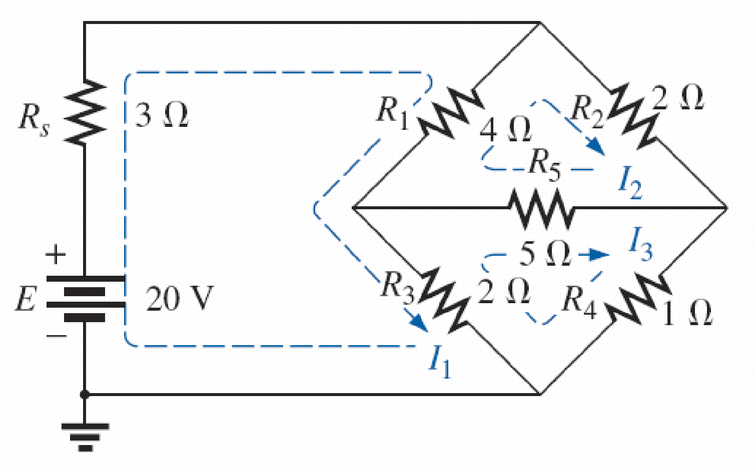

FIG. 8.66 *Assigning the mesh currents to the network in Fig. 8.65.*

BRIDGE NETWORKS

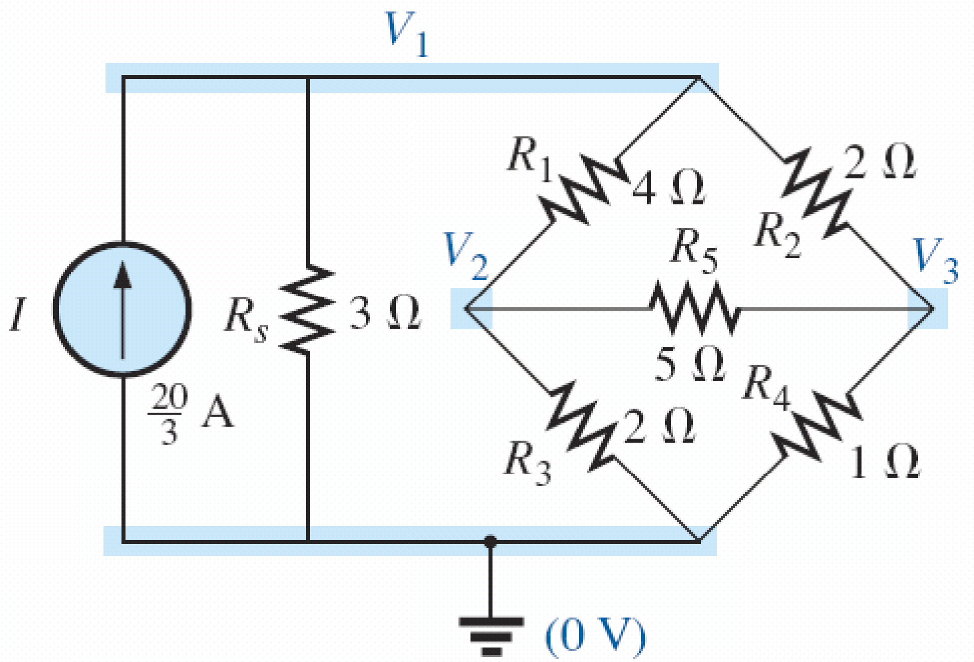

FIG. 8.67 *Defining the nodal voltages for the network in Fig. 8.65.*

BRIDGE NETWORKS

TI-89 Calculator Solution

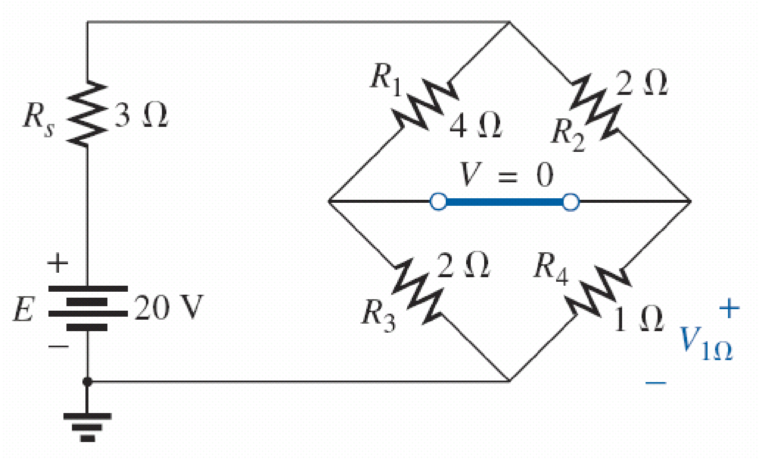

FIG. 8.71 *Substituting the short-circuit equivalent for the balance arm of a balanced bridge.*

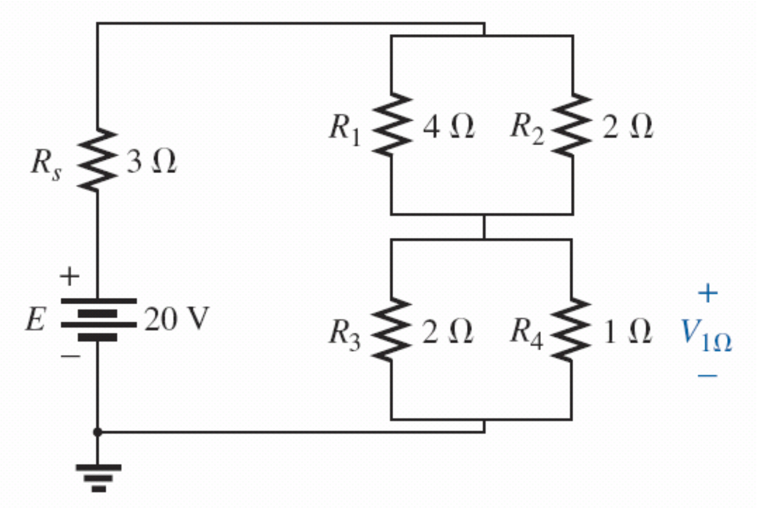

FIG. 8.72 *Redrawing the network in Fig. 8.71.*

BRIDGE NETWORKS
TI-89 Calculator Solution

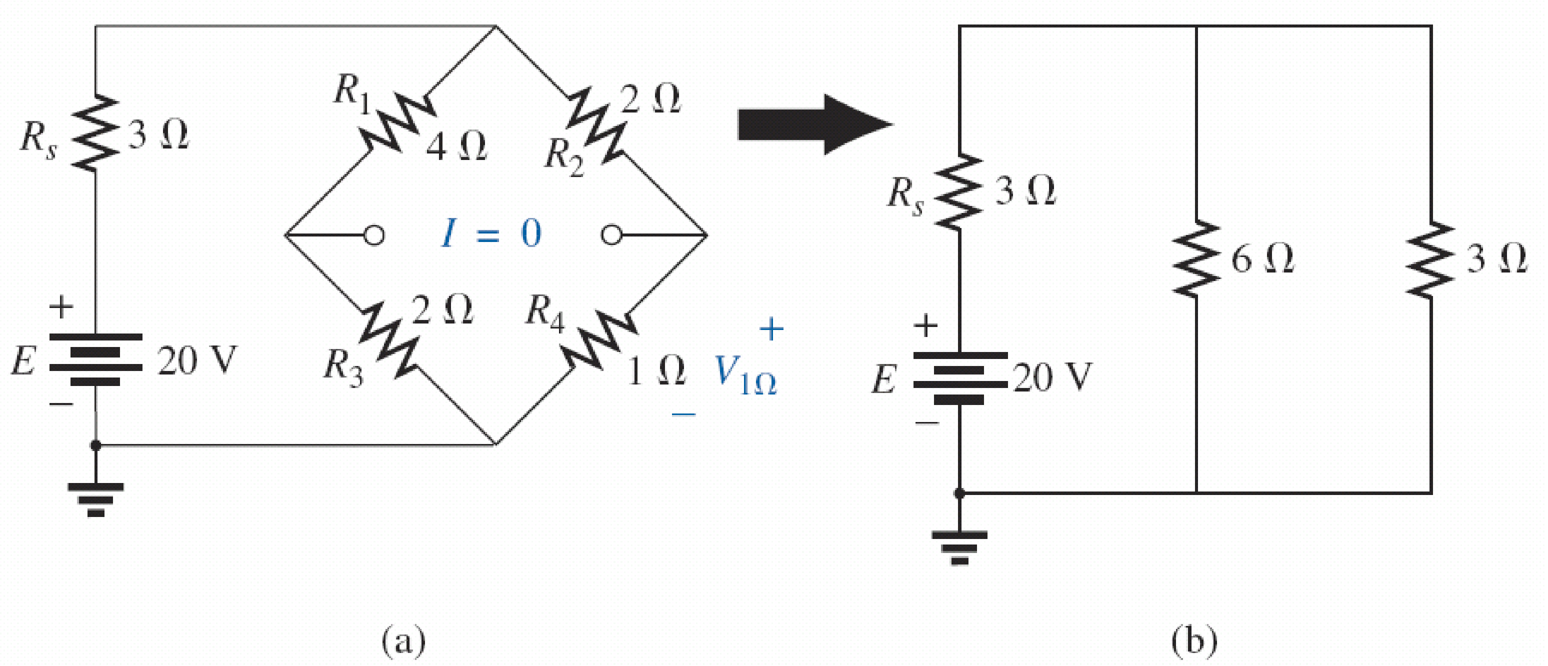

FIG. 8.73 *Substituting the open-circuit equivalent for the balance arm of a balanced bridge.*

BRIDGE NETWORKS

TI-89 Calculator Solution

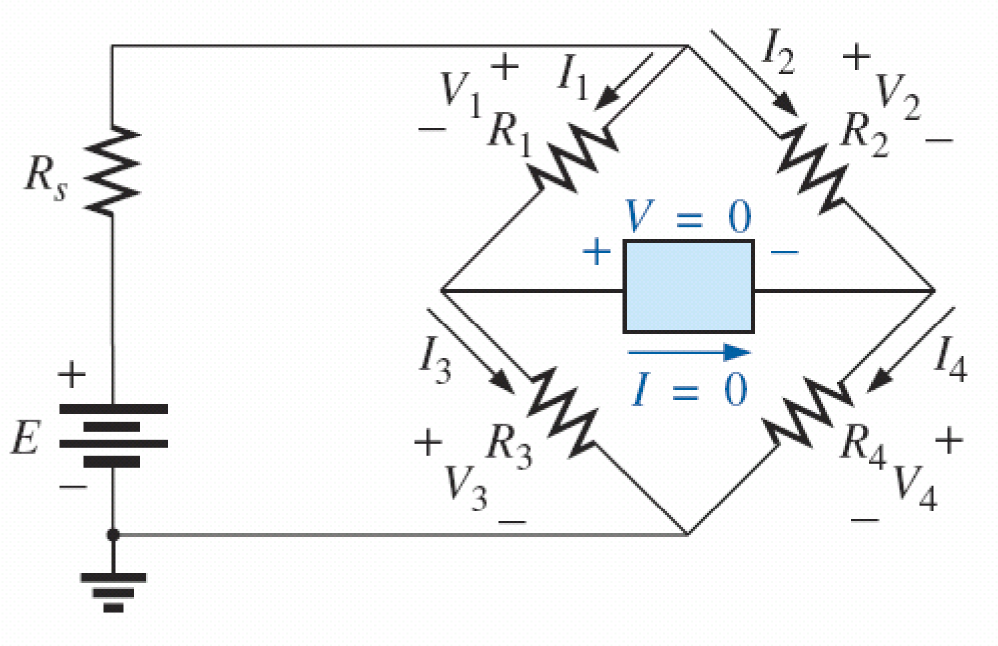

FIG. 8.74 *Establishing the balance criteria for a bridge network.*

BRIDGE NETWORKS
TI-89 Calculator Solution

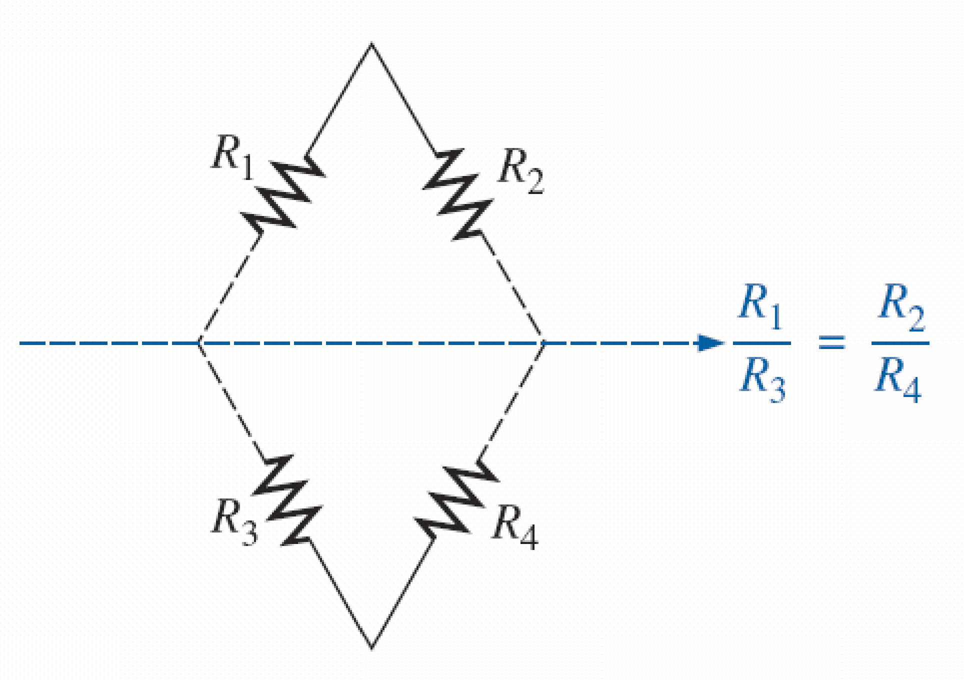

FIG. 8.75 *A visual approach to remembering the balance condition.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

- Circuit configurations are often encountered in which the resistors do not appear to be in series or parallel.
- Under these conditions, it may be necessary to convert the circuit from one form to another to solve for any unknown quantities if mesh or nodal analysis is not applied.
- Two circuit configurations that often account for these difficulties are the **wye (Y)** and **delta (Δ) configurations** depicted in Fig. 8.76(a).
- They are also referred to as the **tee (T)** and **pi (π),** respectively,

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

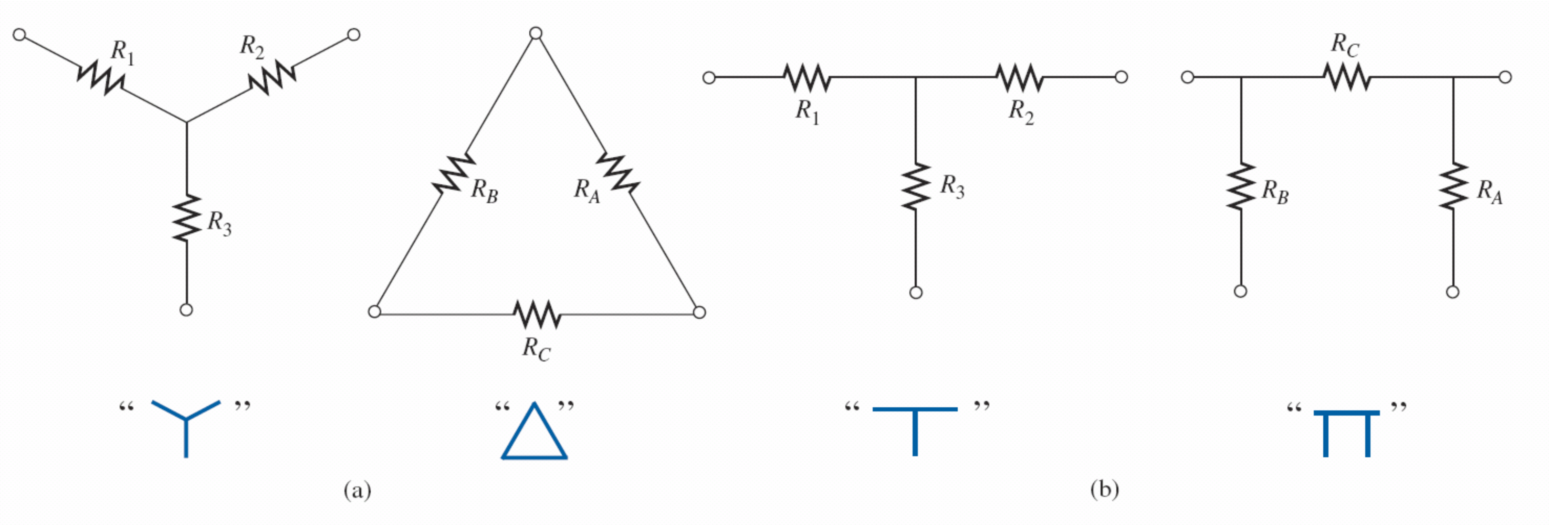

FIG. 8.76 *The Y (T) and Δ (π) configurations.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

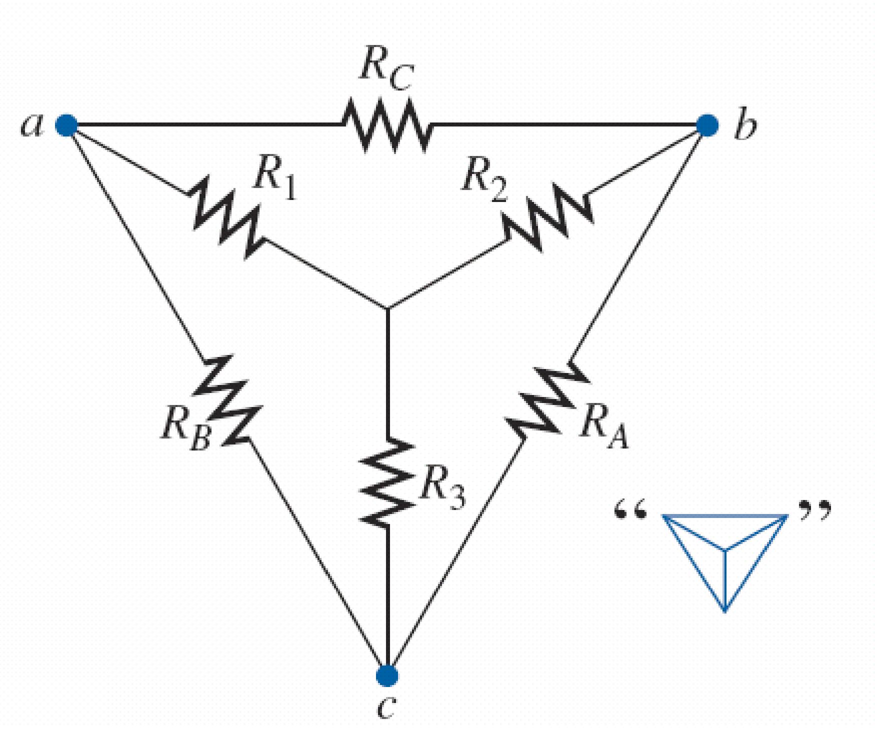

FIG. 8.77 *Introducing the concept of Δ-Y or Y-Δ conversions*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

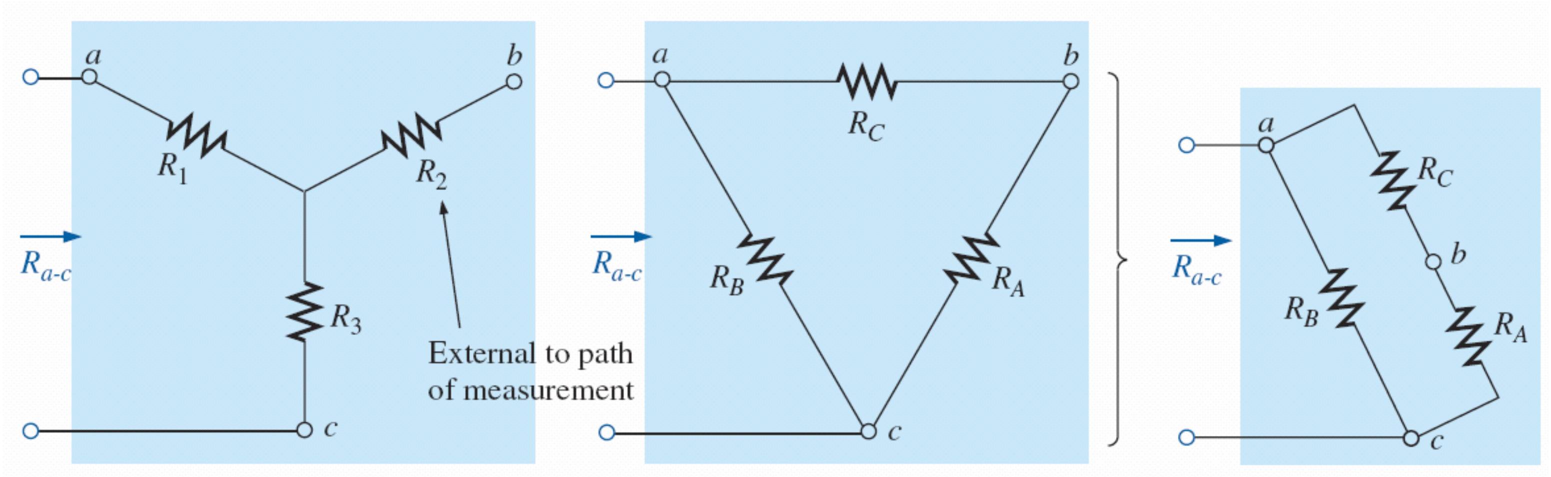

FIG. 8.78 *Finding the resistance $R_{a\text{-}c}$ for the Y and Δ configurations.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

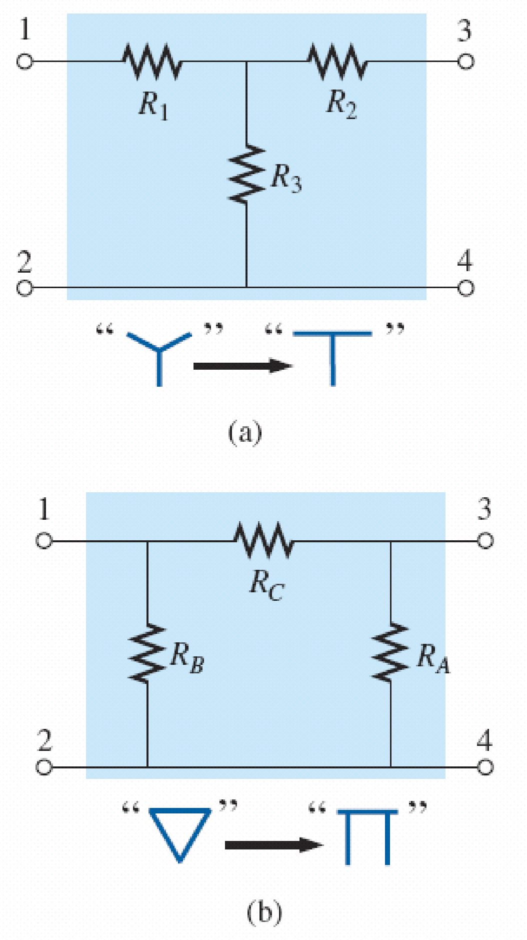

FIG. 8.79 *The relationship between the Y and T configurations and the Δ and π configurations.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

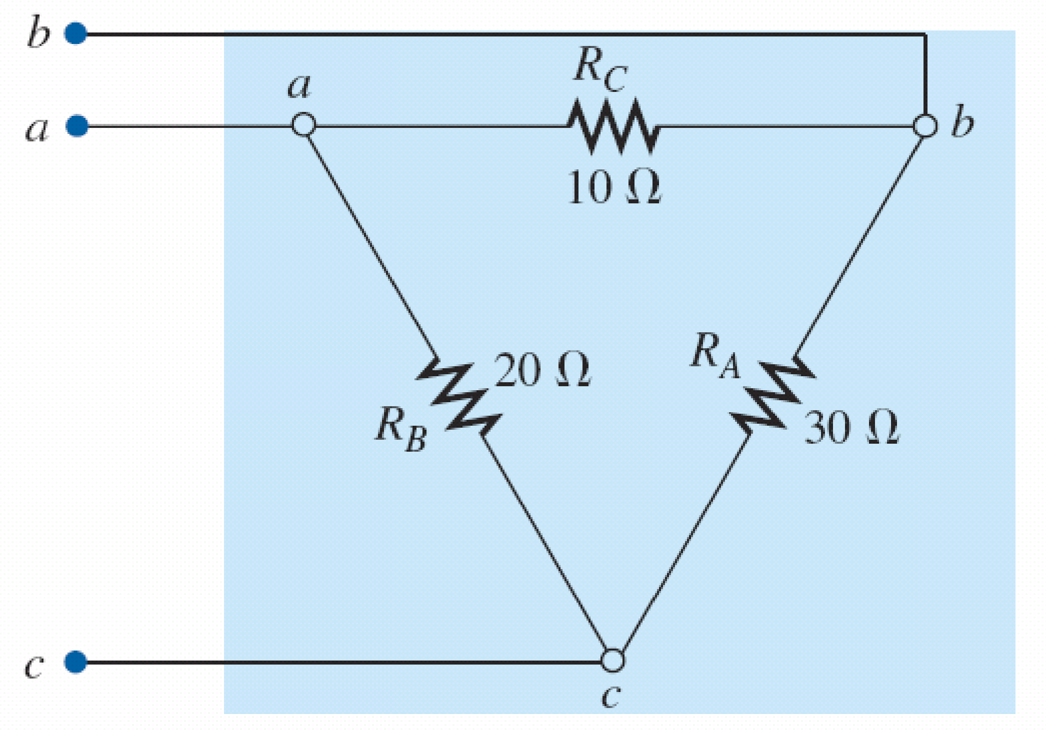

FIG. 8.80 *Example 8.27.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

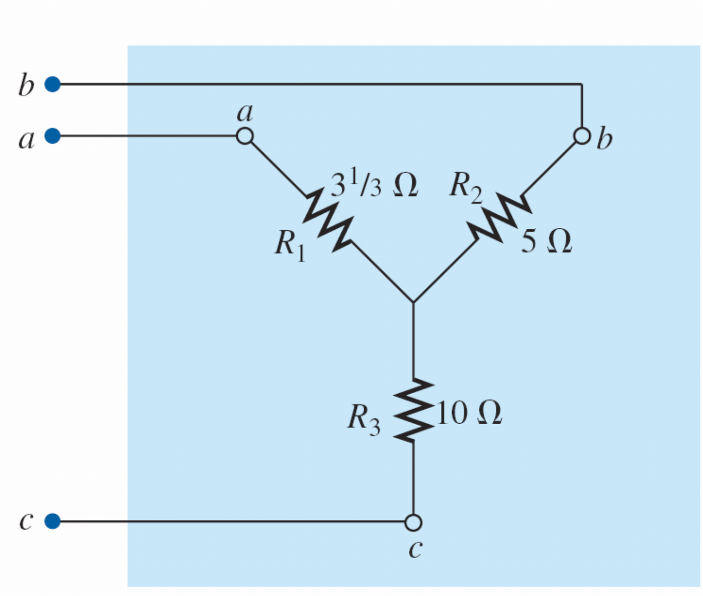

FIG. 8.81 *The Y equivalent for the Δ in Fig. 8.80.*

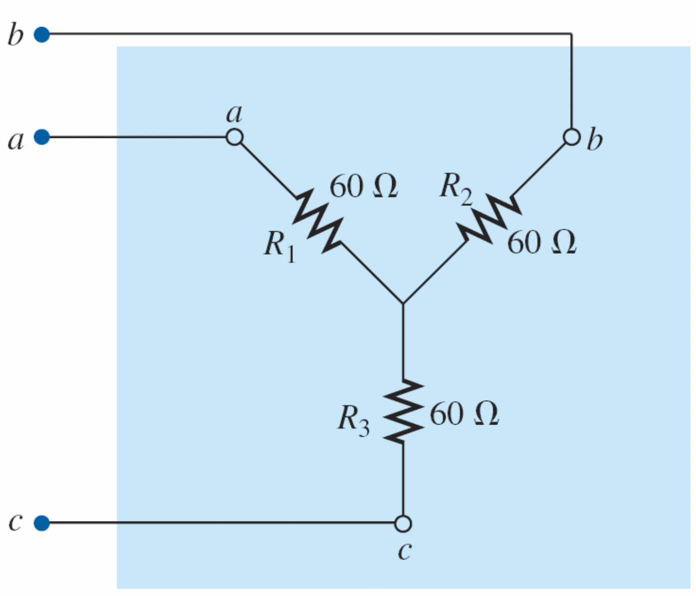

FIG. 8.82 *Example 8.28.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

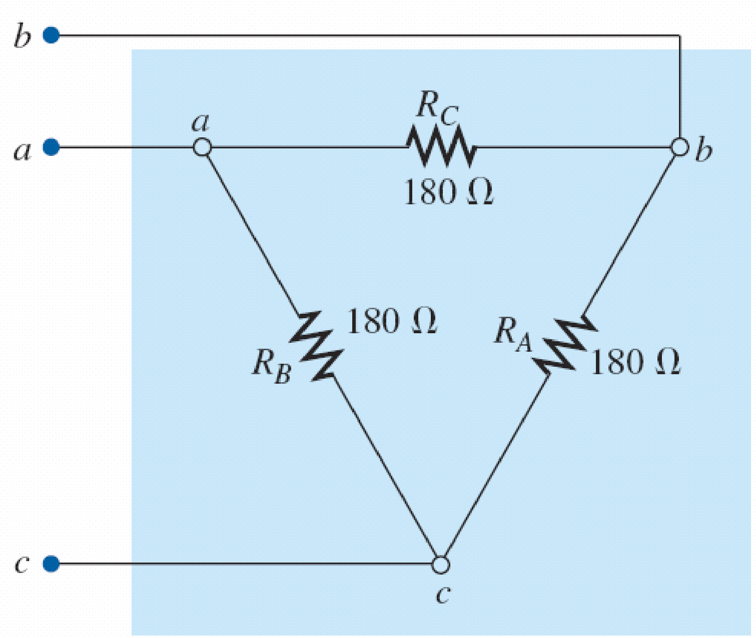

FIG. 8.83 *The Δ equivalent for the Y in Fig. 8.82.*

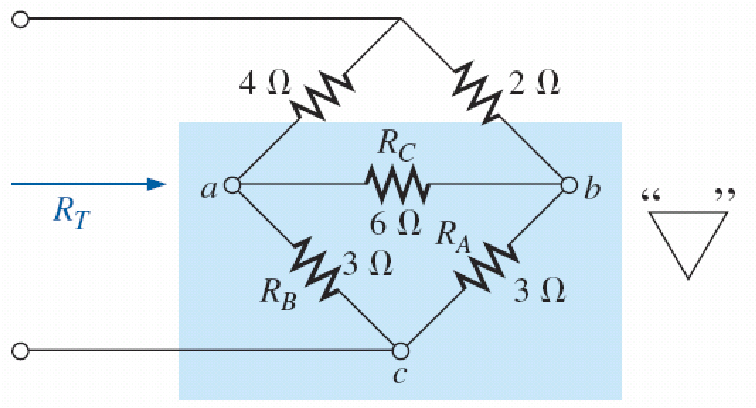

FIG. 8.84 *Example 8.29.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

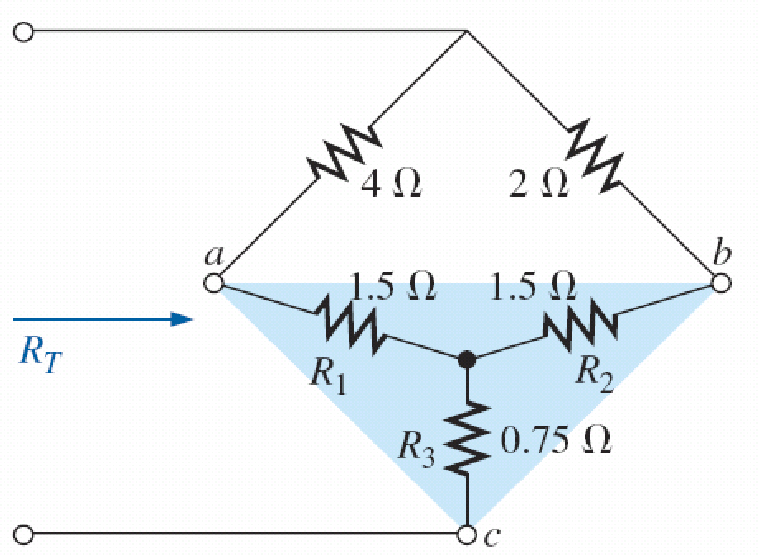

FIG. 8.85 *Substituting the Y equivalent for the bottom Δ in Fig. 8.84.*

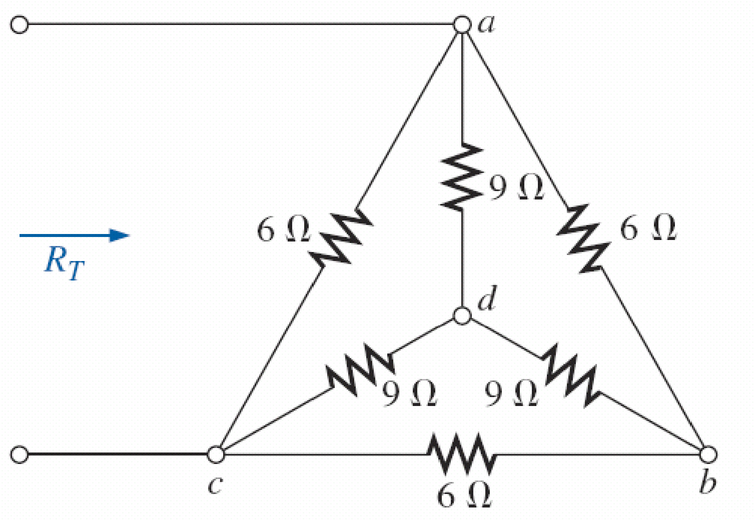

FIG. 8.86 *Example 8.30.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

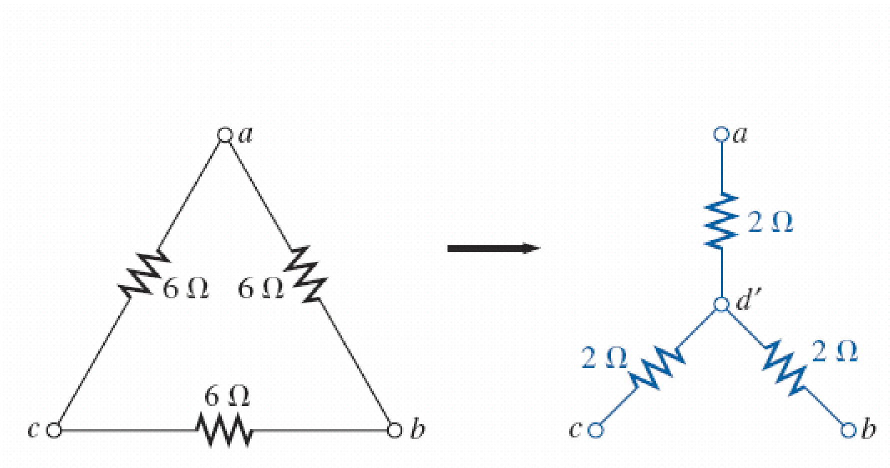

FIG. 8.87 *Converting the Δ configuration of Fig. 8.86 to a Y configuration.*

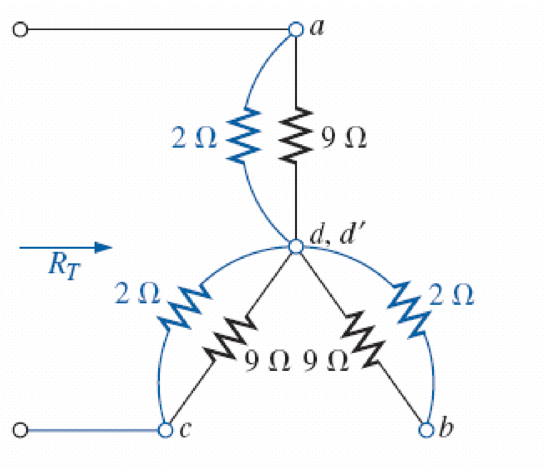

FIG. 8.88 *Substituting the Y configuration for the converted Δ into the network in Fig. 8.86.*

Y-Δ (T-π) AND Δ-Y (π-T) CONVERSIONS

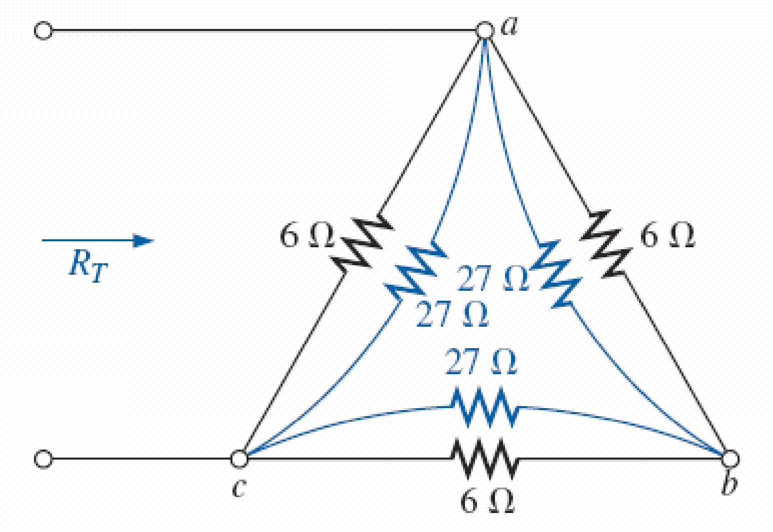

FIG. 8.89 *Substituting the converted Y configuration into the network in Fig. 8.86.*

APPLICATIONS
Constant-Current Alarm Systems

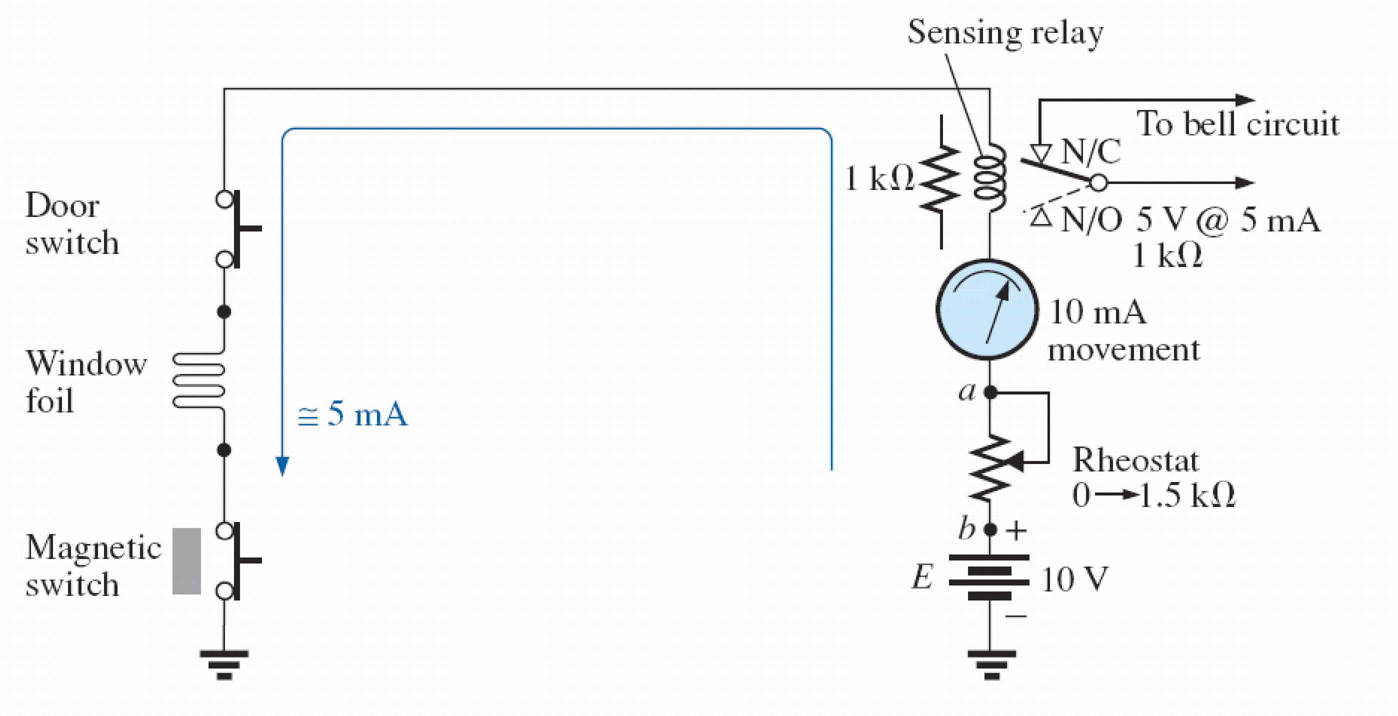

FIG. 8.90 *Constant-current alarm system.*

APPLICATIONS
Constant-Current Alarm Systems

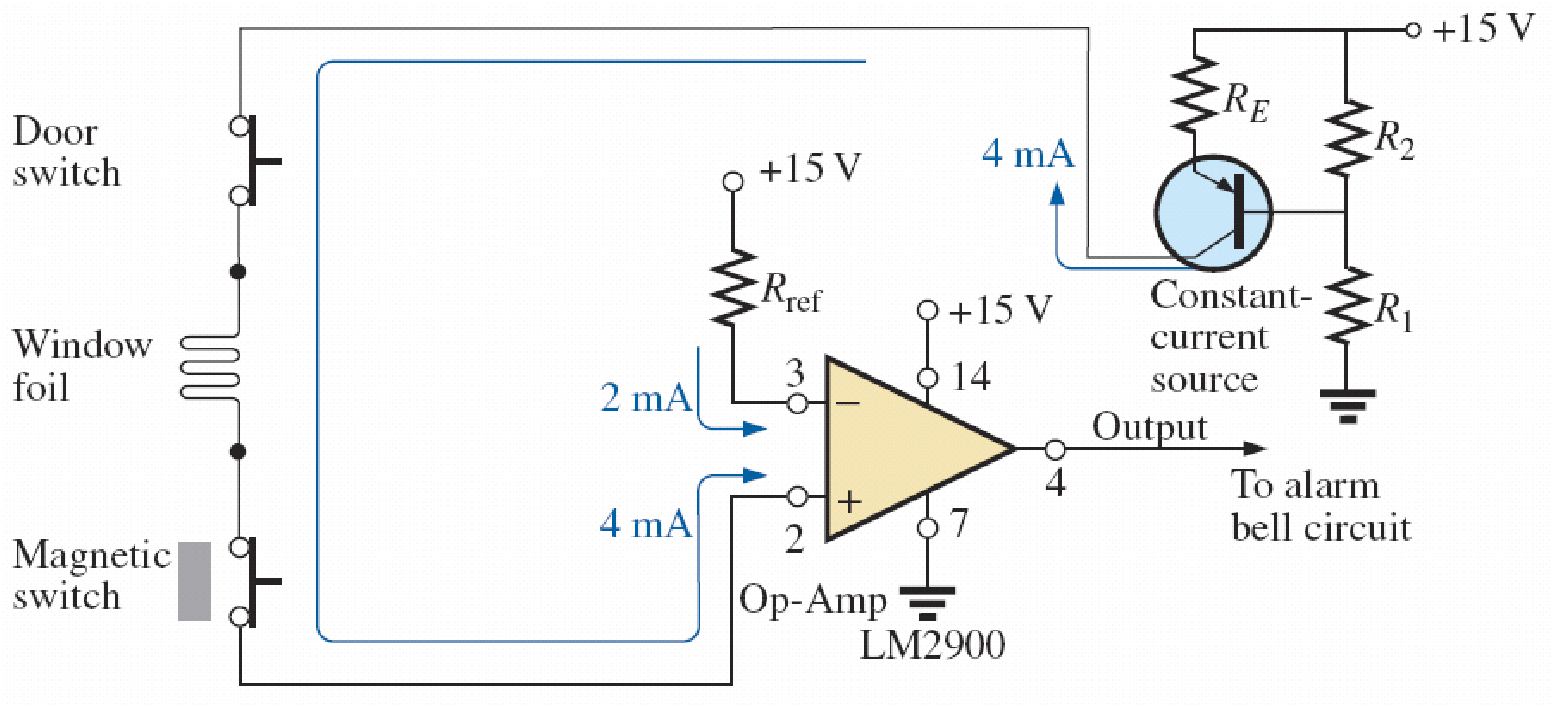

FIG. 8.91 *Constant-current alarm system with electronic components.*

APPLICATIONS
Constant-Current Alarm Systems

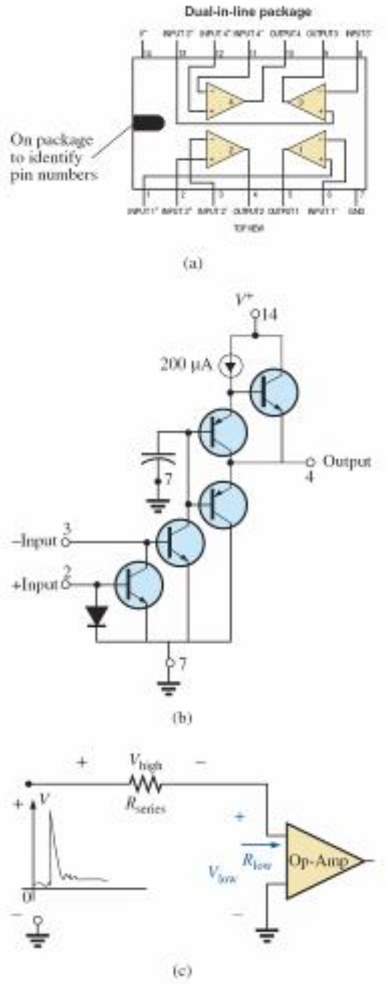

FIG. 8.92 *LM2900 operational amplifier: (a) dual-in-line package (DIP); (b) components; (c) impact of low-input impedance.*

APPLICATIONS
Wheatstone Bridge Smoke Detector

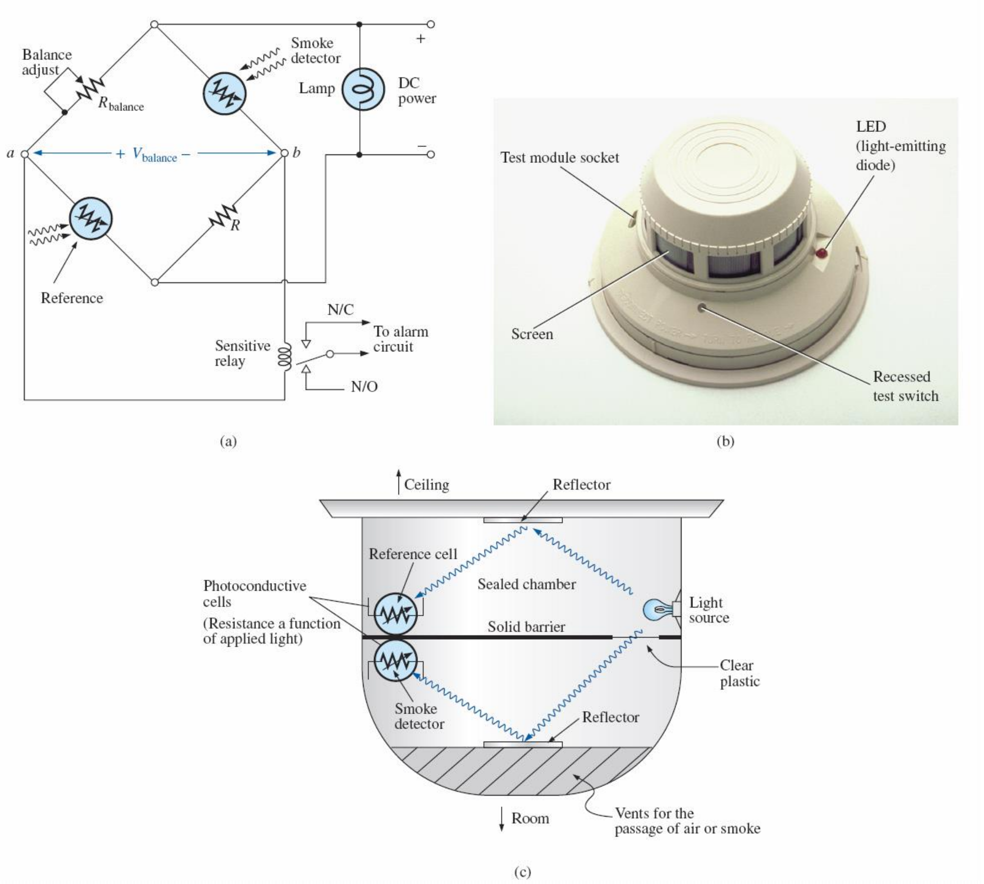

FIG. 8.93 *Wheatstone bridge smoke detector: (a) dc bridge configuration; (b) outside appearance; (c) internal construction.*

APPLICATIONS
Schematic with Nodal Voltages

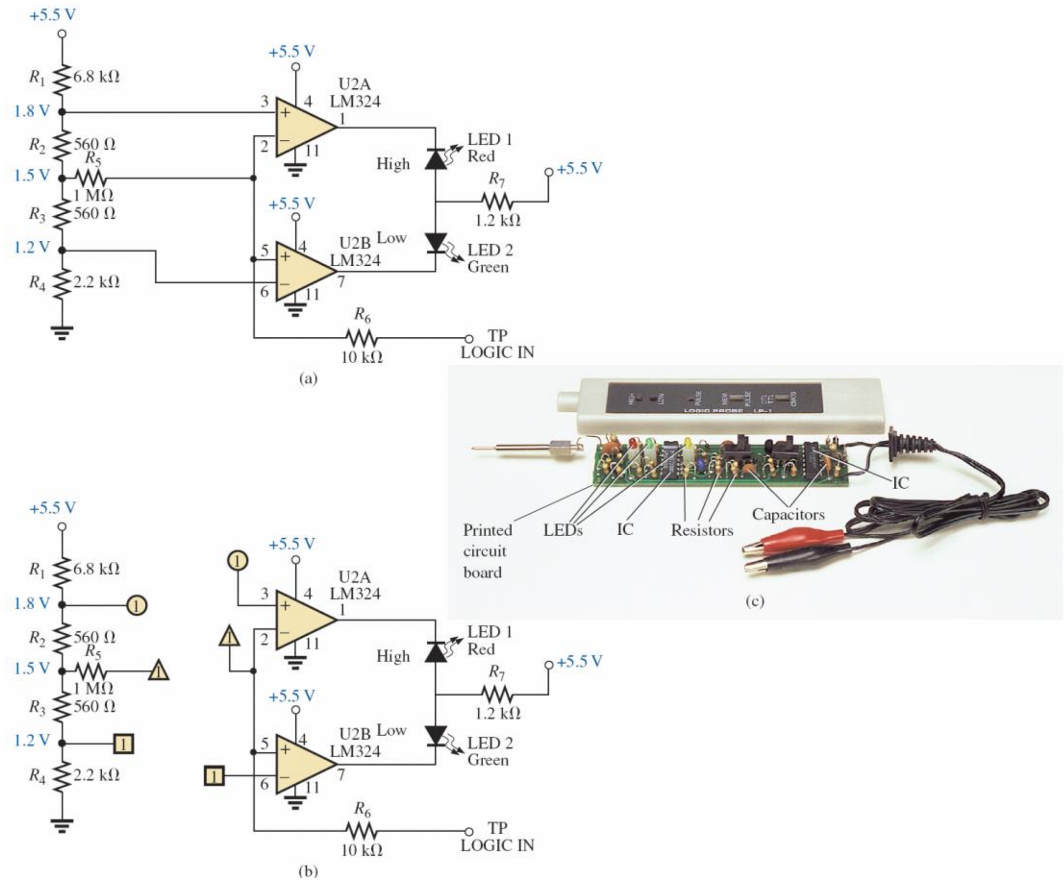

FIG. 8.94 *Logic probe: (a) schematic with nodal voltages; (b) network with global connections; (c) photograph of commercially available unit.*

COMPUTER ANALYSIS

Multisim

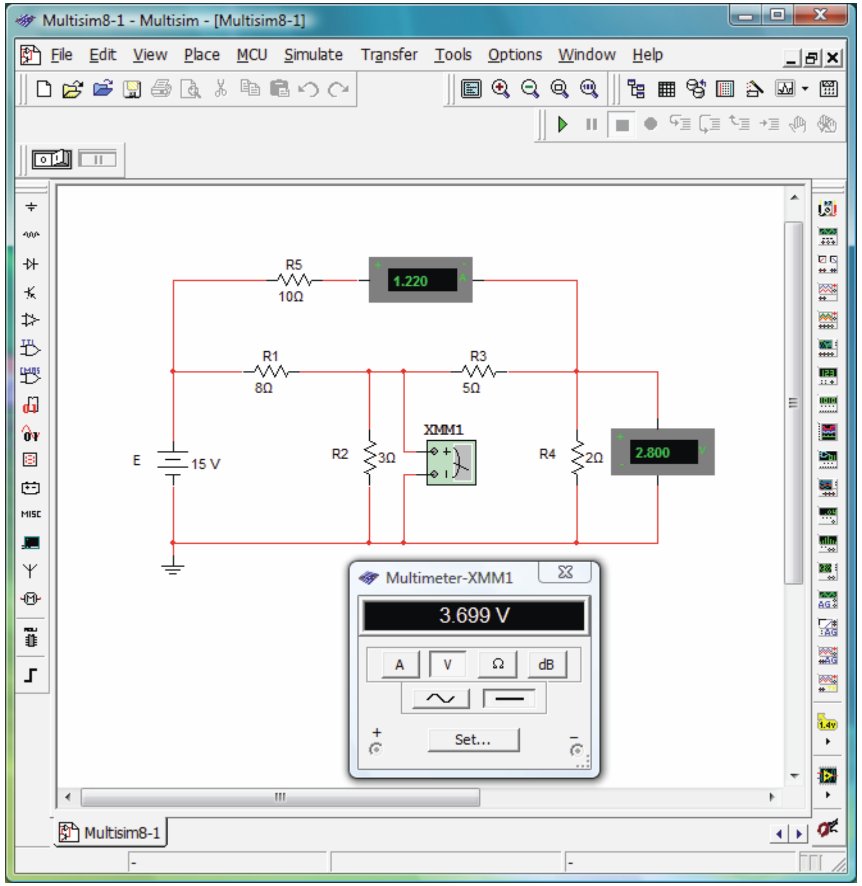

FIG. 8.96 *Using Multisim to verify the results in Example 8.18.*