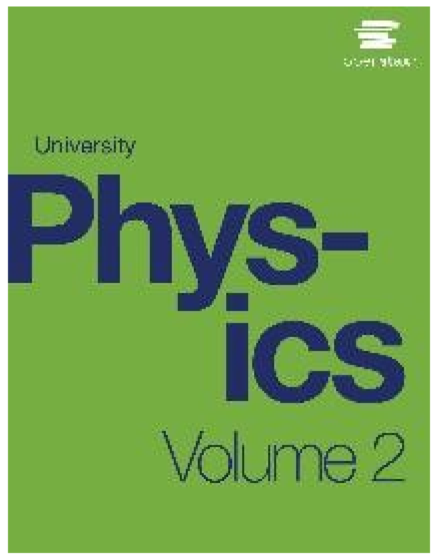
UNIVERSITY PHYSICS

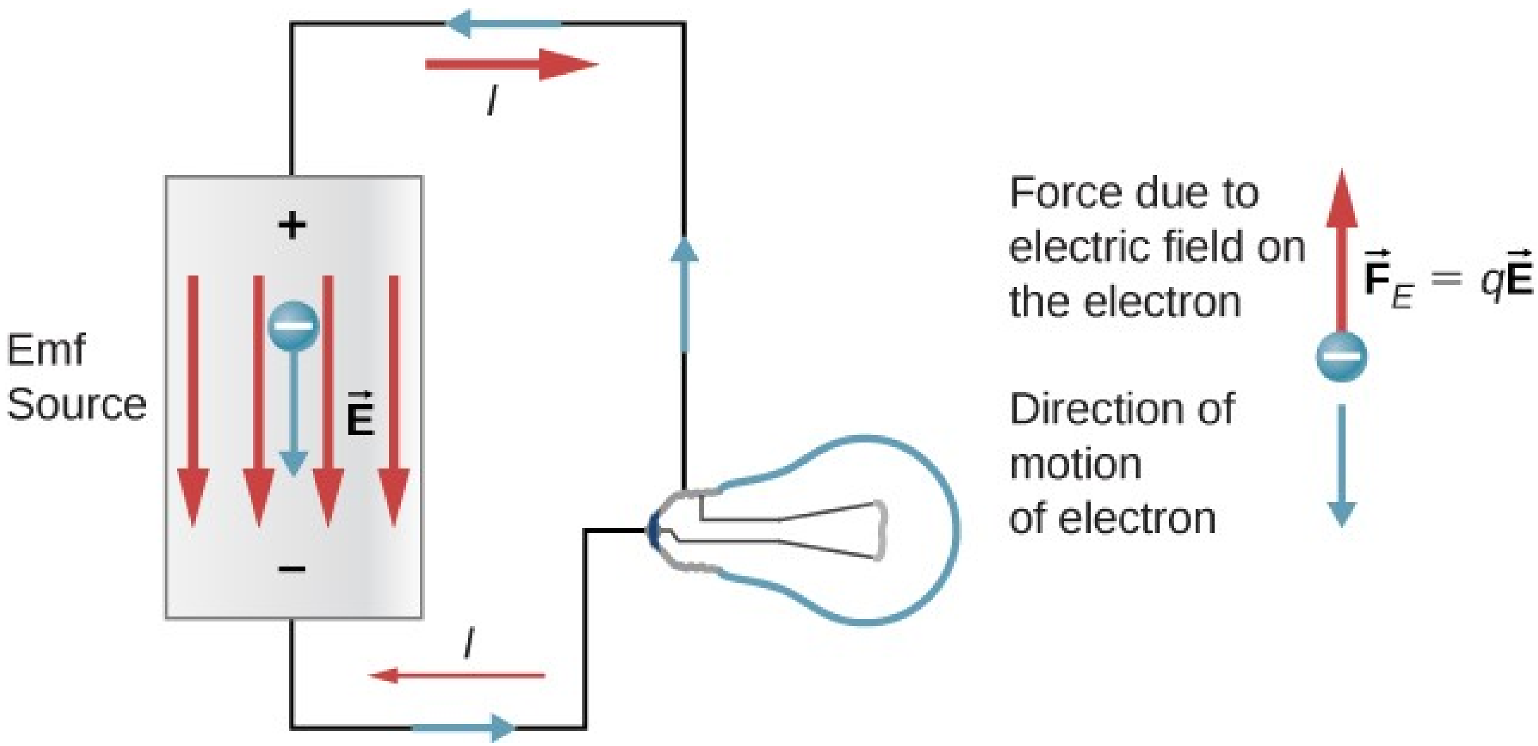
Chapter 10 DIRECT-CURRENT CIRCUITS

PowerPoint Image Slideshow



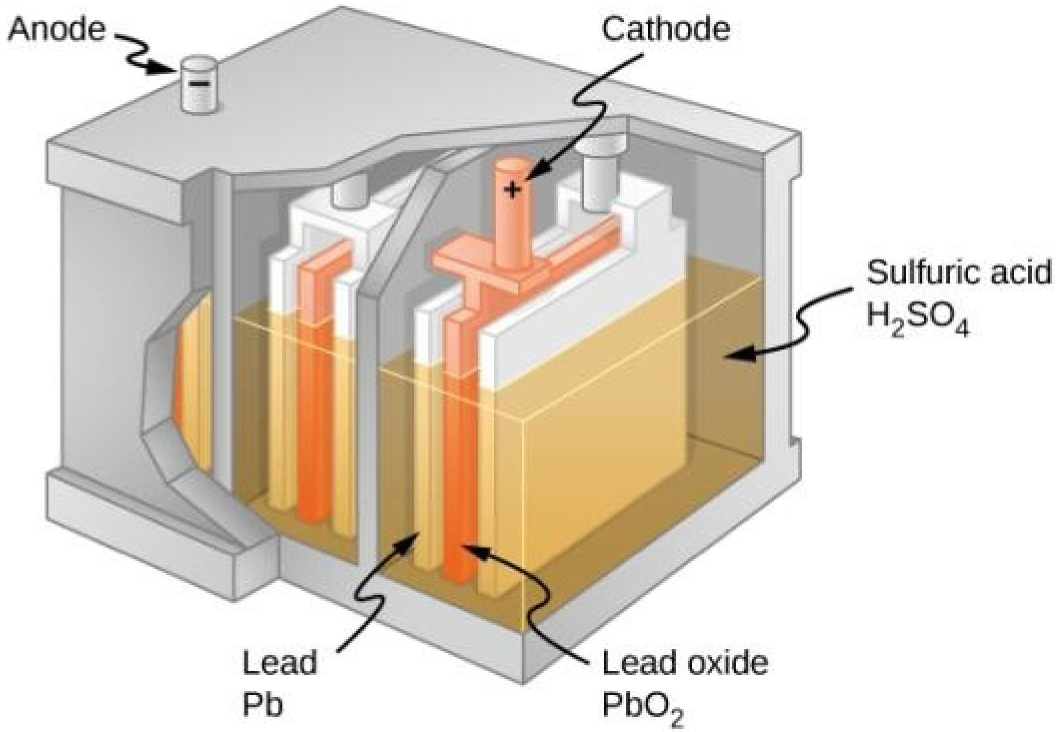
Basic circuits

FIGURE 10.3



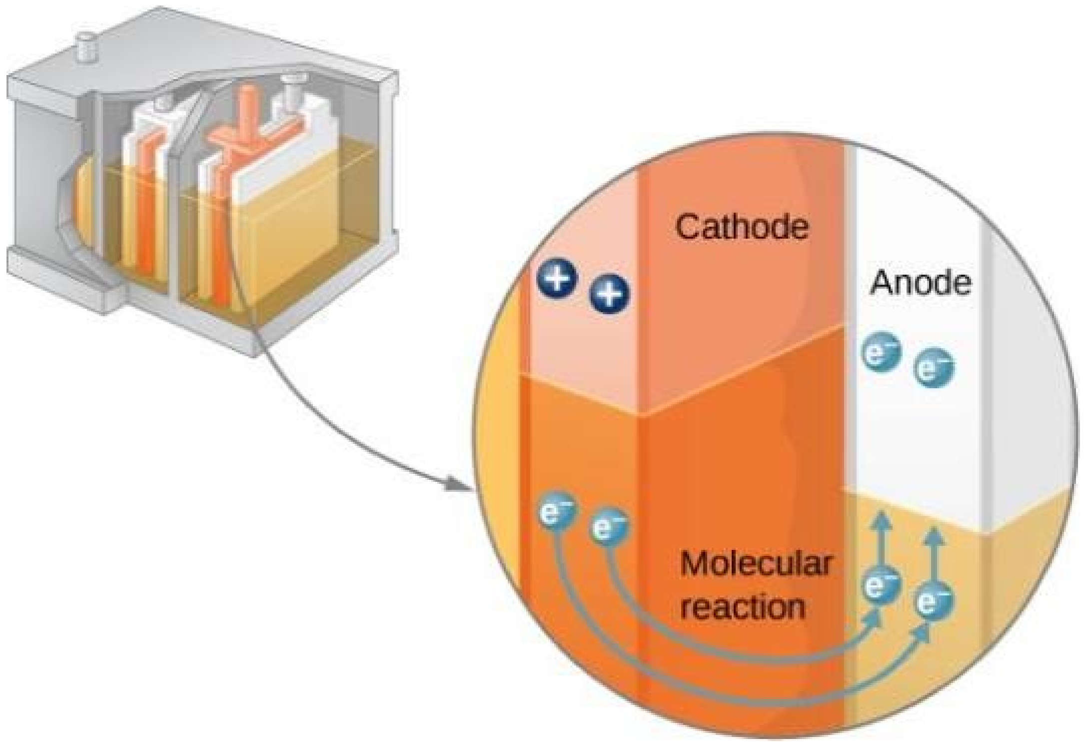
A source of emf maintains one terminal at a higher electric potential than the other terminal, acting as a source of current in a circuit.

FIGURE 10.4



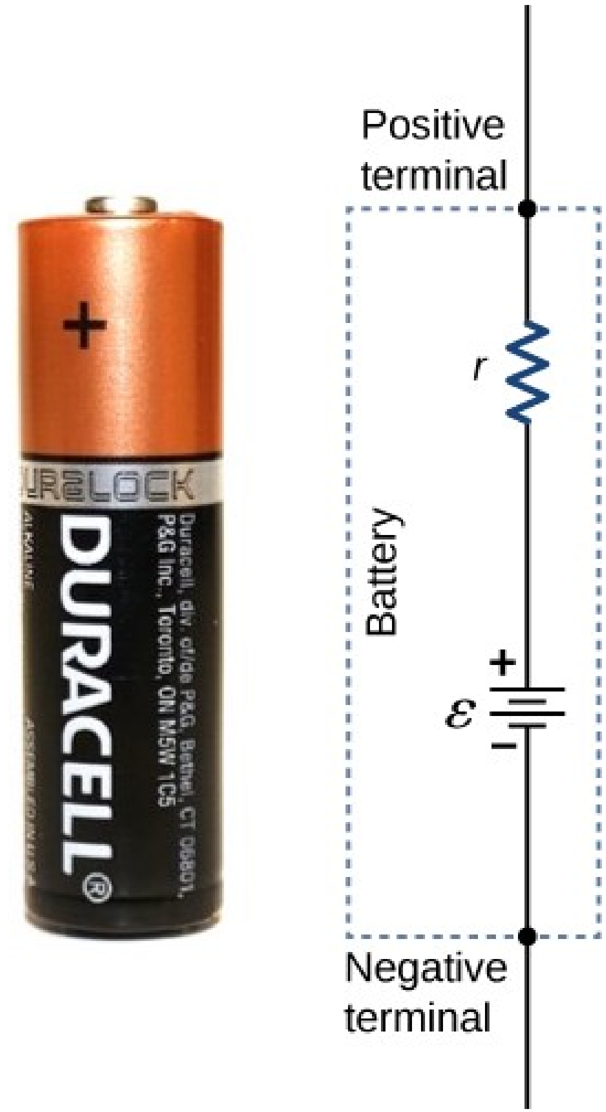
Chemical reactions in a lead-acid cell separate charge, sending negative charge to the anode, which is connected to the lead plates. The lead oxide plates are connected to the positive or cathode terminal of the cell. Sulfuric acid conducts the charge, as well as participates in the chemical reaction.

FIGURE 10.5



In a lead-acid battery, two electrons are forced onto the anode of a cell, and two electrons are removed from the cathode of the cell. The chemical reaction in a lead-acid battery places two electrons on the anode and removes two from the cathode. It requires a closed circuit to proceed, since the two electrons must be supplied to the cathode.

FIGURE 10.6



A battery can be modeled as an idealized emf (ε) with an internal resistance (r). The terminal voltage of the battery is $V_{\text{terminal}} = \varepsilon - Ir$.

FIGURE 10.7

Schematic of a voltage source and its load resistor *R*. Since the internal resistance *r* is in series with the load, it can significantly affect the terminal voltage and the current delivered to the load.

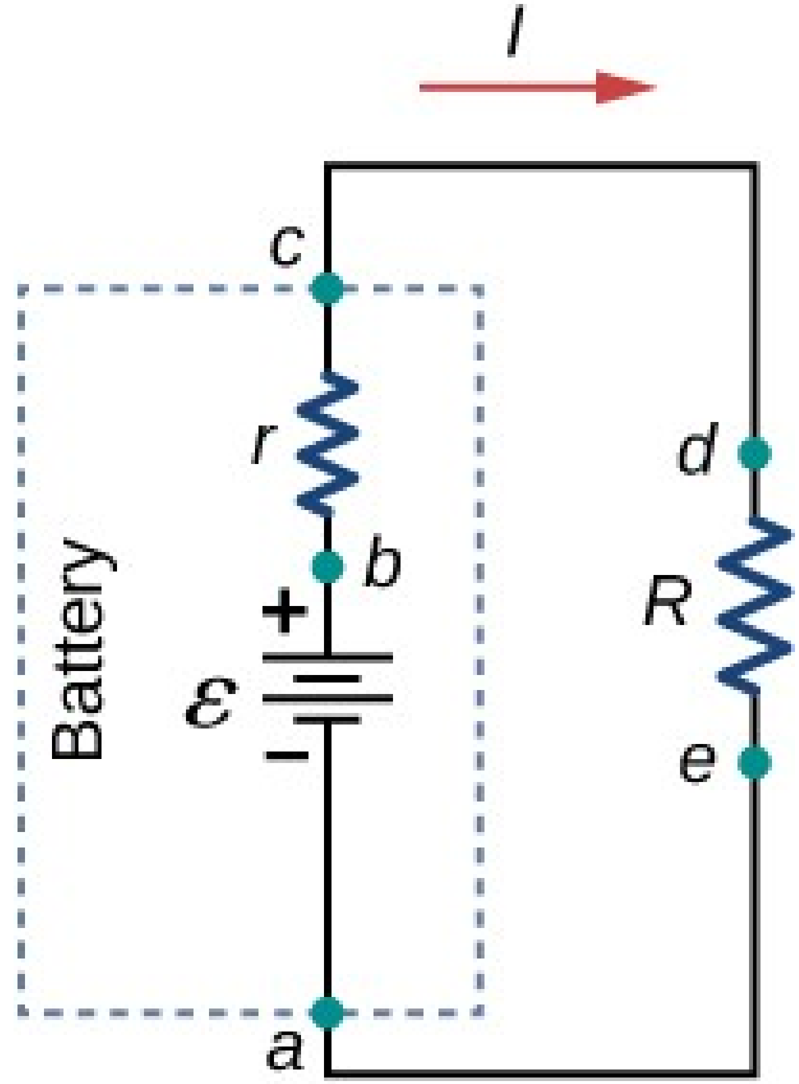
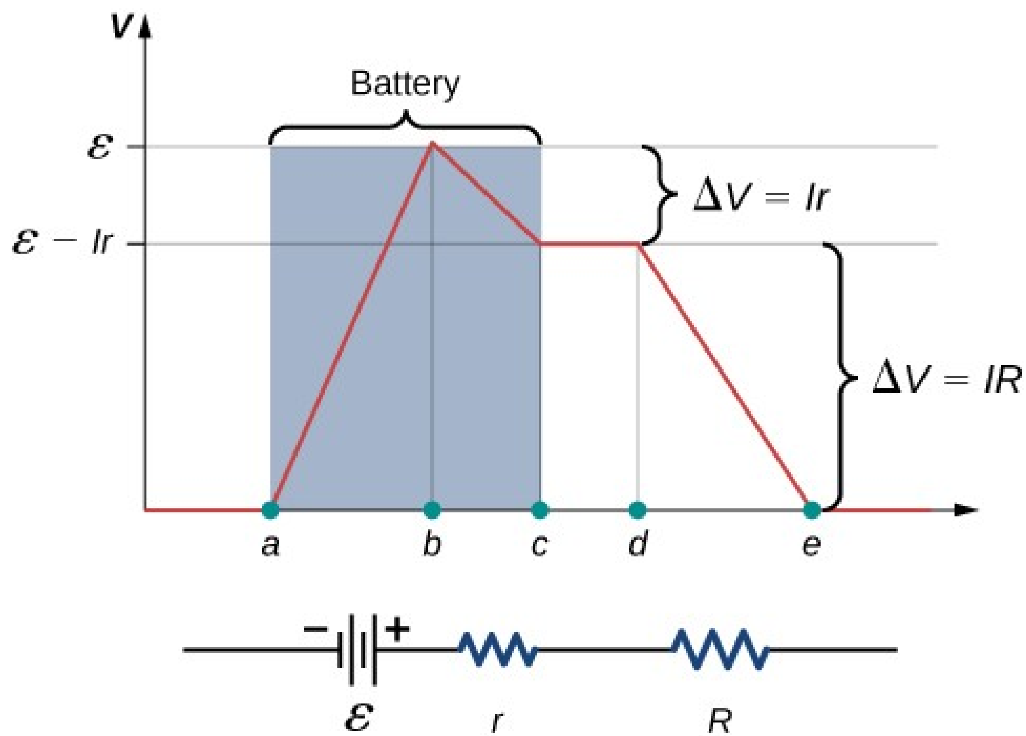
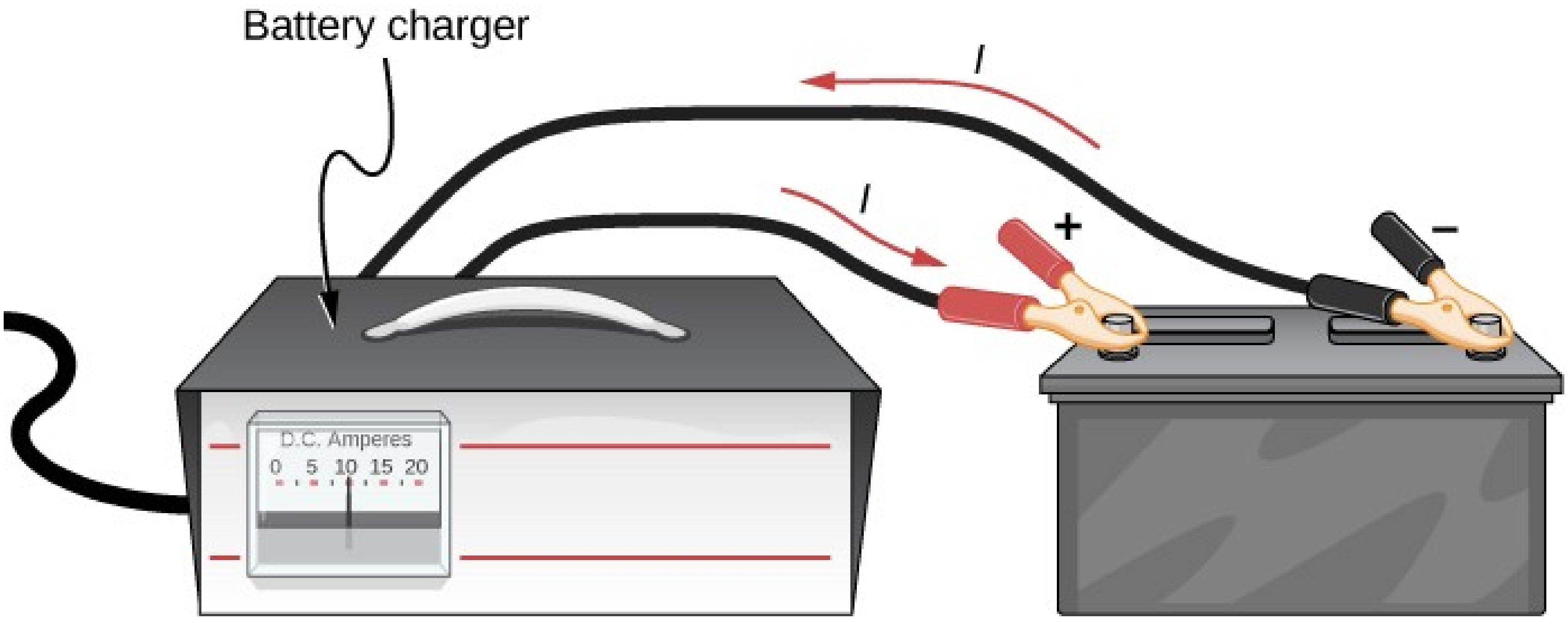


FIGURE 10.8



A graph of the voltage through the circuit of a battery and a load resistance. The electric potential increases the emf of the battery due to the chemical reactions doing work on the charges. There is a decrease in the electric potential in the battery due to the internal resistance. The potential decreases due to the internal resistance ($-Ir$) making the terminal voltage of the battery equal to ($- Ir$). The voltage then decreases by (IR). The current is equal to I .

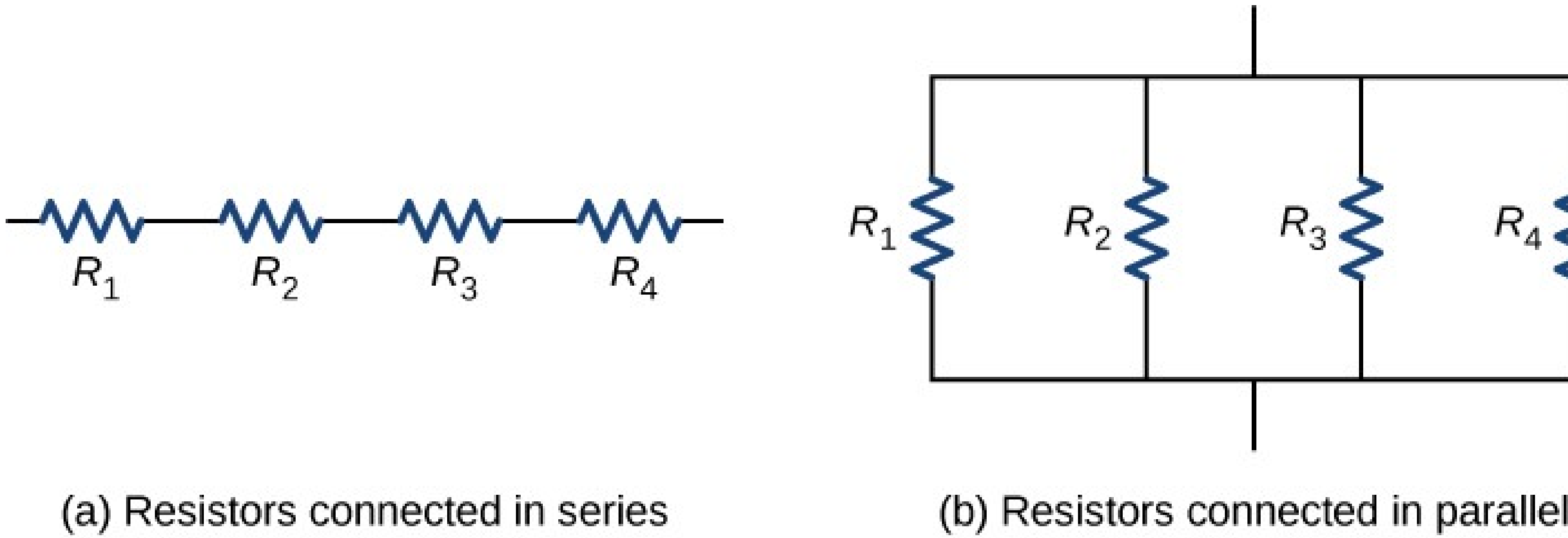
FIGURE 10.10



A car battery charger reverses the normal direction of current through a battery, reversing its chemical reaction and replenishing its chemical potential.

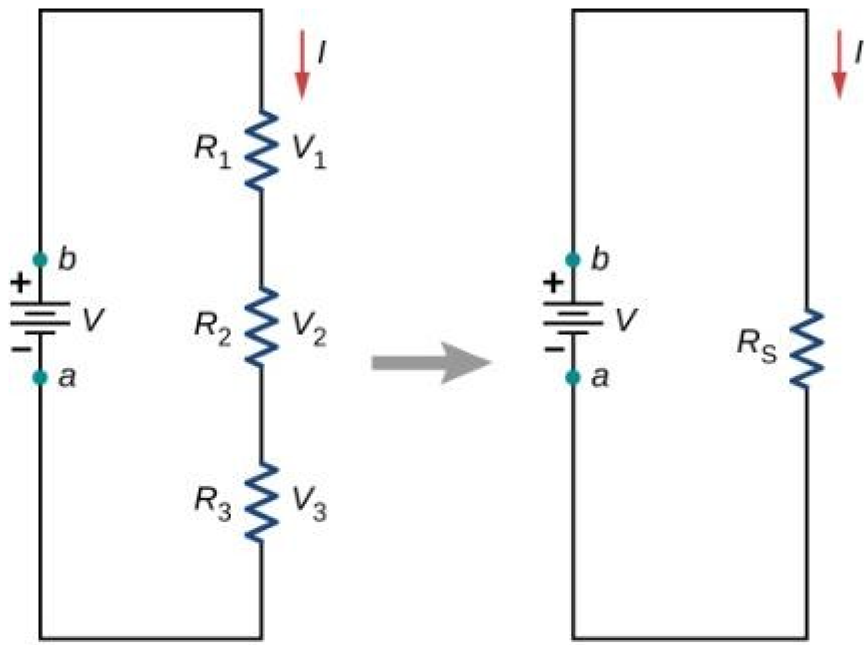
Calculating equivalent circuits - examples

FIGURE 10.11



a) For a series connection of resistors, the current is the same in each resistor.
b) For a parallel connection of resistors, the voltage is the same across each resistor.

FIGURE 10.12



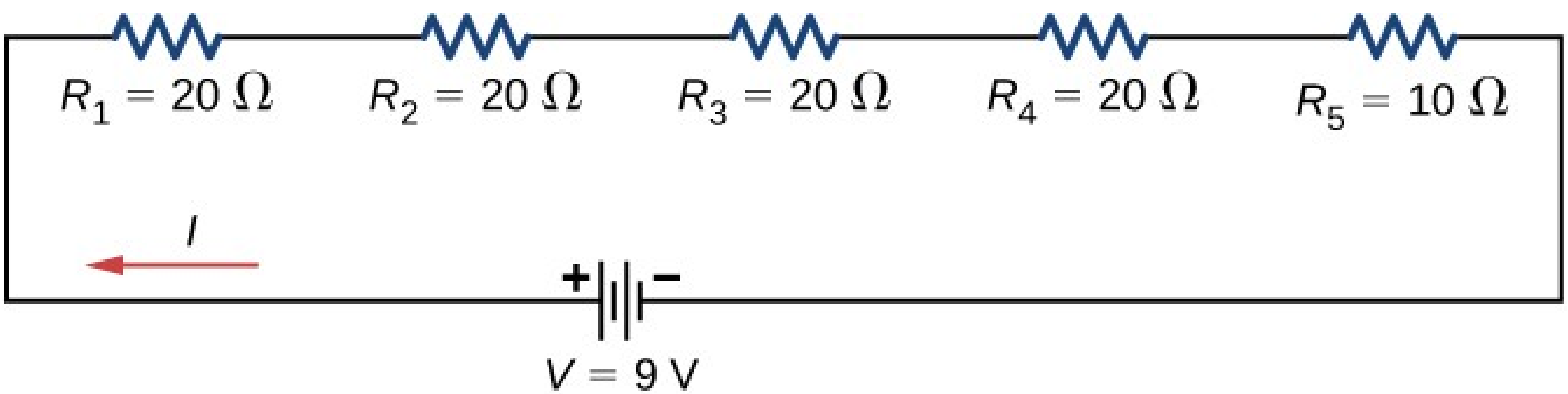
(a) Original circuit

(b) Equivalent circuit

a) Three resistors connected in series to a voltage source.

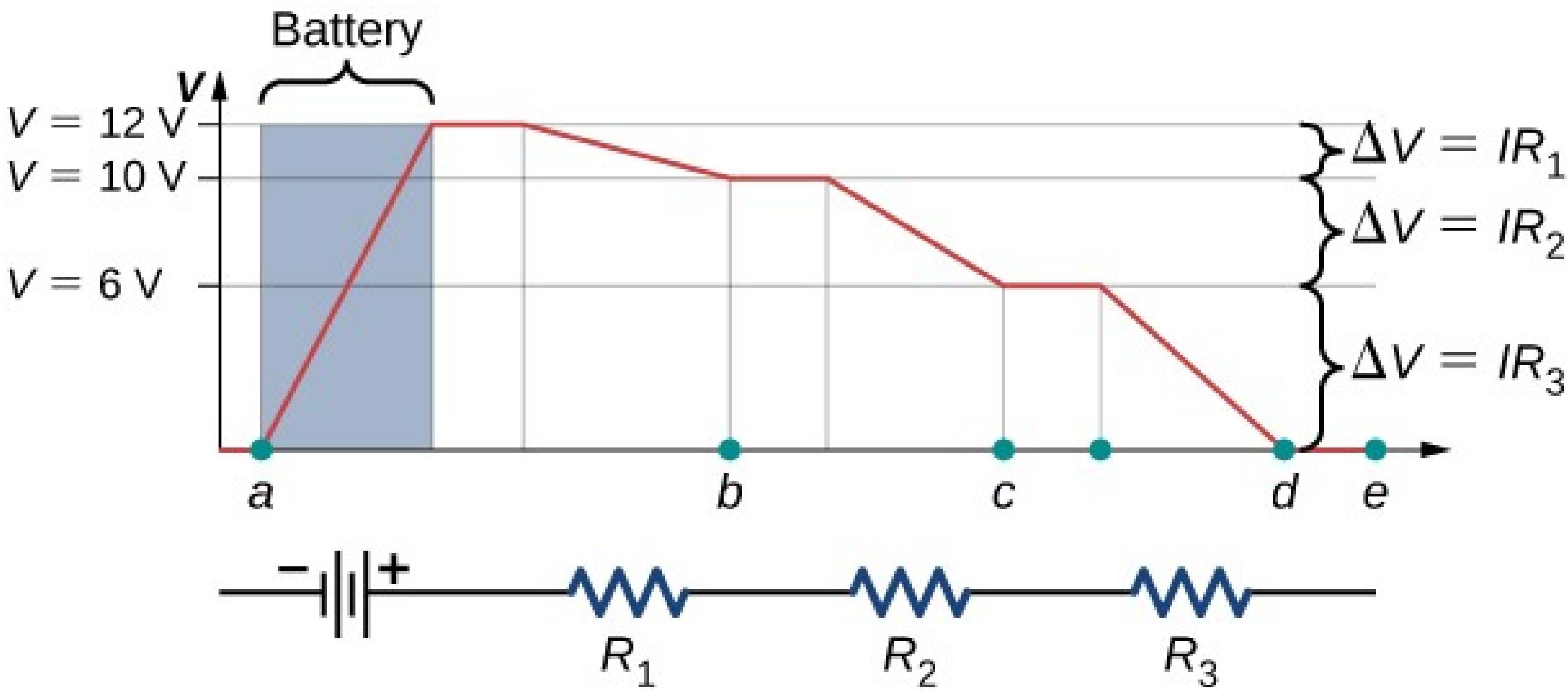
b) The original circuit is reduced to an equivalent resistance and a voltage source.

FIGURE 10.13



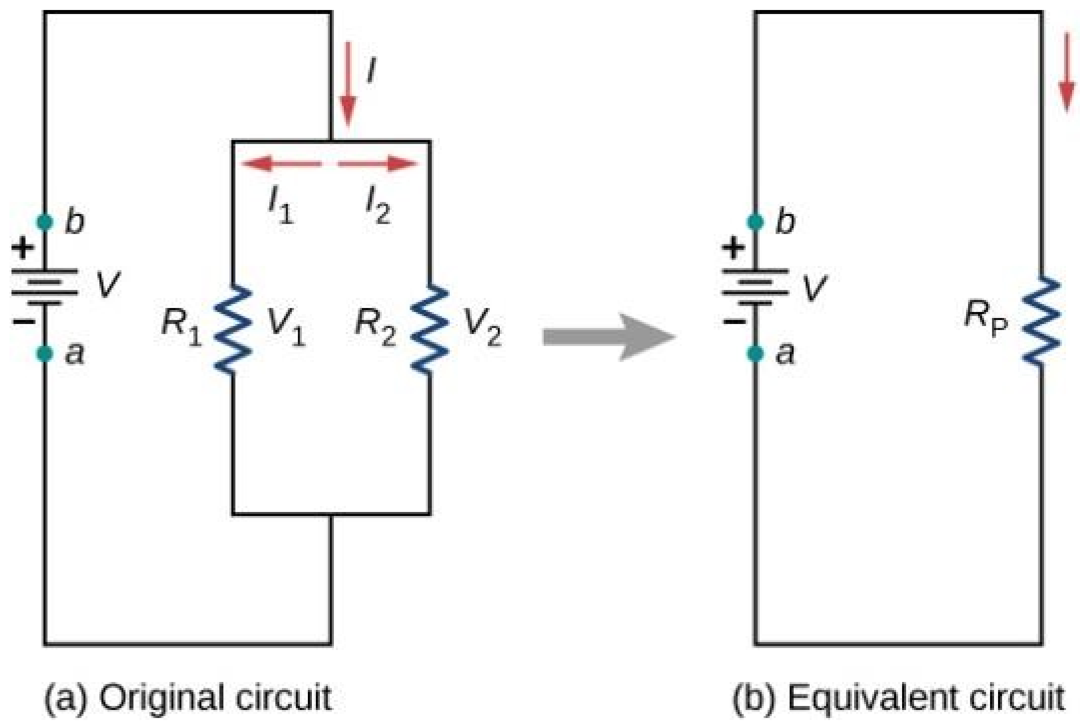
A simple series circuit with five resistors.

FIGURE 10.22



A voltage graph as we travel around the circuit. The voltage increases as we cross the battery and decreases as we cross each resistor. Since the resistance of the wire is quite small, we assume that the voltage remains constant as we cross the wires connecting the components.

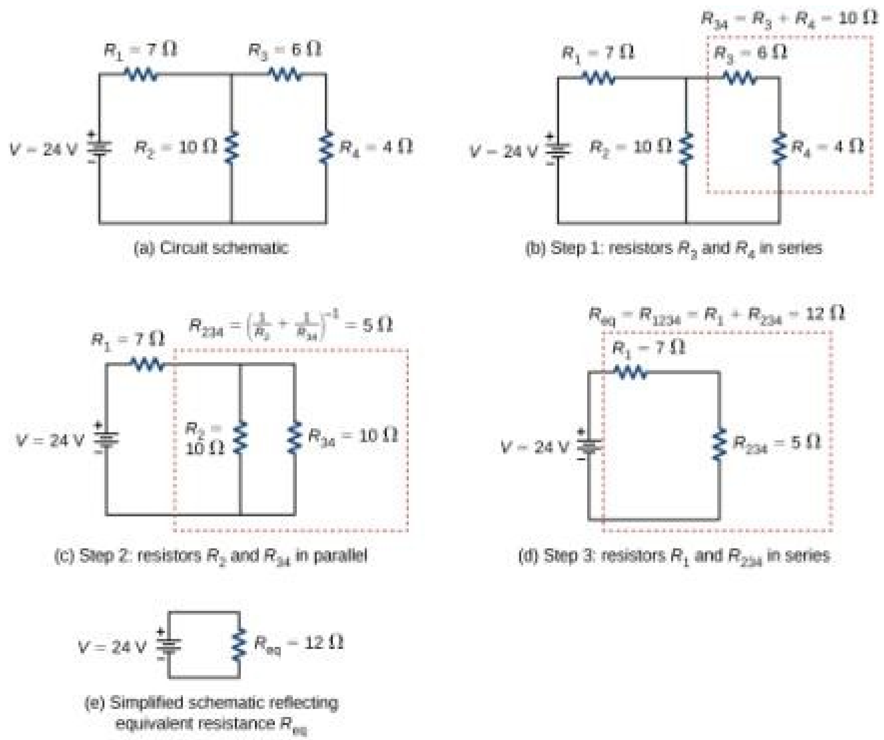
FIGURE 10.14



a) Two resistors connected in parallel to a voltage source.

b) The original circuit is reduced to an equivalent resistance and a voltage source.

FIGURE 10.15



a) The original circuit of four resistors.

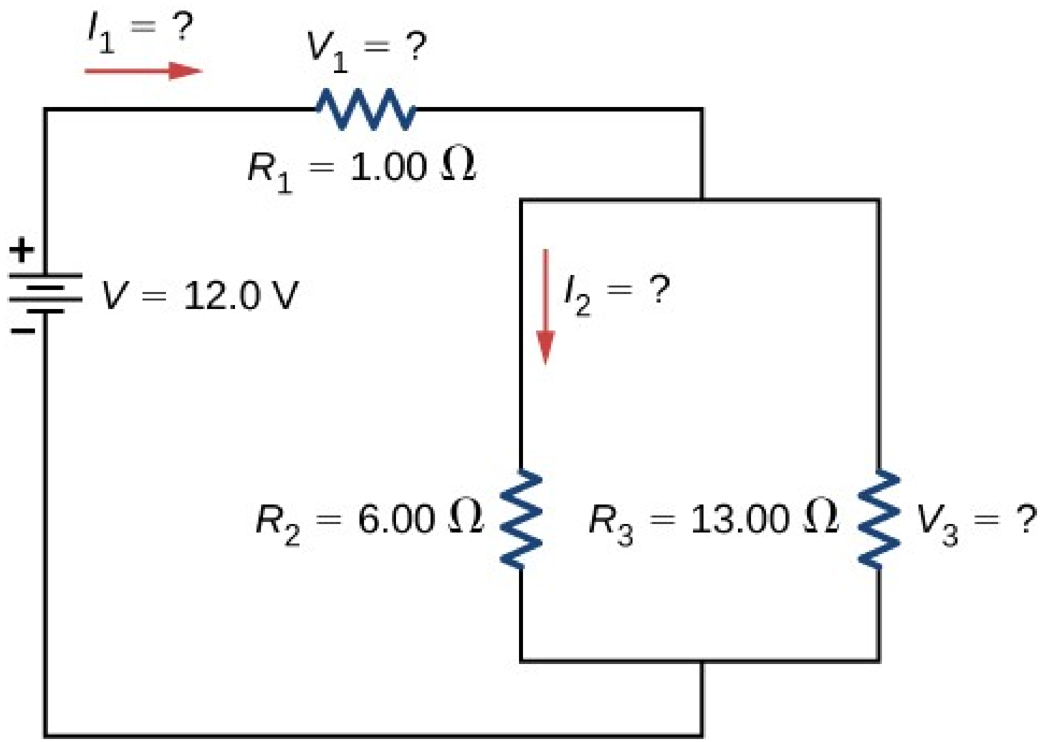
b) Step 1: The resistors R_3 and R_4 are in series and the equivalent resistance is $R_{34} = 10\ \Omega$.

c) Step 2: The reduced circuit shows resistors R_2 and R_{34} are in parallel, with an equivalent resistance of $R_{234} = 5\ \Omega$.

d) Step 3: The reduced circuit shows that R_1 and R_{234} are in series with an equivalent resistance of $R_{1234} = 12\Omega$, which is the equivalent resistance R_{eq}.

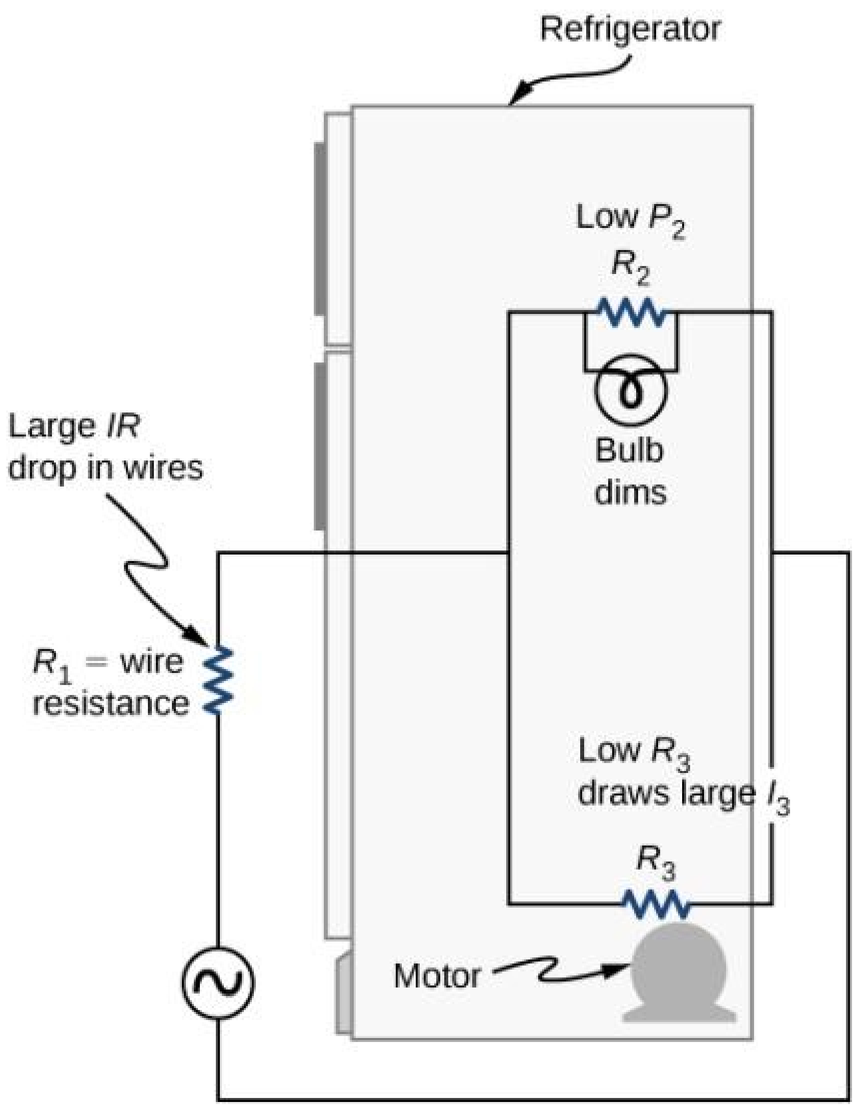
e) The reduced circuit with a voltage source of $V = 24$ V with an equivalent resistance of $R_{eq} = 12\ \Omega$. This results in a current of $I = 2$ A from the voltage source.

FIGURE 10.16



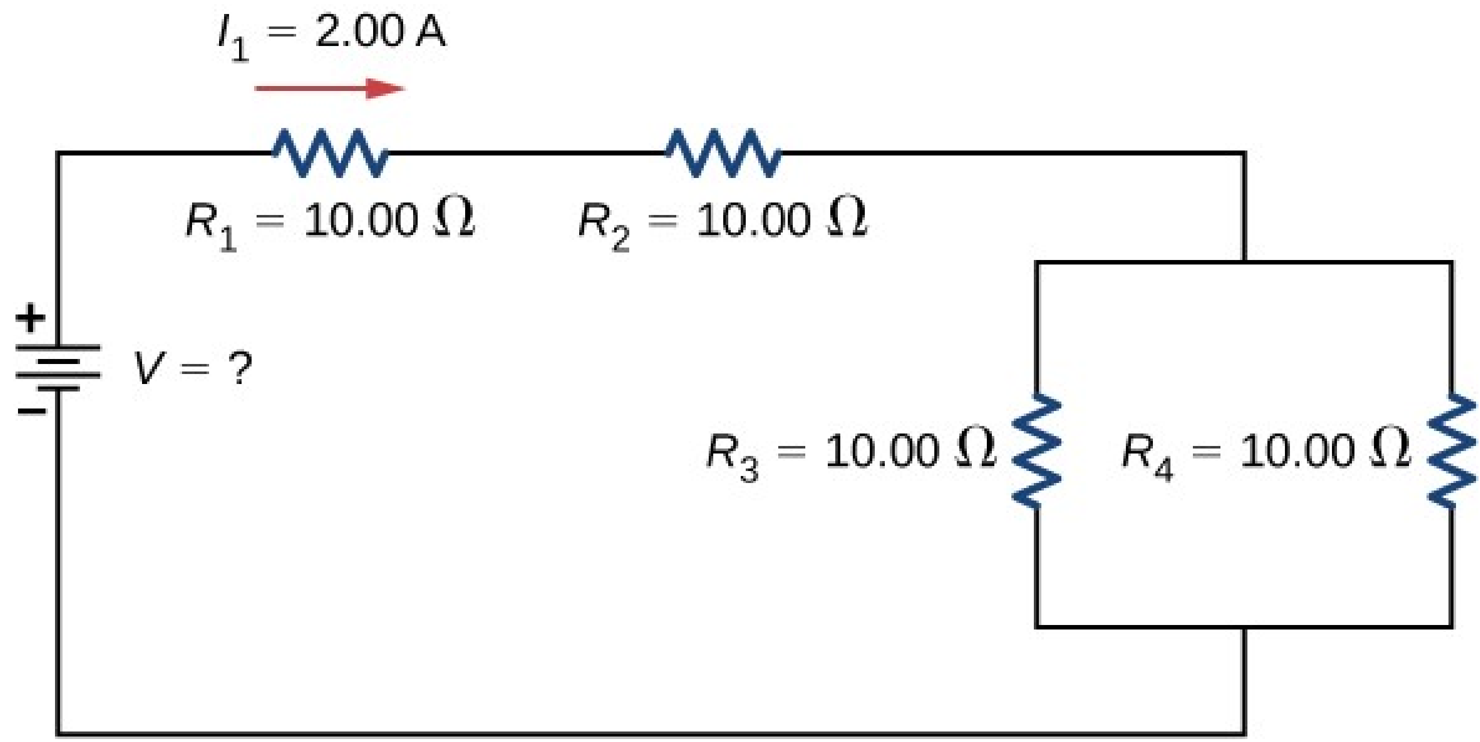
These three resistors are connected to a voltage source so that R_2 and R_3 are in parallel with one another and that combination is in series with R_1.

FIGURE 10.17



Why do lights dim when a large appliance is switched on? The answer is that the large current the appliance motor draws causes a significant *IR* drop in the wires and reduces the voltage across the light.

FIGURE 10.18



To find the unknown voltage, we must first find the equivalent resistance of the circuit.

Kirchoff’s rules

FIGURE 10.19

This circuit cannot be reduced to a combination of series and parallel connections. However, we can use Kirchhoff's rules to analyze it.

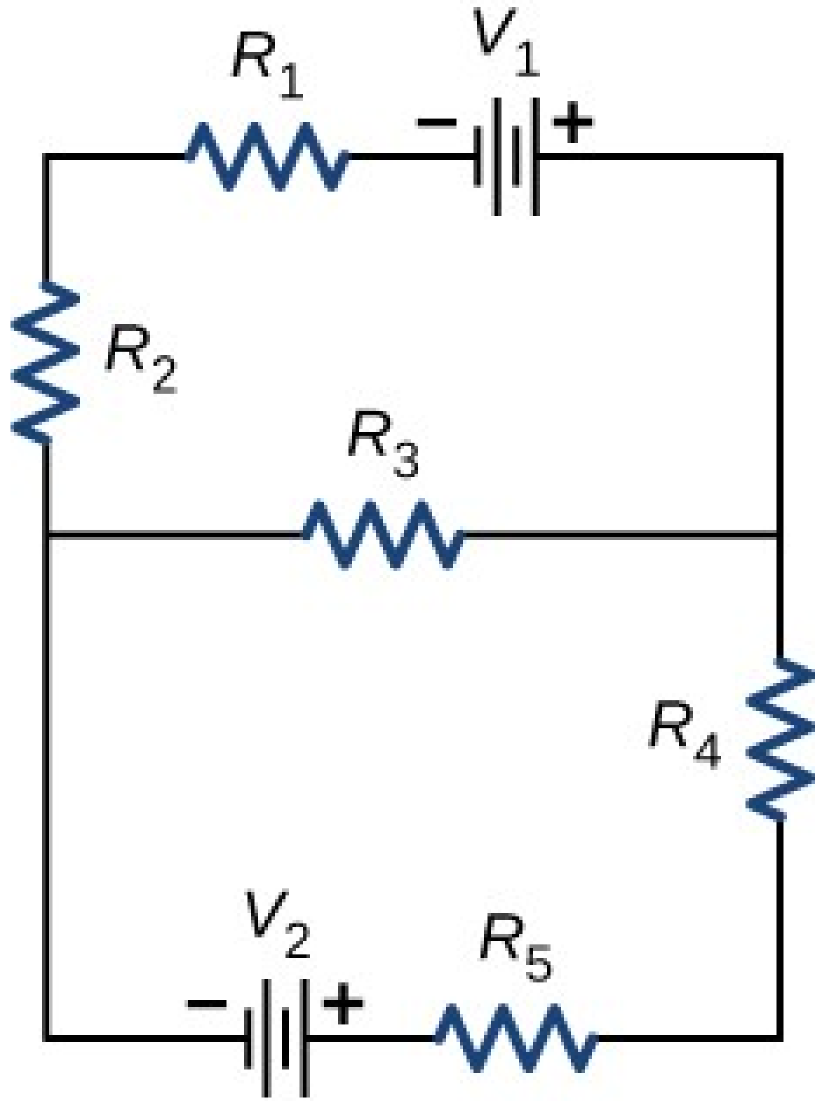
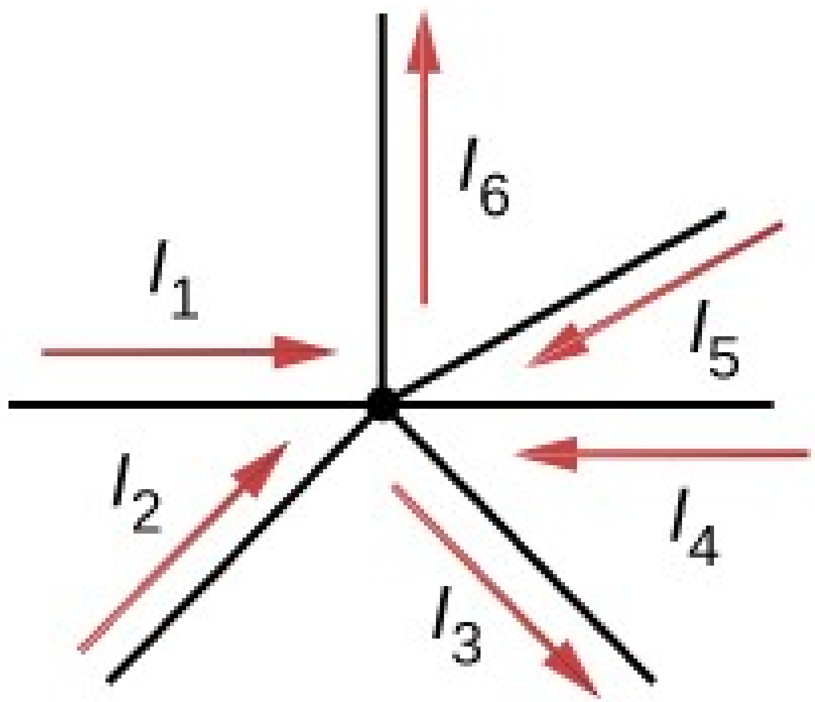


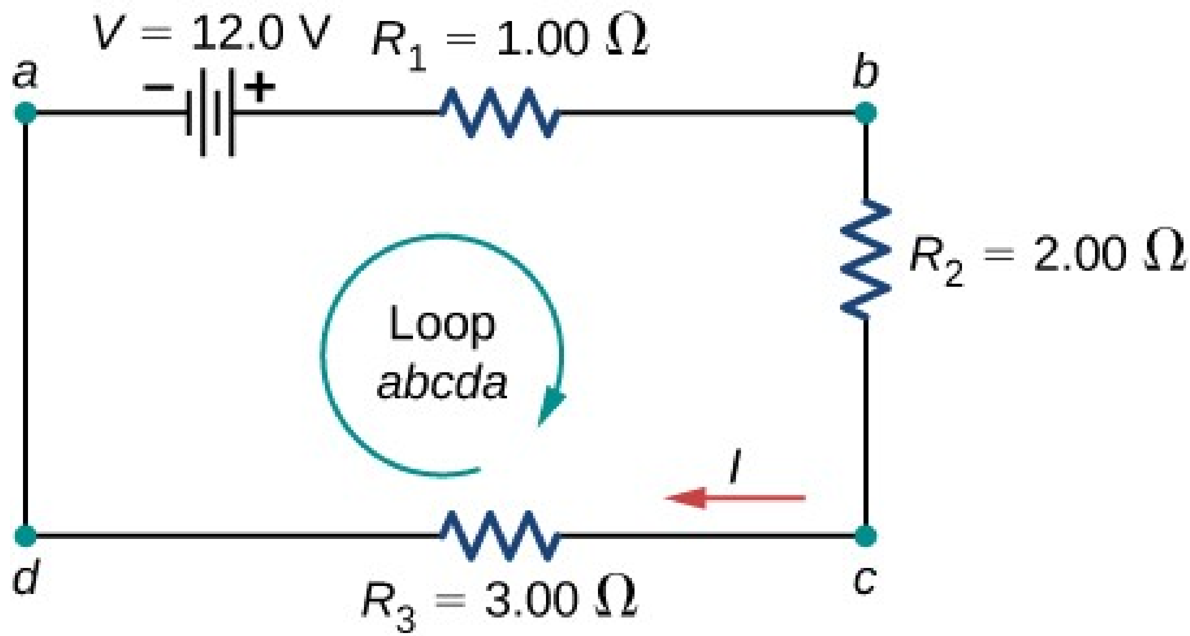
FIGURE 10.20



$$\sum I_{in} = \sum I_{out}$$
$$I_1 + I_2 + I_4 + I_5 = I_3 + I_6$$

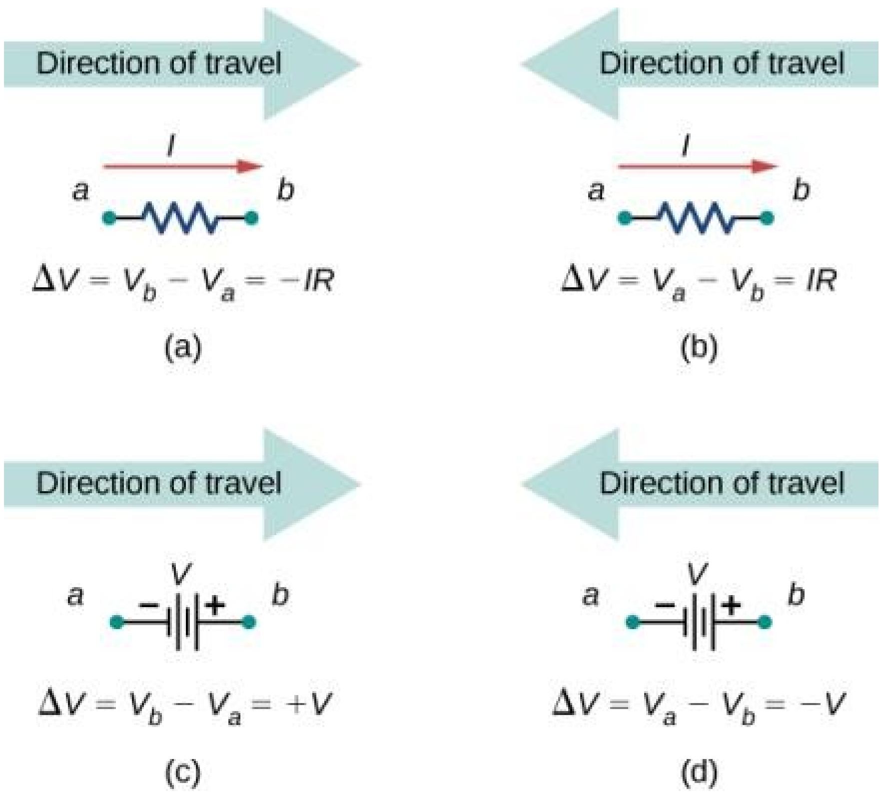
Charge must be conserved, so the sum of currents into a junction must be equal to the sum of currents out of the junction.

FIGURE 10.21



A simple loop with no junctions. Kirchhoff's loop rule states that the algebraic sum of the voltage differences is equal to zero.

FIGURE 10.23



Each of these resistors and voltage sources is traversed from *a* to *b*.

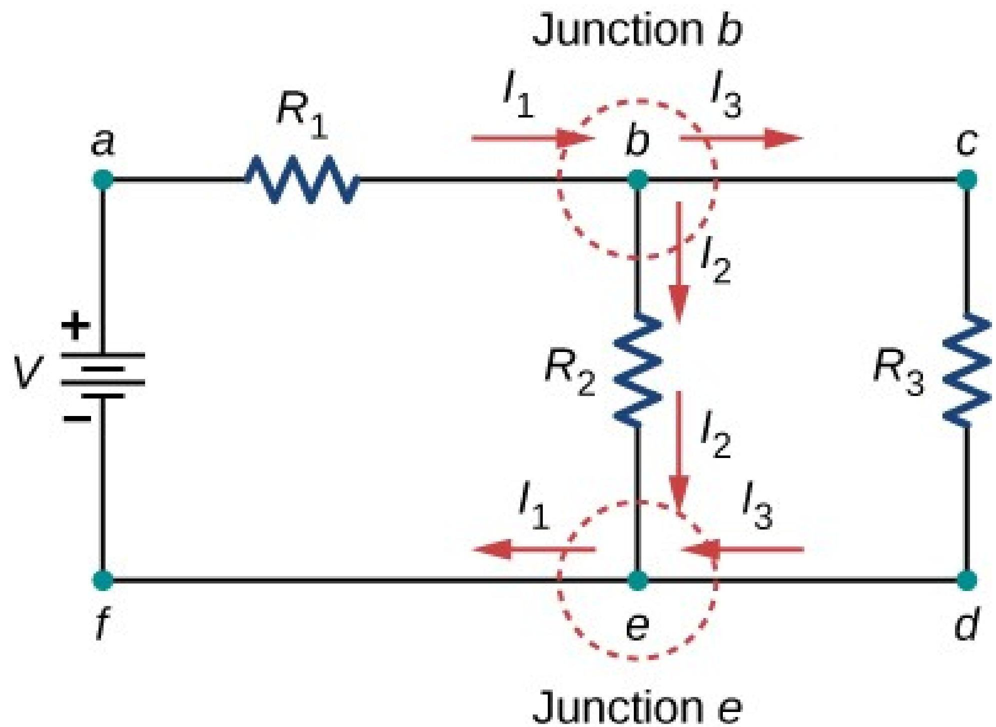
a) When moving across a resistor in the same direction as the current flow, subtract the potential drop.

b) When moving across a resistor in the opposite direction as the current flow, add the potential drop.

c) When moving across a voltage source from the negative terminal to the positive terminal, add the potential drop.

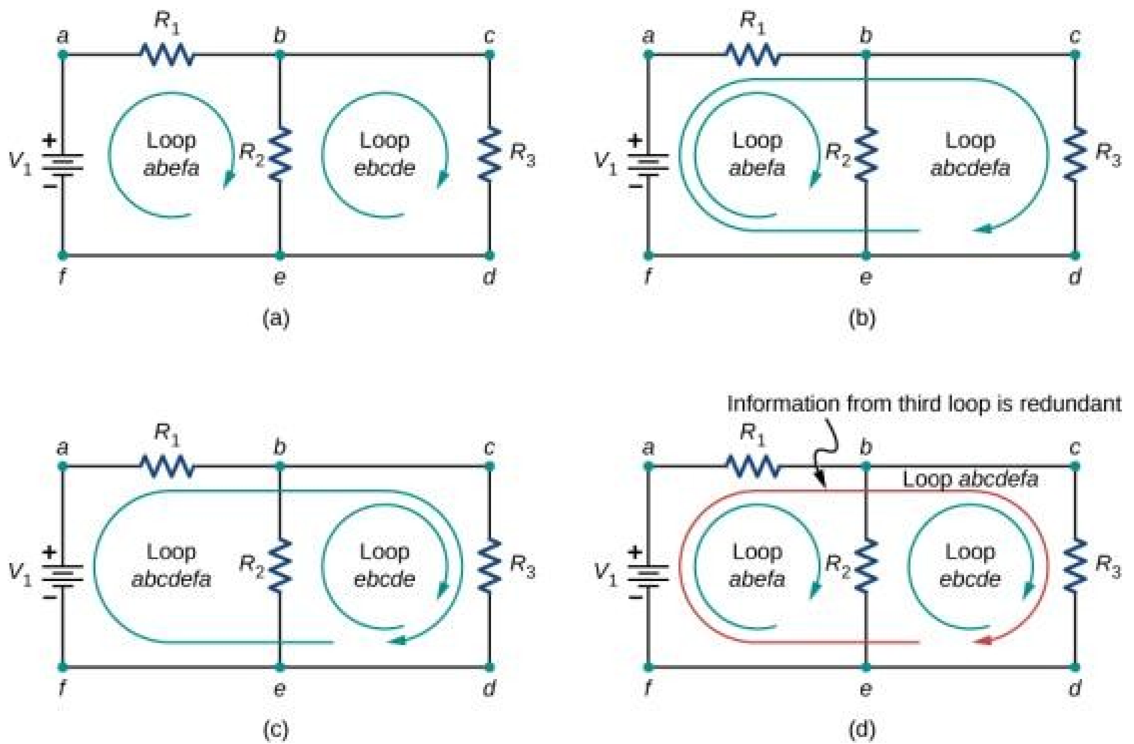
d) When moving across a voltage source from the positive terminal to the negative terminal, subtract the potential drop.

FIGURE 10.24



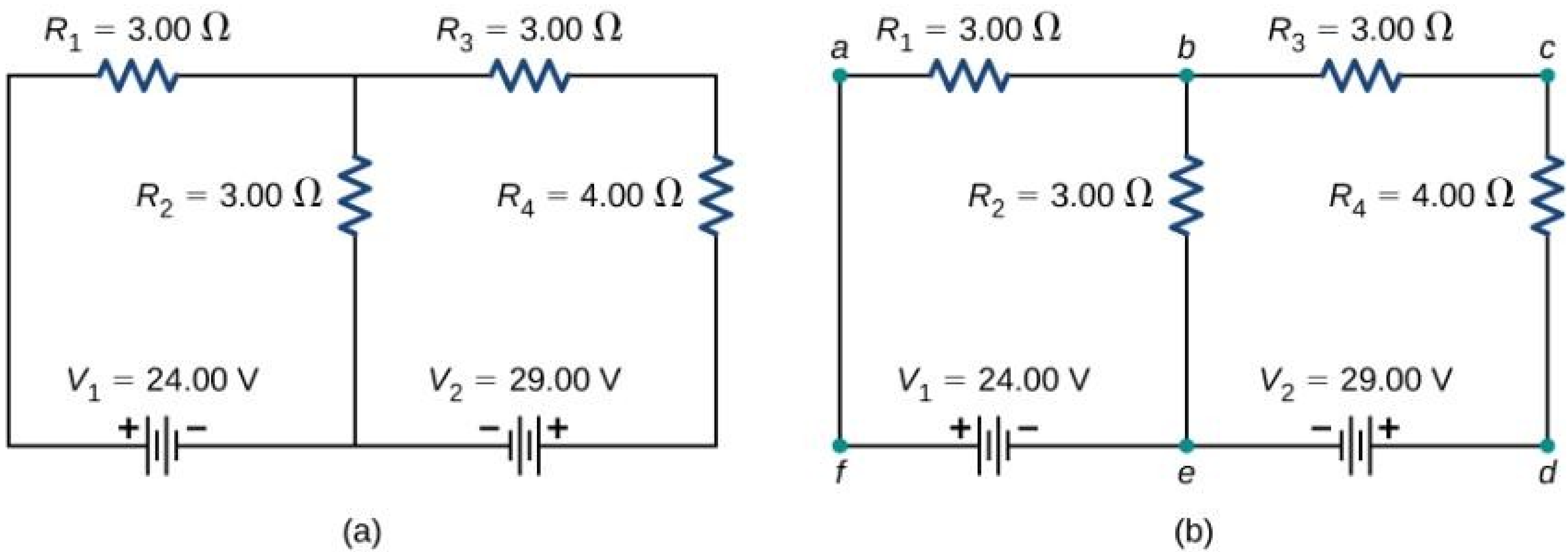
At first glance, this circuit contains two junctions, Junction *b* and Junction *e*, but only one should be considered because their junction equations are equivalent.

FIGURE 10.25



Panels (a)–(c) are sufficient for the analysis of the circuit. In each case, the two loops shown contain all the circuit elements necessary to solve the circuit completely. Panel (d) shows three loops used, which is more than necessary. Any two loops in the system will contain all information needed to solve the circuit. Adding the third loop provides redundant information.

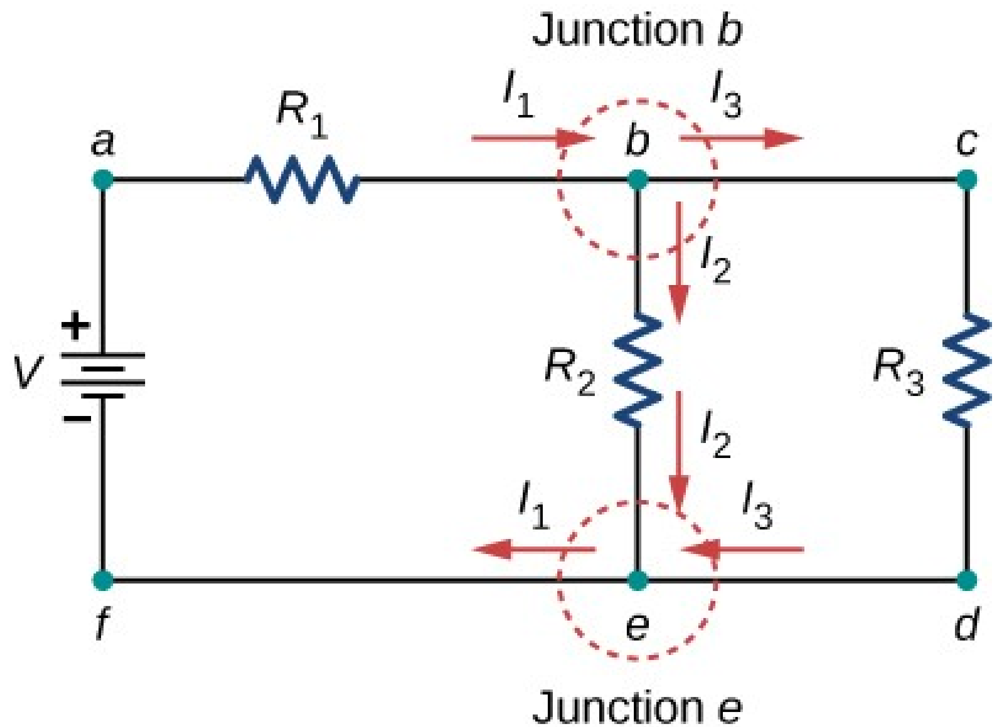
FIGURE 10.26



a) A multi-loop circuit.

b) Label the circuit to help with orientation.

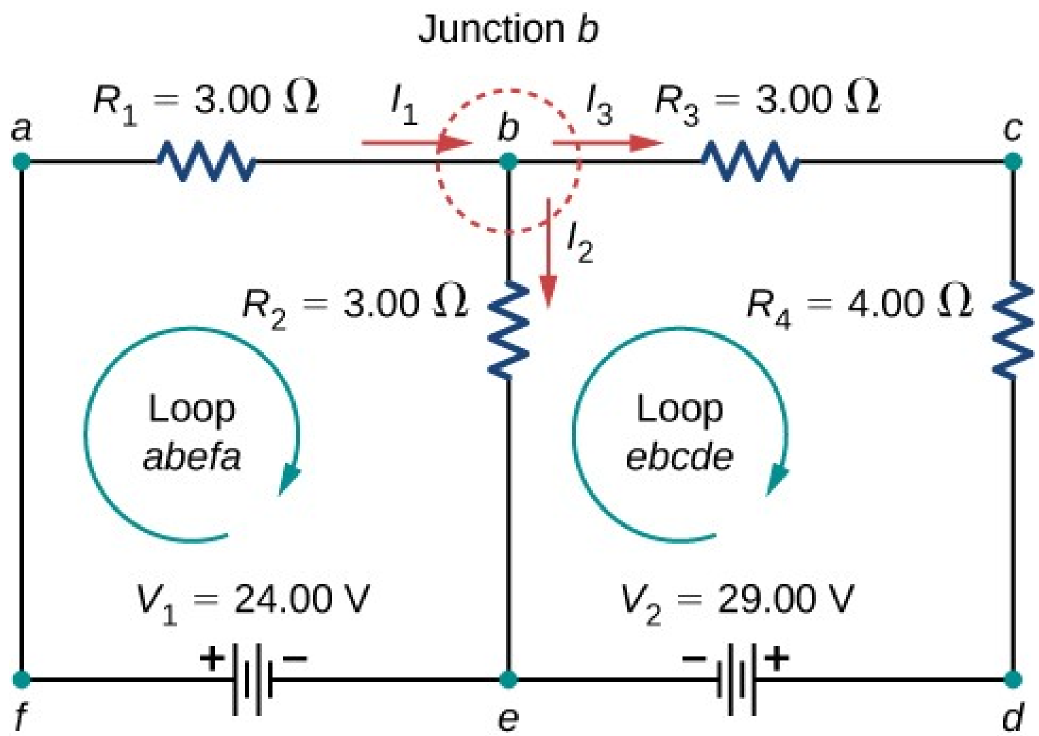
FIGURE 10.27



a) This circuit has two junctions, labeled *b* and *e*, but only node *b* is used in the analysis.

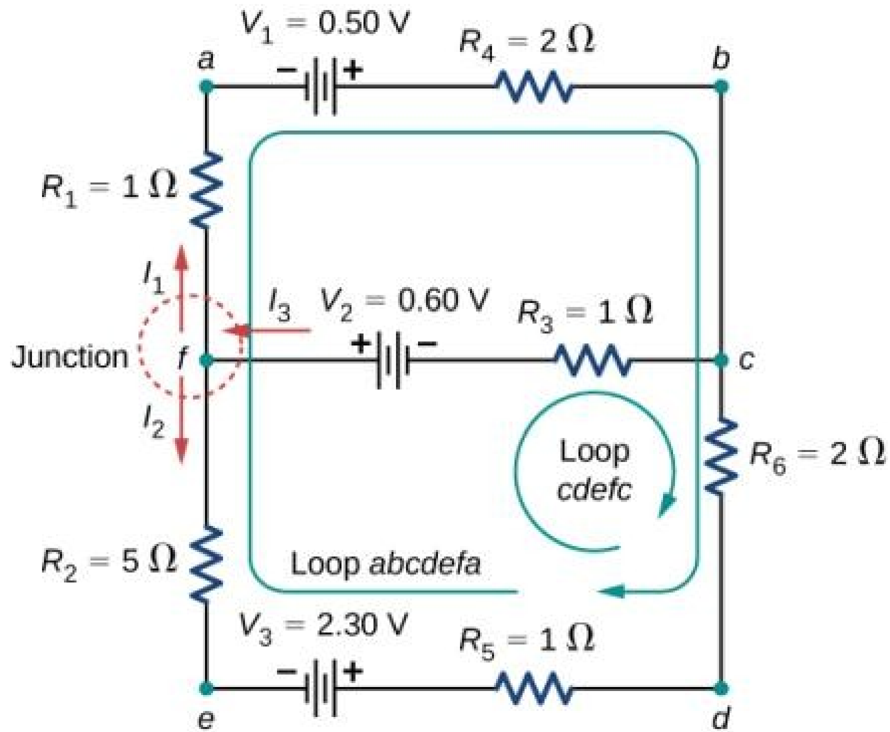
b) Labeled arrows represent the currents into and out of the junctions.

FIGURE 10.28



Choose the loops in the circuit.

FIGURE 10.29



This circuit is combination of series and parallel configurations of resistors and voltage sources. This circuit cannot be analyzed using the techniques discussed in **Electromotive Force** but can be analyzed using Kirchhoff's rules.

RC Circuits

FIGURE 10.38

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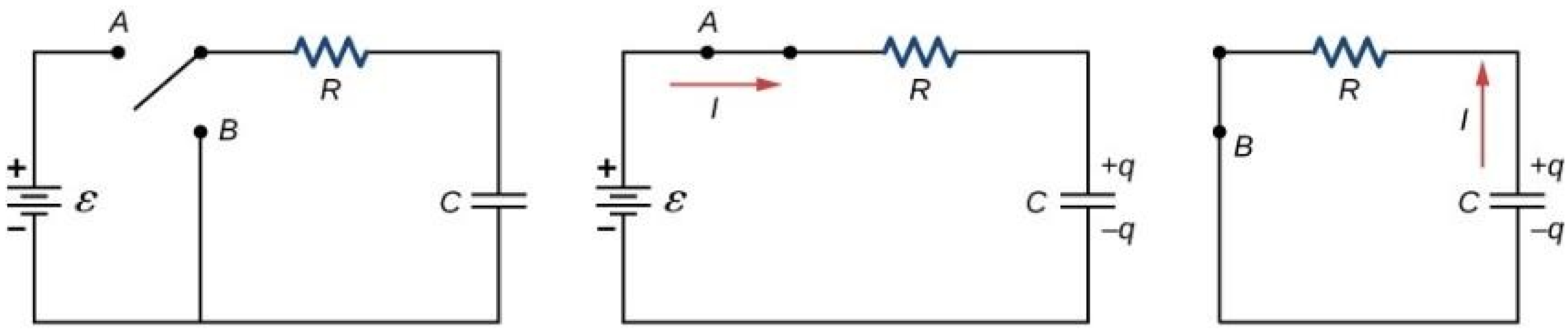


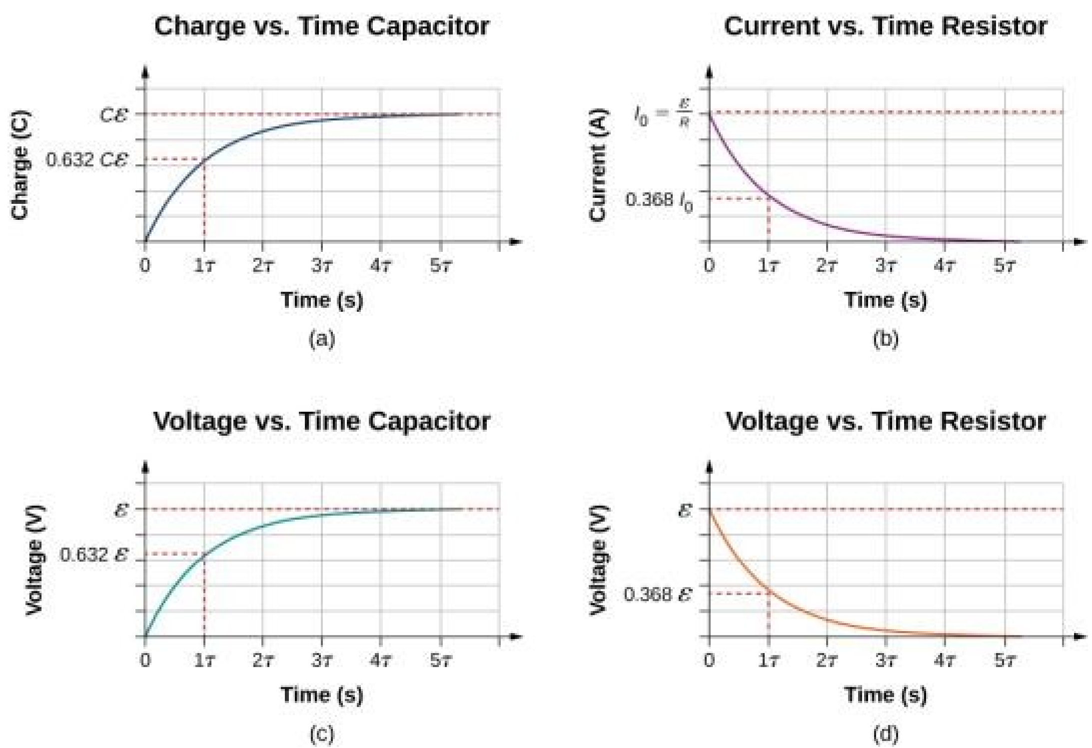
(a) Original circuit (b) Charging capacitor (c) Discharging capacitor

a) An *RC* circuit with a two-pole switch that can be used to charge and discharge a capacitor.

b) When the switch is moved to position *A*, the circuit reduces to a simple series connection of the voltage source, the resistor, the capacitor, and the switch.

c) When the switch is moved to position *B*, the circuit reduces to a simple series connection of the resistor, the capacitor, and the switch. The voltage source is removed from the circuit.

FIGURE 10.39



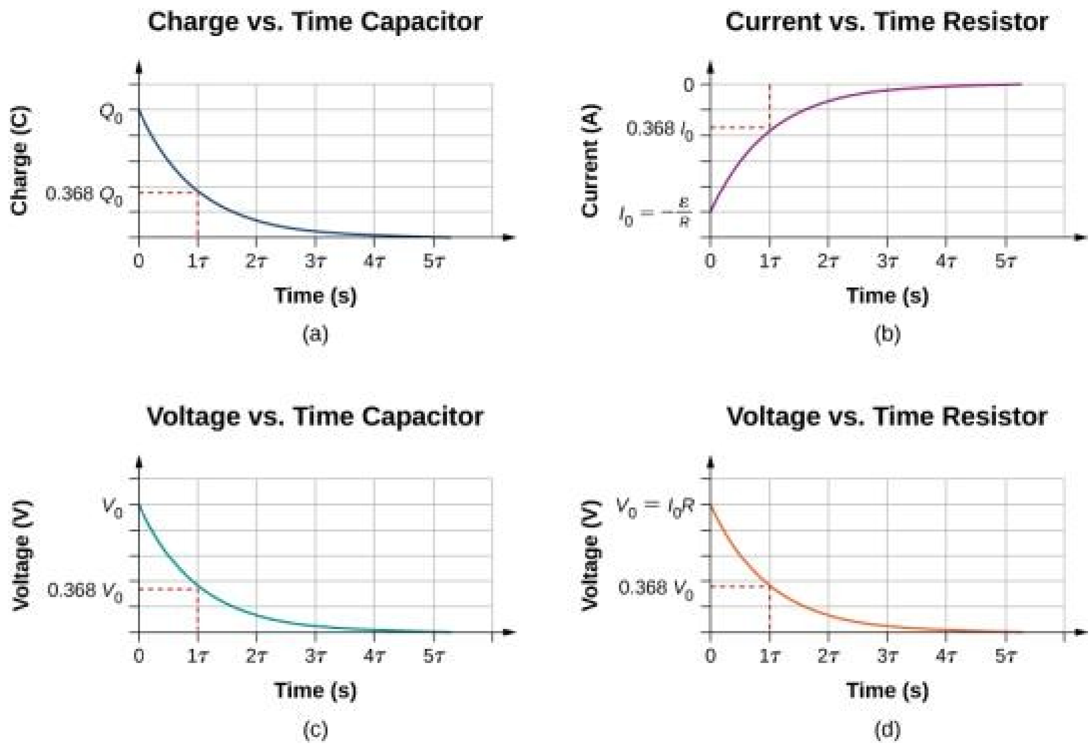
a) Charge on the capacitor versus time as the capacitor charges.

b) Current through the resistor versus time.

c) Voltage difference across the capacitor.

d) Voltage difference across the resistor.

FIGURE 10.40



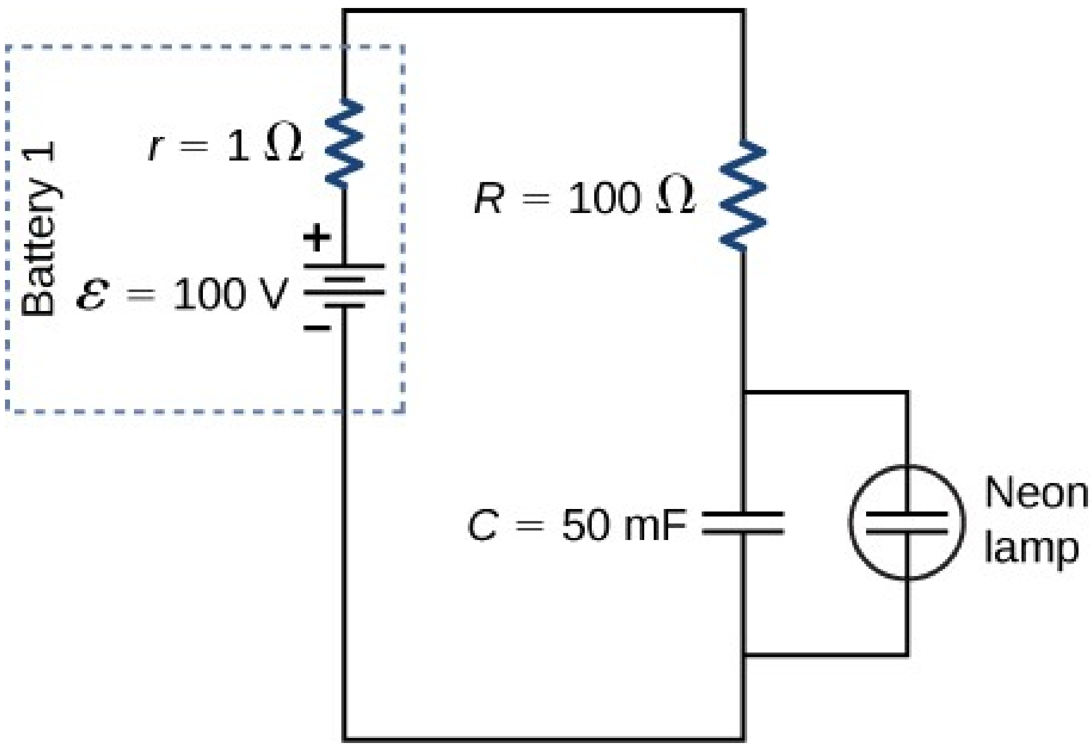
a) Charge on the capacitor versus time as the capacitor discharges.

b) Current through the resistor versus time.

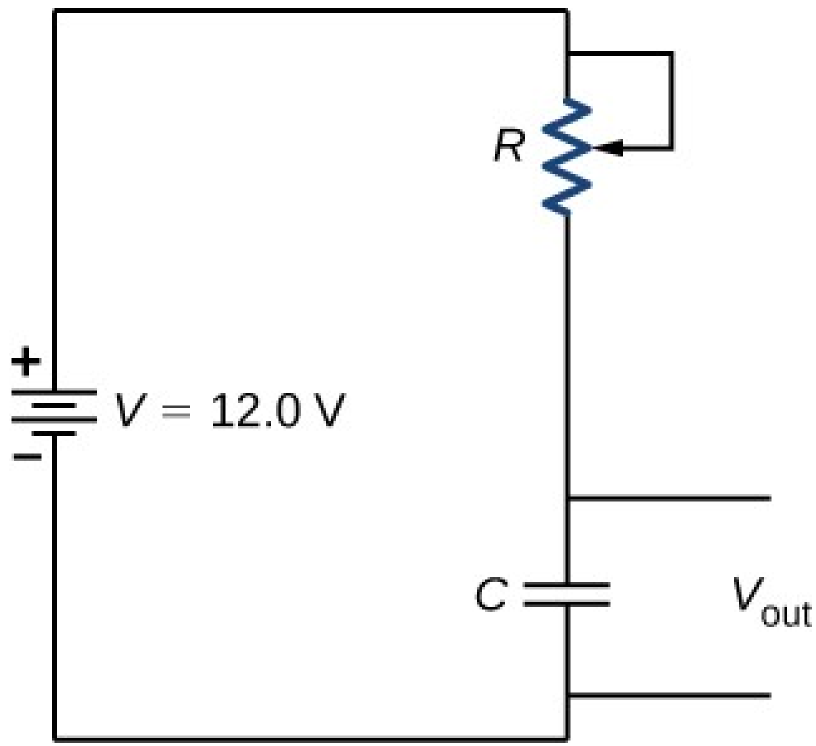
c) Voltage difference across the capacitor.

d) Voltage difference across the resistor.

EXAMPLE 10.8

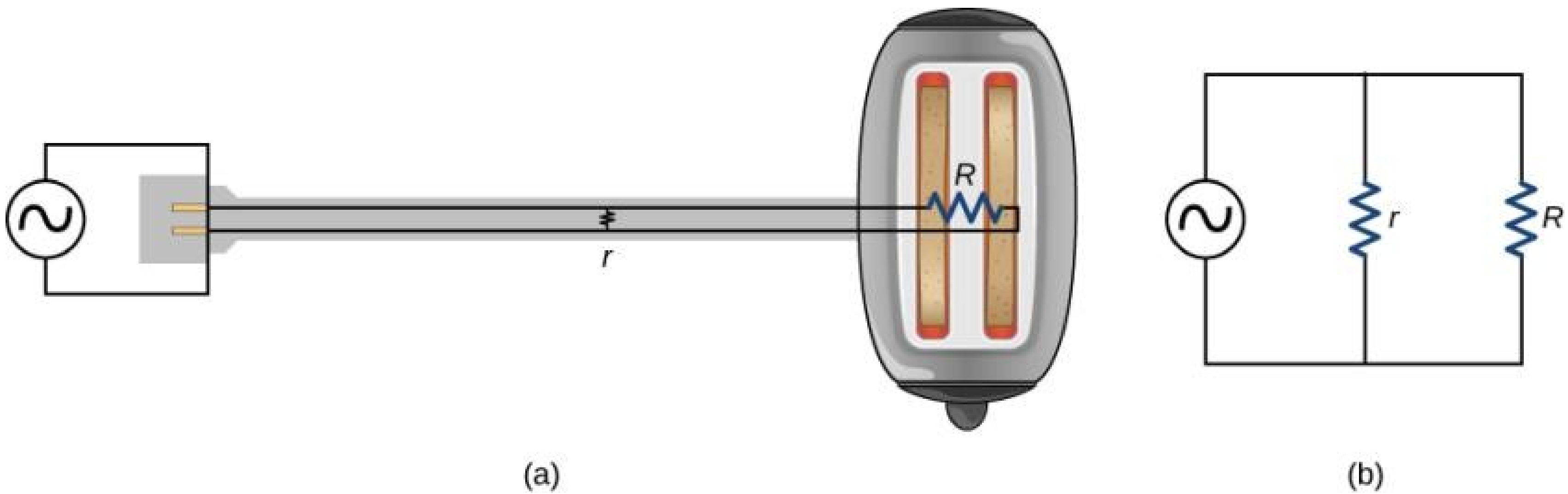


EXAMPLE 10.9



Shocking consequences

FIGURE 10.41

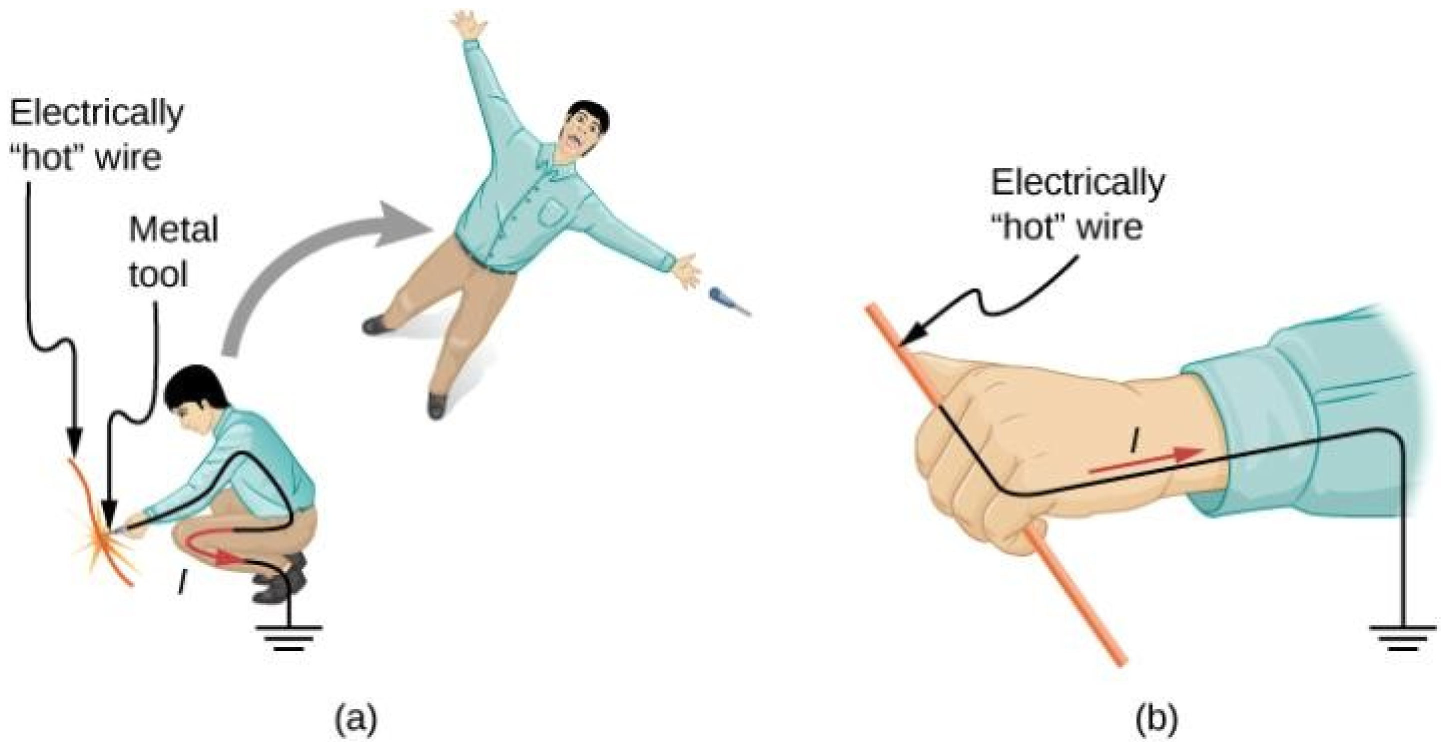


A short circuit is an undesired low-resistance path across a voltage source.

a) Worn insulation on the wires of a toaster allow them to come into contact with a low resistance *r*. Since $P = V^2/r$, thermal power is created so rapidly that the cord melts or burns.

b) A schematic of the short circuit.

FIGURE 10.42

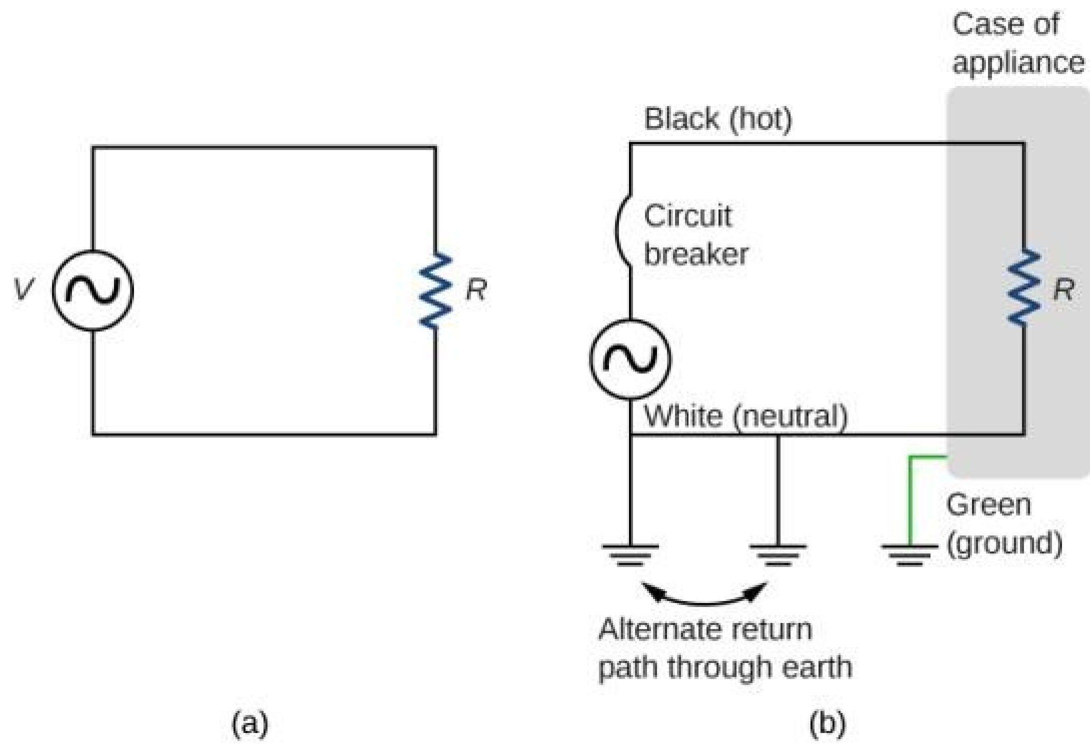


An electric current can cause muscular contractions with varying effects.

a) The victim is “thrown” backward by involuntary muscle contractions that extend the legs and torso.

b) The victim can’t let go of the wire that is stimulating all the muscles in the hand. Those that close the fingers are stronger than those that open them.

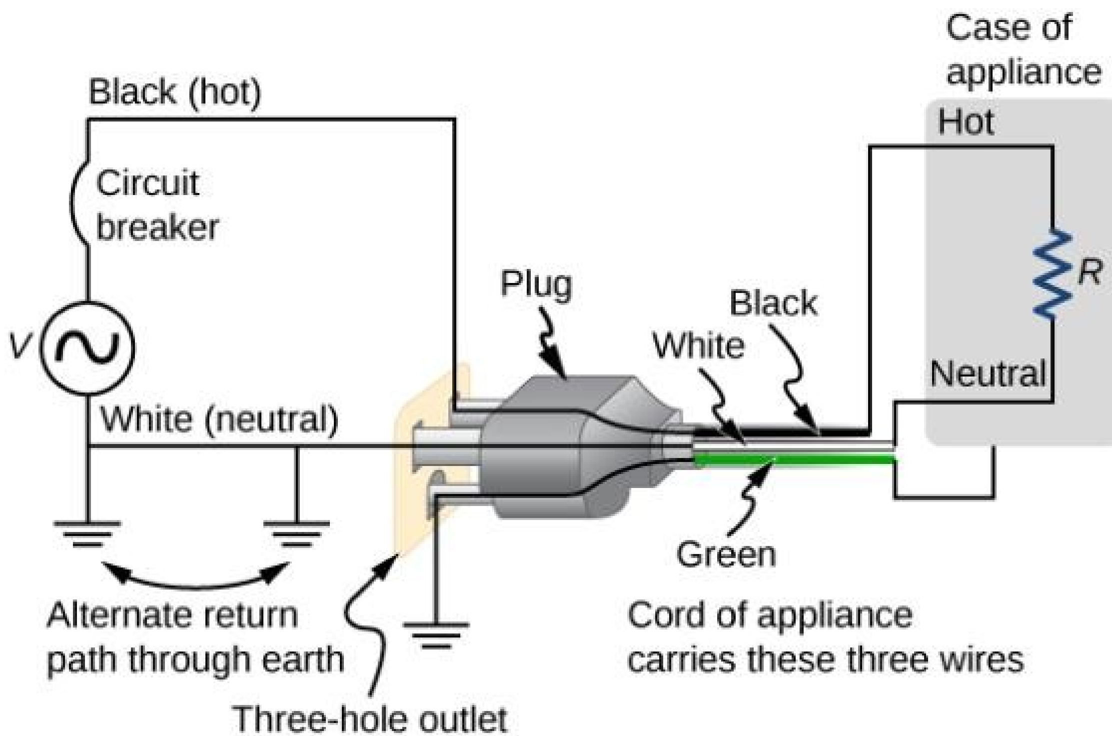
FIGURE 10.43



a) Schematic of a simple ac circuit with a voltage source and a single appliance represented by the resistance *R*. There are no safety features in this circuit.

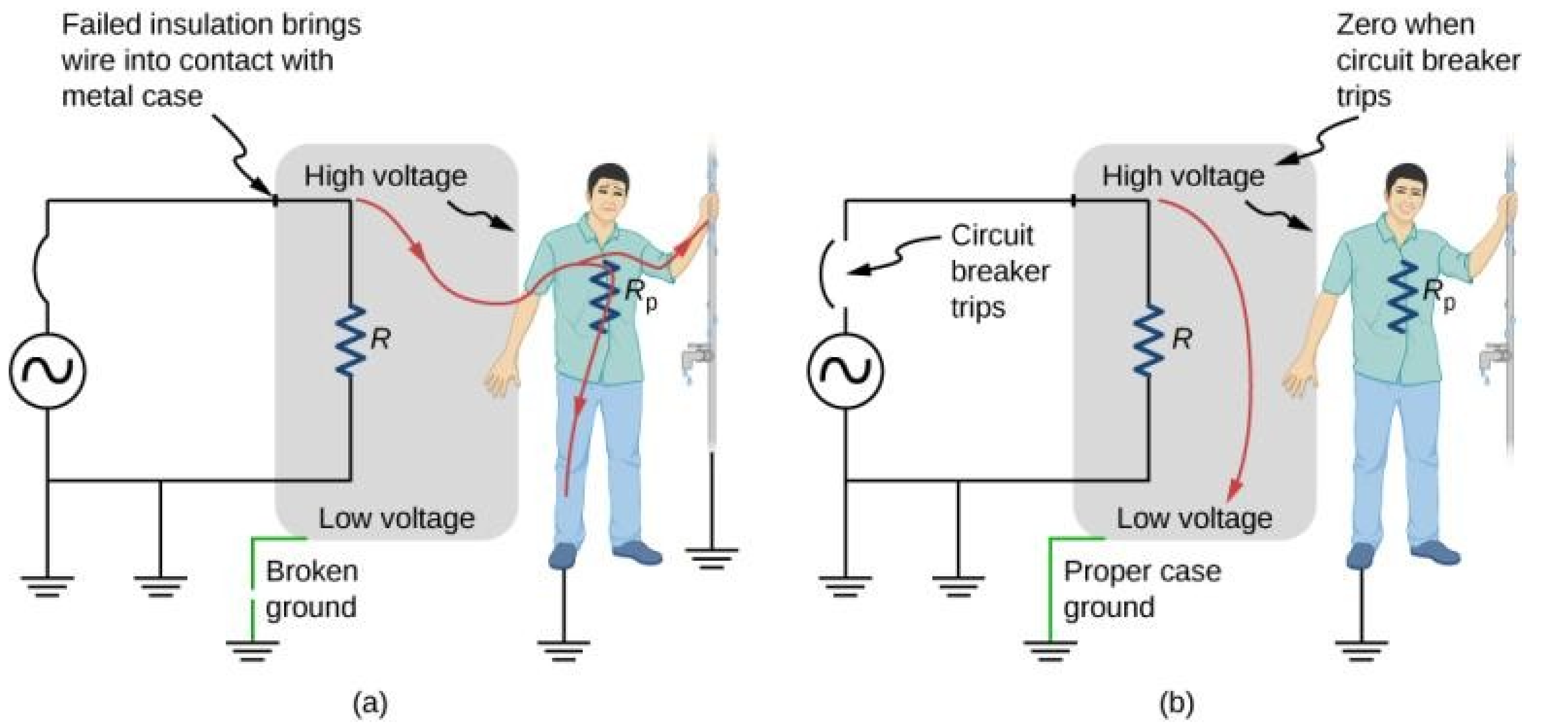
b) The three-wire system connects the neutral wire to ground at the voltage source and user location, forcing it to be at zero volts and supplying an alternative return path for the current through ground. Also grounded to zero volts is the case of the appliance. A circuit breaker or fuse protects against thermal overload and is in series on the active (live/hot) wire.

FIGURE 10.44



The standard three-prong plug can only be inserted in one way, to ensure proper function of the three-wire system.

FIGURE 10.45



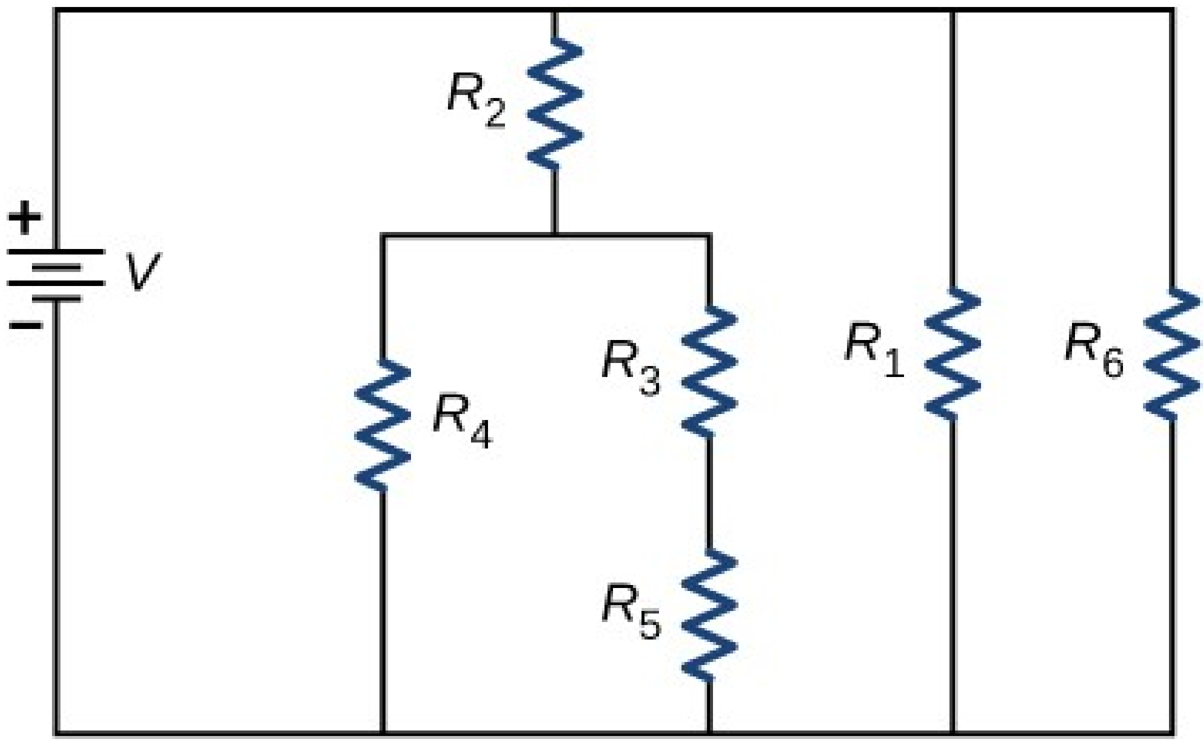
Worn insulation allows the live/hot wire to come into direct contact with the metal case of this appliance.

a) The ground connection being broken, the person is severely shocked. The appliance may operate normally in this situation.

b) With a proper ground, the circuit breaker trips, forcing repair of the appliance.

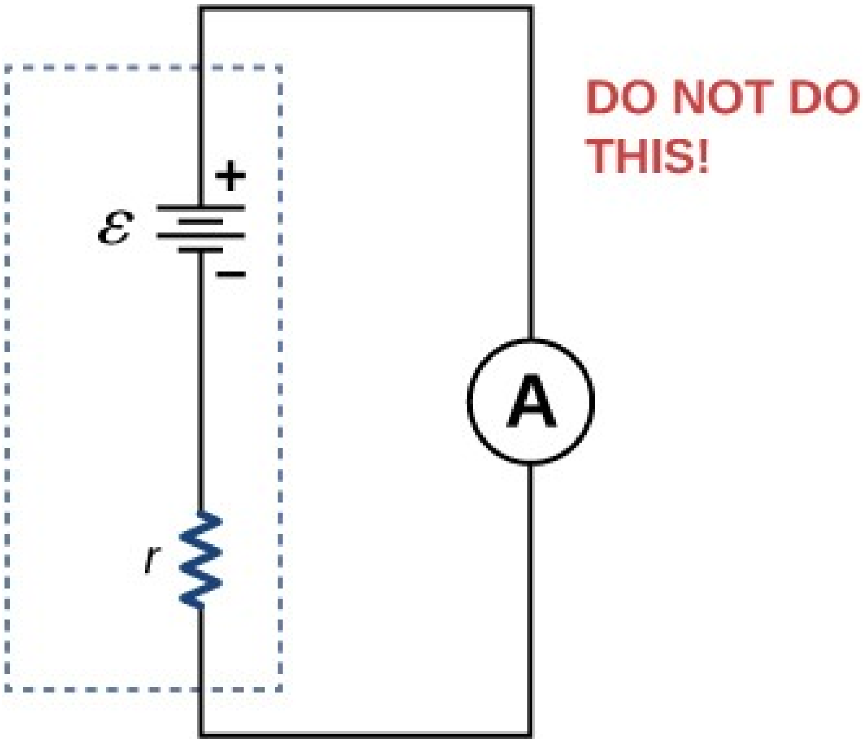
Kirchoff's rules

EXERCISE 9



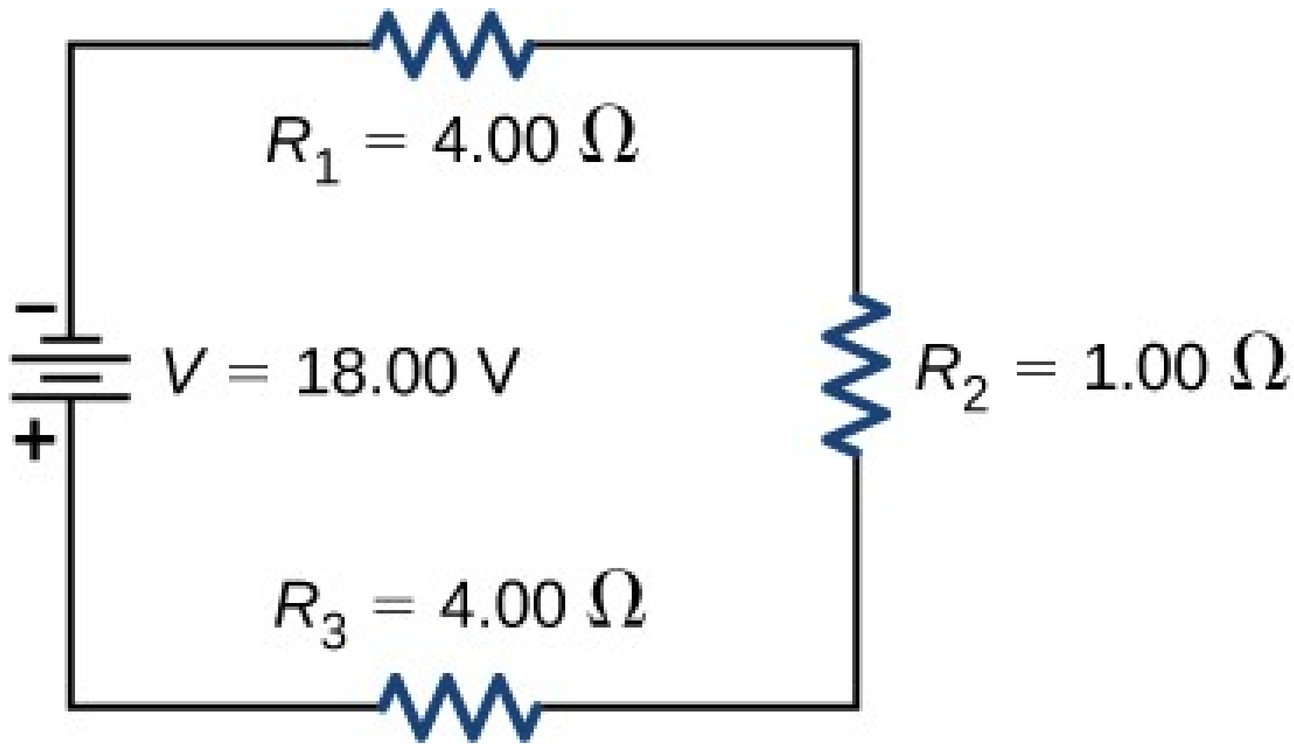
Consider the circuit shown below. Does the analysis of the circuit require Kirchhoff's method, or can it be redrawn to simplify the circuit? If it is a circuit of series and parallel connections, what is the equivalent resistance?

EXERCISE 15



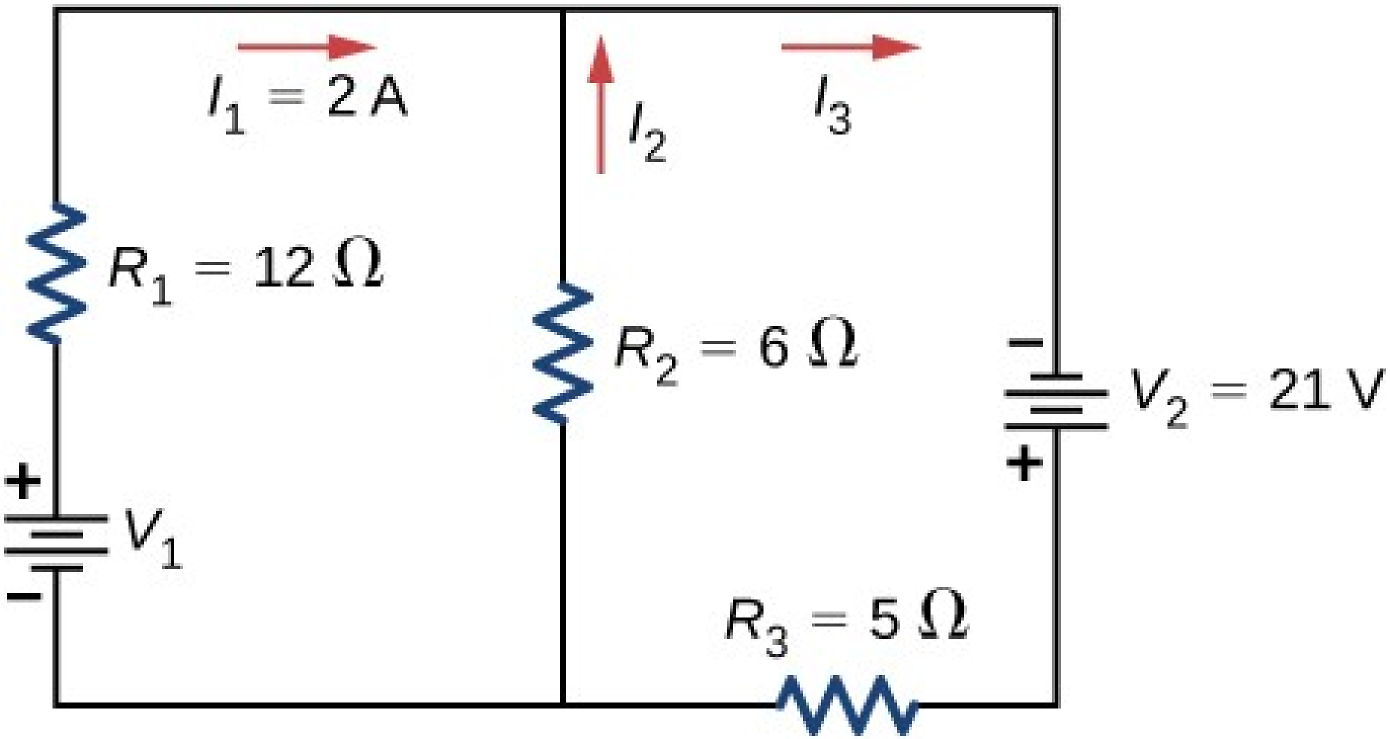
Why should you not connect an ammeter directly across a voltage source as shown below?

EXERCISE 35



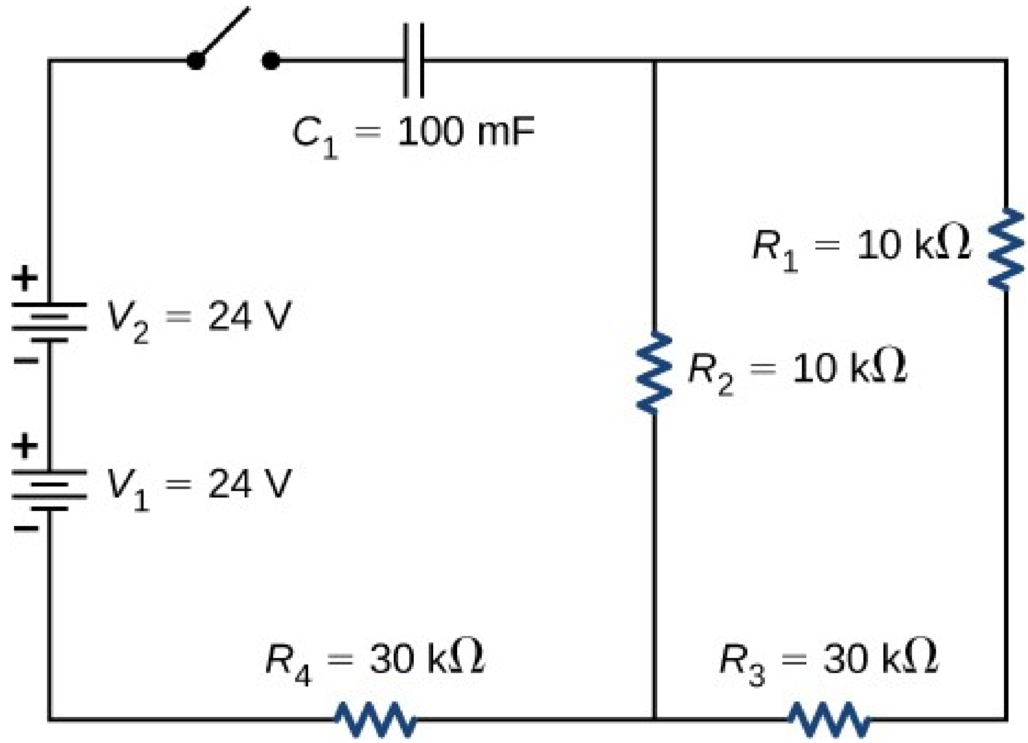
Consider the circuit shown below. The terminal voltage of the battery is (a) Find the equivalent resistance of the circuit. (b) Find the current through each resistor. (c) Find the potential drop across each resistor. (d) Find the power dissipated by each resistor. (e) Find the power supplied by the battery.

EXERCISE 38



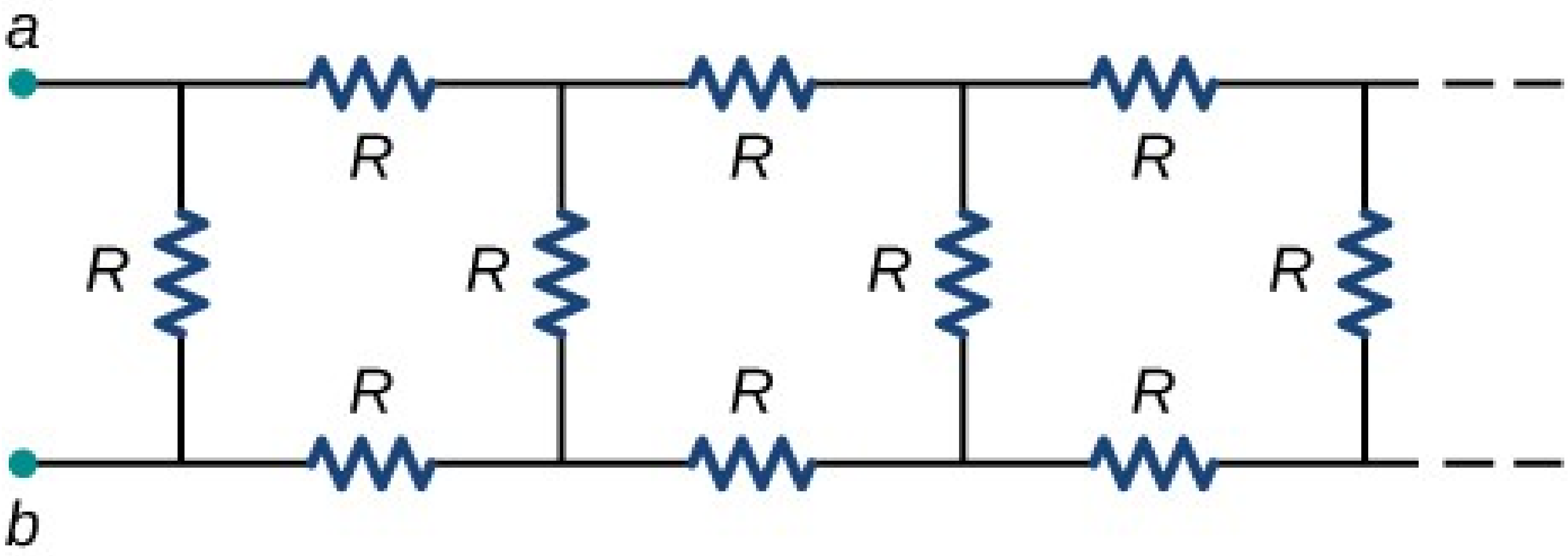
Consider the circuit shown below.
Find the voltages and currents.

EXERCISE 93



Consider the circuit below. (a) What is the RC time constant of the circuit? (b) What is the initial current in the circuit once the switch is closed? (c) How much time passes between the instant the switch is closed and the time the current has reached half of the initial current?

EXERCISE 95



Consider the infinitely long chain of resistors shown below. What is the resistance between terminals a and b?