23.3 Electric Circuits

Lesson Objectives

- Identify the parts of an electric circuit.
- Define electric power, and state how to calculate electrical energy use.
- Identify electric safety features and how to use electricity safely.

Lesson Vocabulary

- electric circuit
- electric power
- parallel circuit
- series circuit

Electric Circuit Basics

A closed loop through which current can flow is called an **electric circuit**. In homes in the U.S., most electric circuits have a voltage of 120 volts. The amount of current (amps) a circuit carries depends on the number and power of electrical devices connected to the circuit. But home circuits generally have a safe upper limit of about 20 or 30 amps.

Parts of an Electric Circuit

All electric circuits have at least two parts: a voltage source and a conductor.

- The voltage source of the circuit in **Figure** 23.16 is a battery. In a home circuit, the source of voltage is an electric power plant, which may supply electric current to many homes and businesses in a community or even to many communities.
- The conductor in most circuits consists of one or more wires. The conductor must form a closed loop from the source of voltage and back again. In **Figure** 23.16, the wires are connected to both terminals of the battery, so they form a closed loop.

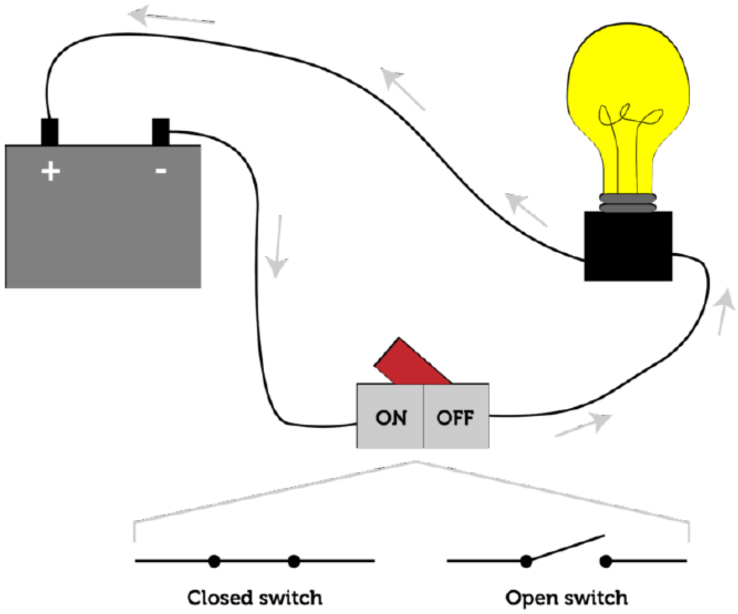


FIGURE 23.16
A circuit must be closed for electric devices such as light bulbs to work. The arrows in the diagram show the direction in which electrons flow through the circuit. The current is considered to flow in the opposite direction.

Circuit Diagrams

When a contractor builds a new home, she uses a set of plans called blueprints that show her how to build the house. The blueprints include circuit diagrams that show how the wiring and other electrical components are to be installed in order to supply current to appliances, lights, and other electrical devices in the home. You can see an example of a very simple circuit diagram in **Figure** 23.17. Different parts of the circuit are represented by standard symbols, as defined in the figure. An ammeter measures the flow of current through the circuit, and a voltmeter measures the voltage. A resistor is any device that converts some of the electricity to other forms of energy. It could be a light bulb, doorbell, or similar device.

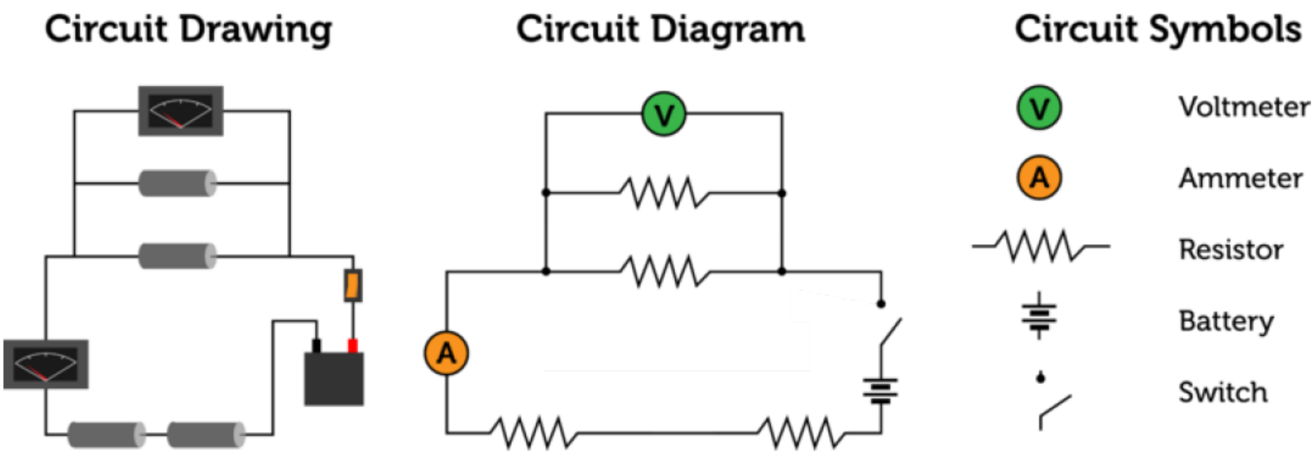


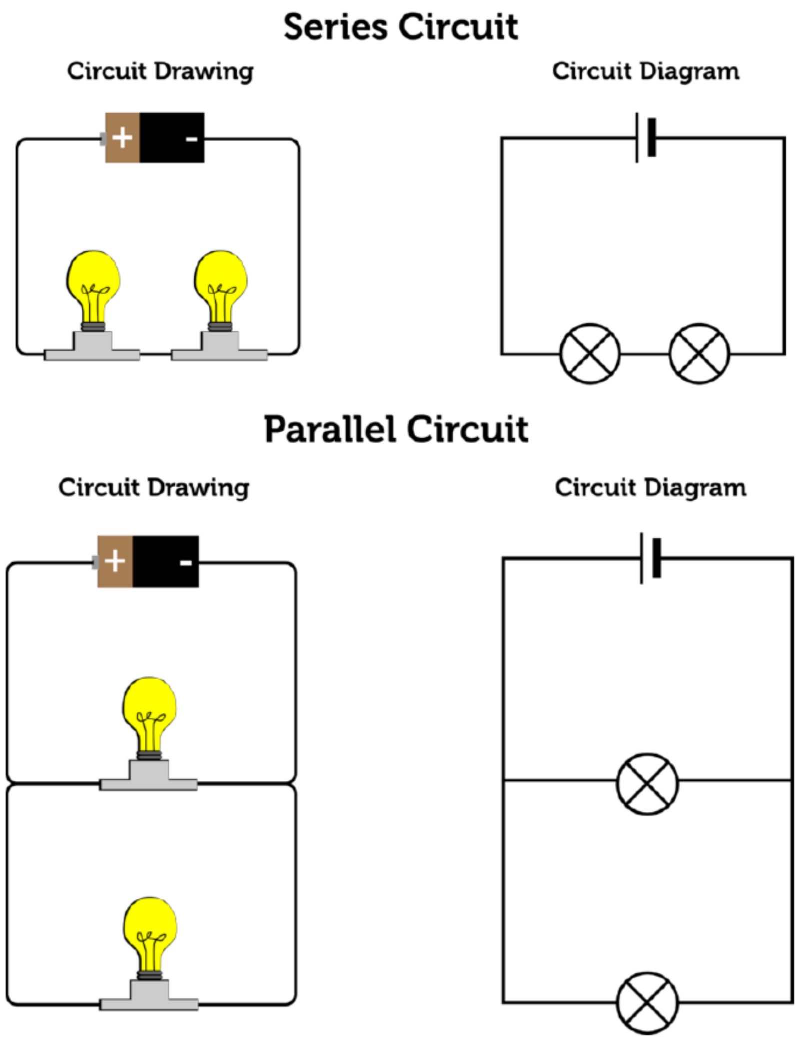
FIGURE 23.17

The circuit diagram on the right represents the circuit drawing on the left. To the right are some of the standard symbols used in circuit diagrams.

Series and Parallel Circuits

There are two basic types of electric circuits, called series and parallel circuits. They differ in the number of loops through which current can flow. You can see an example of each type of circuit in **Figure** 23.18.

- A **series circuit** has only one loop through which current can flow. If the circuit is interrupted at any point in the loop, no current can flow through the circuit and no devices in the circuit will work. In the series circuit in **Figure** 23.18, if one light bulb burns out the other light bulb will not work because it won't receive any current. Series circuits are commonly used in flashlights. You can see an animation of a series circuit at this URL: http://regentsprep.org/regents/physics/phys03/bsercir/default.htm.
- A **parallel circuit** has two loops through which current can flow. If the circuit is interrupted in one of the loops, current can still flow through the other loop. For example, if one light bulb burns out in the parallel circuit in **Figure** 23.18, the other light bulb will still work because current can by-pass the burned-out bulb. The wiring in a house consists of parallel circuits. You can see an animation of a parallel circuit at this URL: http://regentsprep.org/regents/physics/phys03/bsercir/default.htm.



1. **Circuits and Schematics Lab**
2. **Voltage and Current Experimental lab**
3. **Voltage and Current Virtual Lab**

Ohm's Law

Voltage, or a difference in electric potential energy, is needed for electric current to flow. As you might have guessed, greater voltage results in more current. Resistance, on the other hand, opposes the flow of electric current, so greater resistance results in less current. These relationships between current, voltage, and resistance were first demonstrated by a German scientist named Georg Ohm in the early 1800s, so they are referred to as **Ohm's law**. Ohm's law can be represented by the following equation.

$$\text{Current (amps)} = \frac{\text{Voltage (volts)}}{\text{Resistance (ohms)}}$$

Understanding Ohm's Law

You may have a better understanding of Ohm's law if you compare current flowing through a wire from a battery to water flowing through a garden hose from a tap. Increasing voltage is like opening the tap wider. When the tap is opened wider, more water flows through the hose. This is like an increase in current. Stepping on the hose makes it harder for the water to pass through. This is like increasing resistance, which causes less current to flow through a material. Still not sure about the relationship among voltage, current, and resistance? Watch the video at this URL: http://www.youtube.com/watch?v=KvVTh3ak5dQ(2:00).

Ohm's Law: Example Problems

Solve for the missing value:

1. V= 6.0
   I= 0.15
   R=?

2. V= ?
   I= 0.5
   R=240

3. V= 120
   I= ?
   R=100

4. V=?
   I= 4.60
   R= 26

Ohm's Law: Example Problems

5. V=120
   I= ?
   R= 14

6. V= 240
   I= ?
   R= 12.8

7. Calculate the resistance of a light bulb that has a voltage of 6.0 V and a current of 0.25 amps.

8. What is the current if a 120V battery has 240Ω of resistance?

Ohm's Law: Example Problems

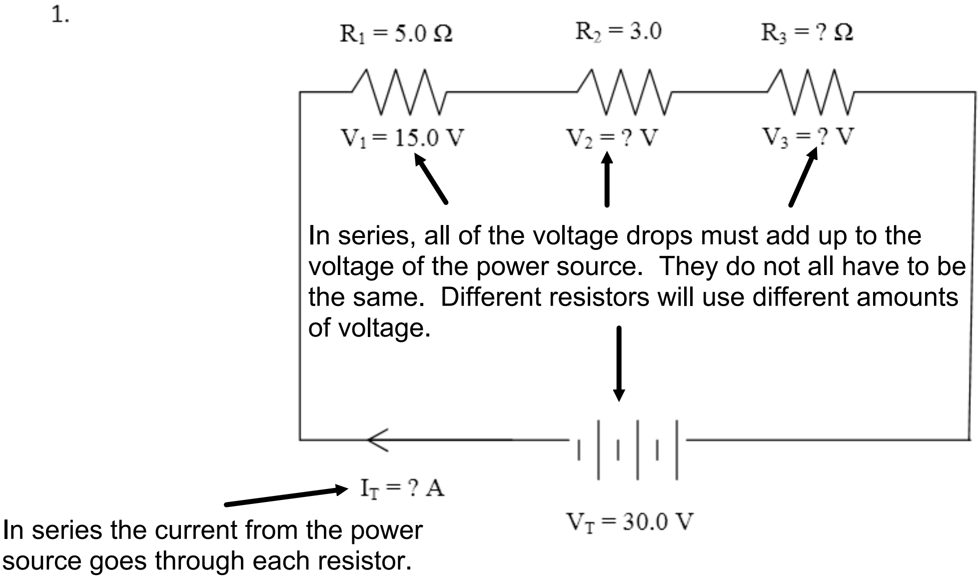
9. What is the voltage through a circuit containing 1.20A and 100Ω of resistance?

10. Calculate the resistance for a 120V coffee grinder with 4.60 amps of current running through it.

Circuit Diagrams and Ohm's Law

Calculate the missing information using your knowledge of series and parallel circuits.

1.



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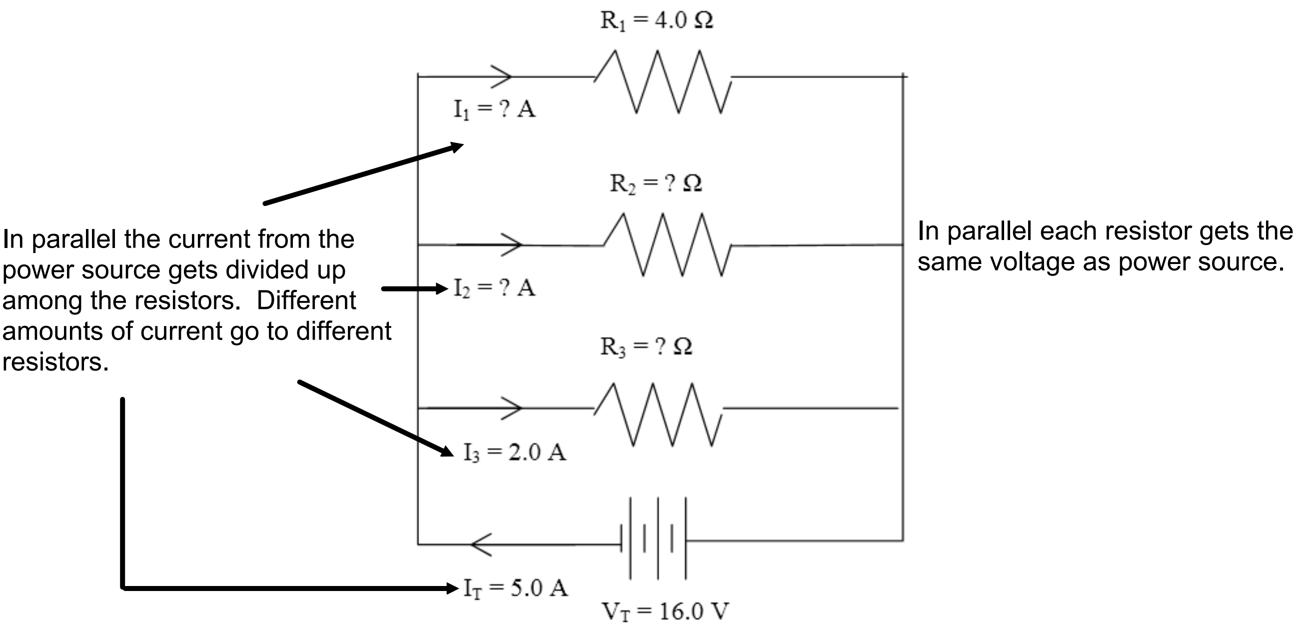
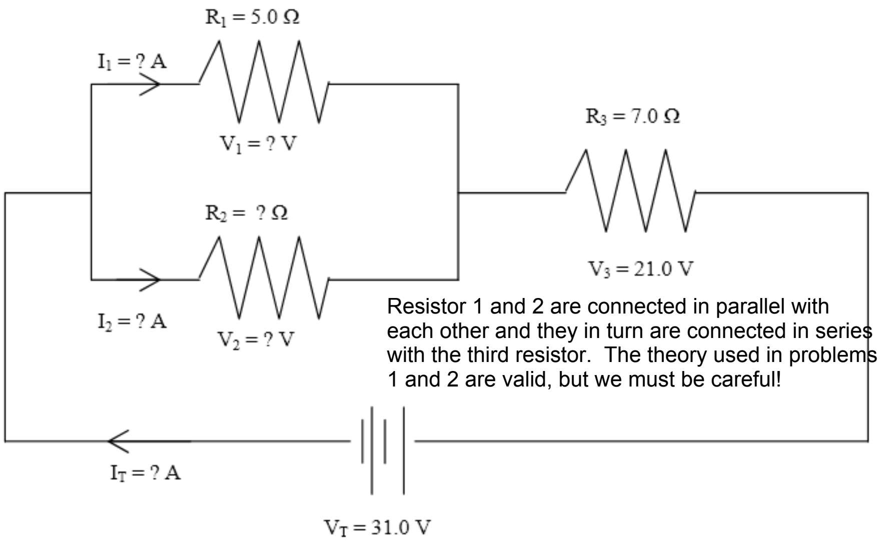


The next two problems combine the theory of series and parallel circuits.

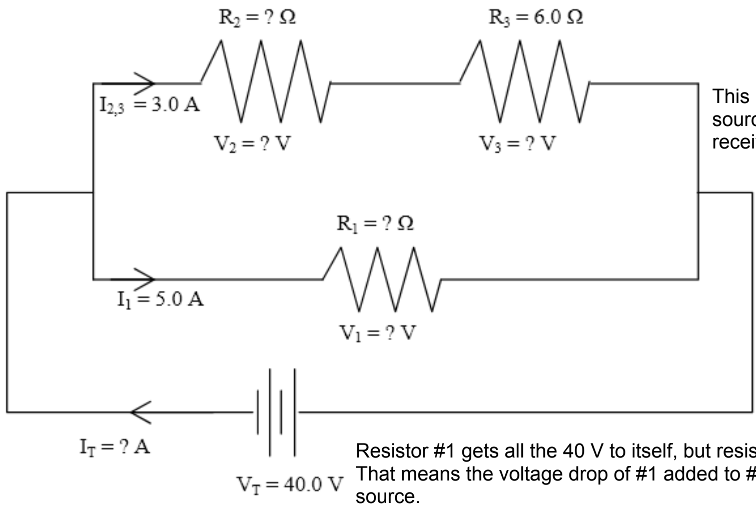
3.



Resistor 1 and 2 are connected in parallel with each other and they in turn are connected in series with the third resistor. The theory used in problems 1 and 2 are valid, but we must be careful!

Follow the schematic carefully, the current from the power source divides up then recombines to go through the third resistor. The voltage available to the parallel section added with the third resistor must equal the power source. The voltage available to the parallel section applies to *both* resistors. So, in this example the third resistor has a voltage drop of 21 V. That leaves 10 V for the parallel section so both resistor #1 and #2 have a voltage drop of 1 Please note that all of the voltage drops *do not* have to add up to the voltage of the power source, but the sections in series do.

4.



This is a parallel circuit connected to a power source so each parallel "line" of resistors receives the voltage of the power source.

Resistor #1 gets all the 40 V to itself, but resistor #2 and #3 must share the 40 V. That means the voltage drop of #1 added to #2 must add up the 40 V from the power source.

V-I-R Table for Schematic #1

Resistor #	V (V)	I (A)	R (Ω)
1			
2			
3			
Totals	V_T=	I_T=	R_{eq}=

These are called Voltage-Current-Resistance or V-I-R tables. They aid in organizing the information given in circuit schematic problems and solving for the unknown quantities.

Ohm's Law, V = I x R, is obeyed for every resistor and for the circuit as a whole. In every row the voltage must equal the current multiplied by the resistance.

R_{eq} stands for *equivalent resistance*, it is the net resistance that determines how much current will be drawn from the power source (it is not always the sum of all the resistors so be careful - it is always $V_T \div I_T$.) Depending on how the resistors are connected it is possible to "fool" the battery into thinking there is less resistance than it seems!

Use these tables in combination with the actual diagram to fill in or calculate all the missing data. Pay very close attention to the type of circuit you are working with.

V-I-R Table for Schematic #2

Resistor #	V (V)	I (A)	R (Ω)
1			
2			
3			
Totals	V_T=	I_T=	R_{eq}=

V-I-R Table for Schematic #3

Resistor #	V (V)	I (A)	R (Ω)
1			
2			
3			
Totals	V_T=	I_T=	R_{eq}=

Look at V_1 and V_2, they are the same because they are in parallel but their voltage adds with V_3 to give the total voltage of the power source.

V-I-R Table for Schematic #4

Resistor #	V (V)	I (A)	R (Ω)
1			
2			
3			
Totals	V_T=	I_T=	R_{eq}=

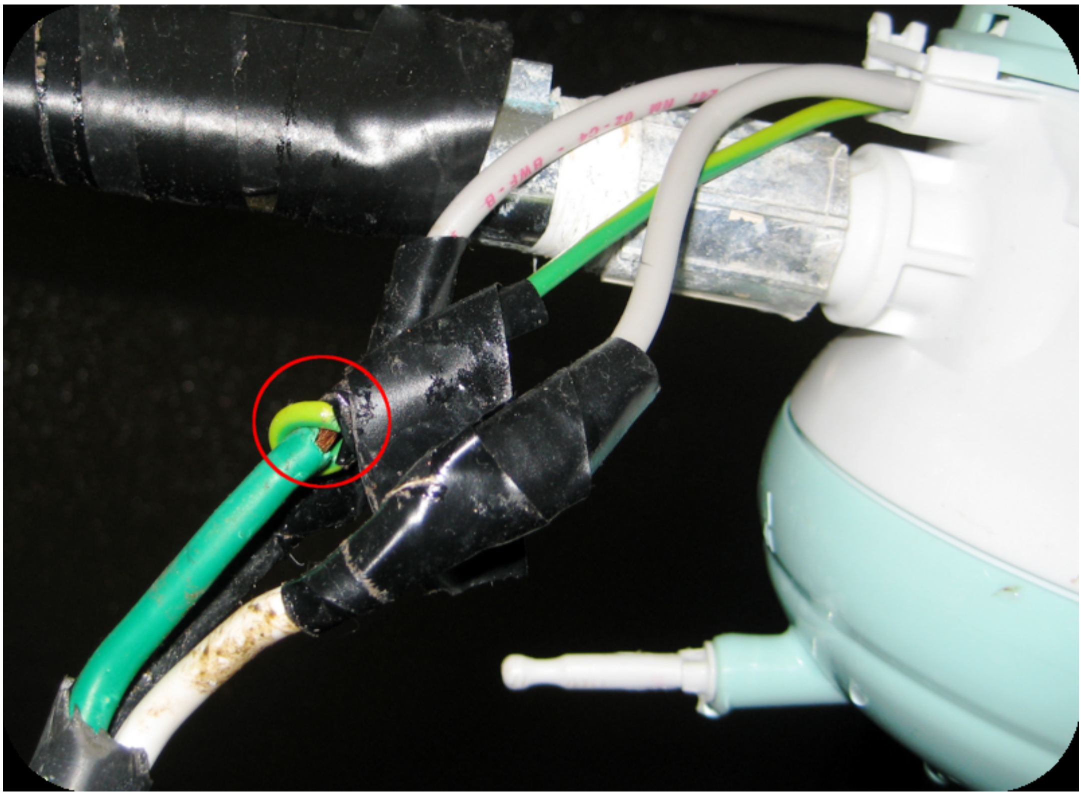
Here the power source supplies 40 V to each parallel "line" of resistors. Looking at the schematic, the top row must share that voltage because they are in series.

Electric Safety

Electricity is dangerous. Contact with electric current can cause severe burns and even death. Electricity can also cause serious fires. A common cause of electric hazards and fires is a short circuit.

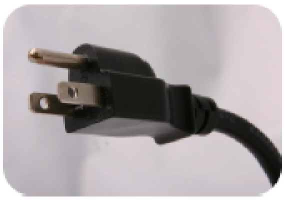
How a Short Circuit Occurs

An electric cord contains two wires. One wire carries current from the outlet to the appliance or other electric device, and one wire carries current back to the outlet. Did you ever see an old appliance with a damaged cord, like the one in **Figure** 23.19? A damaged electric cord can cause a severe shock if it allows current to pass from the cord to a person who touches it. A damaged cord can also cause a short circuit. A short circuit occurs when electric current follows a shorter path than the intended loop of the circuit. For example, if the two wires in a damaged cord come into contact with each other, current flows from one wire to the other and bypasses the appliance. This may cause the wires to overheat and start a fire.

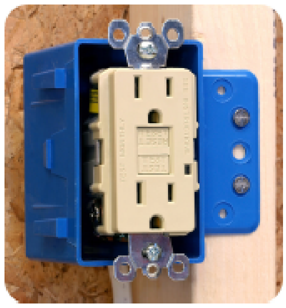


Electric Safety Feature

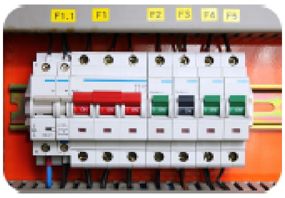
Three-Prong Plug



GFCI Outlet



Circuit Breaker



Using Electricity Safely

Even with electric safety features, electricity is still dangerous if it is not used safely. Follow the safety rules below to reduce the risk of injury or fire from electricity.

- Never mix electricity and water. Don't turn on or plug in electric lights or appliances when your hands are wet, you are standing in water, or you are in the shower or bathtub. The current could flow through the water—and you—because water is a very good electric conductor.
- Never overload circuits. Avoid plugging too many devices into one outlet or extension cord. The more devices that are plugged in, the more current the circuit carries. Too much current can overheat a circuit and start a fire.
- Never use devices with damaged cords or plugs. They can cause shocks, shorts, and fires.
- Never put anything except plugs into electric outlets. Plugging in other objects is likely to cause a serious shock that could be fatal.
- Never go near fallen electric lines. They could be carrying a lot of current. Report fallen lines to the electric company as soon as possible.

Electric Power and Electrical Energy Use

We use electricity for many purposes. Devices such as lights, stoves, and stereos all use electricity and convert it to energy in other forms. However, devices may vary in how quickly they change electricity to other forms of energy.

Electric Power

The rate at which a device changes electric current to another form of energy is called **electric power**. The SI unit of power—including electric power—is the watt. A watt equals 1 joule of energy per second. High wattages are often expressed in kilowatts, where 1 kilowatt equals 1000 watts. The power of an electric device, such as a microwave, can be calculated if you know the current and voltage of the circuit. This equation shows how power, current, and voltage are related:

$$\text{Power (watts)} = \text{Current (amps)} \times \text{Voltage (volts)}$$

Consider a microwave that is plugged into a home circuit. Assume the microwave is the only device connected to the circuit. If the voltage of the circuit is 120 volts and it carries 10 amps of current, then the power of the microwave is:

$$\text{Power} = 120 \text{ volts} \times 10 \text{ amps} = 1200 \text{ watts, or } 1.2 \text{ kilowatts}$$

You Try It!

Problem: A hair dryer is connected to a 120-volt circuit that carries 12 amps of current. What is the power of the hair dryer in kilowatts?

Electrical Energy Use

Did you ever wonder how much electrical energy it takes to use an appliance such as a microwave or hair dryer? Electrical energy use depends on the power of the appliance and how long it is used. It can be represented by the equation:

$$\text{Electrical Energy} = \text{Power} \times \text{Time}$$

Suppose you use a 1.2-kilowatt microwave for 5 minutes ($\frac{1}{12}$ hour). Then the energy used would be:

$$\text{Electrical Energy} = 1.2 \text{ kilowatts} \times \frac{1}{12} \text{ hour} = 0.1 \text{ kilowatt-hours}$$

Electrical energy use is typically expressed in kilowatt-hours, as in this example. How much energy is this? One kilowatt-hour equals 3.6 million joules of energy. Therefore, the 0.1 kilowatt-hours used by the microwave equals 0.36 million joules of energy.

You Try It!

Problem: A family watches television for an average of 2 hours per day. The television has 0.12 kilowatts of power. How much electrical energy does the family use watching television each day?