Chapter 9

Circuits are designed to control the transfer of electrical energy.

Electricity is such a common part of our lifestyle that we tend to forget the amazing processes involved in its production and distribution. With the "flick of the switch" you can light up a room, play video games, or cook your favourite dish. Chances are that the electrical energy you use here in British Columbia originated at a hydroelectric dam like this one on the Peace River.

The huge wall of water behind the dam has potential energy. Once allowed to fall to the river below, this potential energy is transformed into enough electrical energy to meet the demands of cities and communities hundreds of kilometres away. Tall transmission lines carry this energy at voltages that can exceed 1 million volts. These transmission lines end at distribution centres that send this electricity along various different paths throughout your community. When one of these paths enters your home, the electricity is divided into several circuits. You plug in your device, which itself contains many different circuits. Next time you put your bread in the toaster, take a moment to appreciate the wonder of electrical energy and circuits.

What You Will learn

In this chapter, you will
- **differentiate** between series and parallel circuits in terms of current, voltage, and resistance
- **define** electrical energy and power
- **calculate** power using voltage and current
- **determine** energy consumption given the power rating of a device and duration of use

Why It Is Important

We use electrical energy in many devices that help make our lives easier and more comfortable. The cost to operate these devices is determined by the energy they consume.

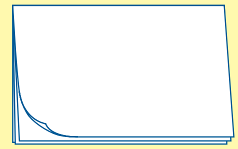
Skills You Will Use

In this chapter, you will
- **measure** current and voltage in both series and parallel circuits
- **model** series and parallel circuits
- **evaluate** energy consumption of common electric devices

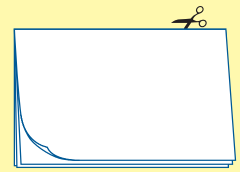
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 9.

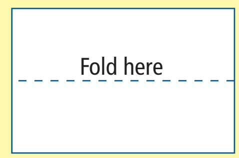
STEP 1 **Fold** two vertical sheets of paper in half horizontally.



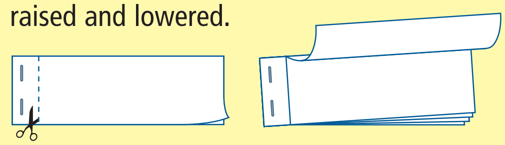
STEP 2 **Cut** along the fold lines, making four half sheets. (**Hint:** Use as many half sheets as necessary for additional pages in your book.)



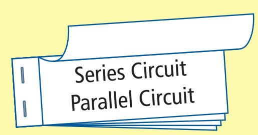
STEP 3 **Fold** each half sheet in half horizontally.



STEP 4 **Place** the folded sides of all sheets at the top and **staple** them together on the left side. About 2 cm from the stapled edge, **cut** the front page of each folded sheet to the top. These cuts form flaps that can be raised and lowered.



STEP 5 **Label** the four individual Flip Book Foldables with the four key points in the "What You Will Learn" section:
(1) series and parallel circuits
(2) electrical energy and power
(3) voltage and current
(4) energy consumption



Record information, definitions, and examples beneath the tabs.

Define As you read the chapter, under the appropriate tabs define the key terms and concepts needed to understand electrical energy.

9.1 Series and Parallel Circuits

In a series circuit, there is only one path for current to travel. The current is the same in each part of a series circuit. Each load in a series circuit uses a portion of the same source voltage. When a resistor is placed in series with other resistors, the total resistance of the circuit increases. In a parallel circuit, there is more than one path for current to travel. The voltage across each resistor in a parallel circuit is the same. Current entering a parallel circuit must divide among the possible paths. The current in each path depends on the resistance of that path. When you connect resistors in parallel, the total resistance decreases.

Words to Know

junction point
parallel circuit
series circuit

Lights are a part of many special celebrations. Some families use mini lights to decorate their homes in the winter. Cities sometimes use lights to decorate trees and buildings at night (Figure 9.1). Decorative lights are different from the light bulbs we use to light the rooms of our homes. They are smaller and less bright. Another difference can be the way they are connected together.

In your house, if a light bulb is removed or "burns out," the lights in the rest of the house stay lit (Figure 9.2). Some strings of decorative lights may be connected in such a way that if one of the bulbs is removed, the rest of the string of lights does not light. What accounts for this difference? The decorative lights and the house lights are on two different types of electric circuits.

Did You Know?

Thomas Edison did not invent the light bulb, but he did develop the first light bulb that could be used in homes. Edison realized that each light bulb should be able to be turned on or off without affecting the other light bulbs connected in the circuit. Since only part of the current goes to each bulb, Edison designed a high resistance filament that required only a small current to produce large amounts of heat and light.

Figure 9.1 Some decorative lights are connected so that each light acts independently of the others. In other types, if one light is removed, none of the remaining lights will be lit.

Figure 9.2 The lights in your home are connected such that if someone turns off one light the rest of the lights stay lit.

9-1A Turn Out the Lights

Find Out ACTIVITY

In this activity, you will construct two different circuits and compare the flow of electrons in each circuit.

Safety

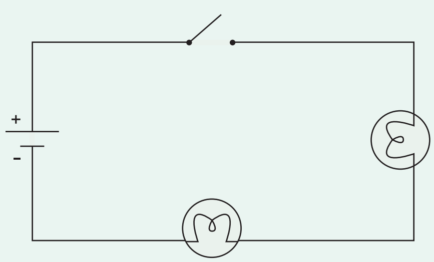
- Disconnect the circuit if any wires become hot.

Materials

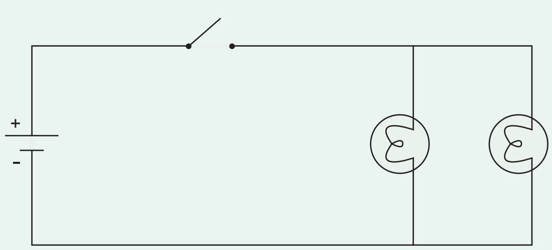
- 1.5 V cell
- two 2.0 V light bulbs
- switch
- connecting wires

What to Do

1. Using the materials provided, build circuit 1 as shown in the diagram.
2. Close the switch and observe the two light bulbs.
3. With the switch still closed, gently unscrew one of the light bulbs. Observe what happens to the remaining light bulb.
4. Replace the light bulb so that both bulbs are again lit. Gently unscrew the other light bulb. Again observe the remaining light bulb. Open the switch after you have made your observations.



Circuit 1



Circuit 2

5. Take circuit 1 apart. Build circuit 2 as shown in the diagram.
6. Close the switch and observe the two light bulbs.
7. With the switch still closed, gently unscrew one of the light bulbs. Observe what happens to the remaining light bulb.
8. Replace the light bulb so that both are again lit. Gently unscrew the other light bulb. Again observe the remaining light bulb. Open the switch after you have made your observations.
9. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Imagine you are an electron leaving the negative terminal of the cell in circuit 1.
   (a) How many ways are there for you to travel through the circuit in order to arrive at the positive terminal?
   (b) How many light bulbs do you have to travel through?
2. In circuit 1, when one bulb is removed is the other bulb still lit? Why?
3. Imagine you are an electron leaving the negative terminal of the cell in circuit 2.
   (a) How many ways are there for you to travel through the circuit in order to arrive at the positive terminal?
   (b) In any one of these paths, how many light bulbs do you have to travel through?
4. In circuit 2, when one bulb is removed is the other bulb still lit? Why?

Charges with One Path to Follow

A simple waterslide at the local water park might consist of one set of stairs leading to a slide that travels down to a pool (Figure 9.3). Every person who climbs the stairs must travel down the same slide. If a person decides to stop either on the stairs or on the slide, the rest of the people using the slide must also stop because this person is blocking the only pathway.

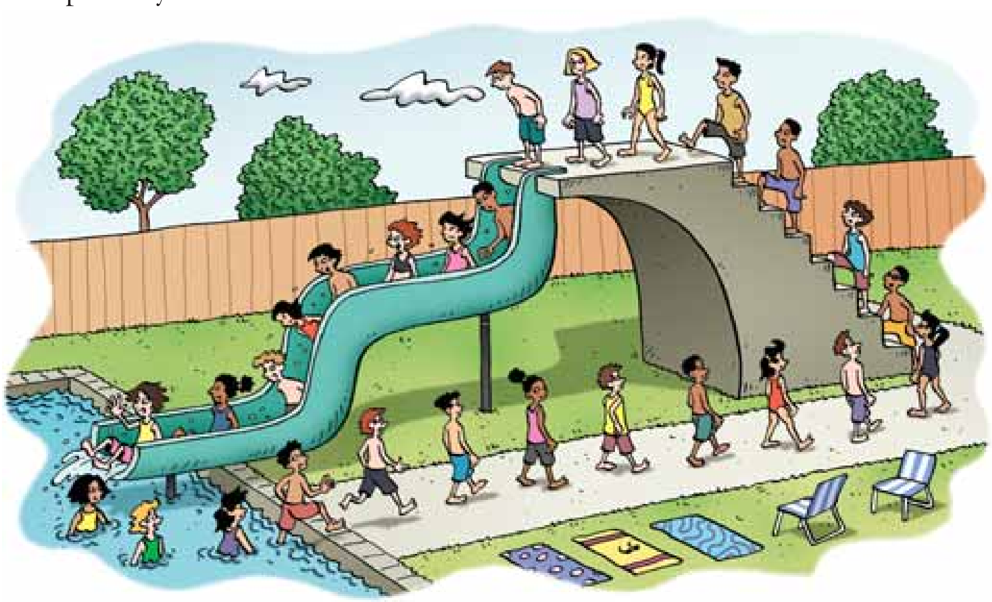


Figure 9.3 Everyone who uses this slide follows the same path.

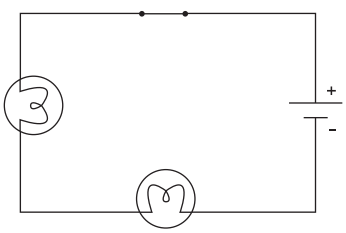


Figure 9.4 Electrons leaving the negative terminal of the battery in this circuit have only one path to return to the battery at the positive terminal.

Figure 9.4 is an electric circuit that is like the simple waterslide. A circuit that has only one path for current to travel is called a **series circuit**. In other words, electrons have only one pathway to travel through a series circuit. If the switch is opened, all electrons are blocked and the current stops.

9-1B Is the World Series a Series Circuit? — Think About It

A series circuit is a complete loop that has only one pathway. There are many physical examples of loops that have only one path. For example, running one lap on the school track is like a series circuit because it is one path that makes a complete loop. Another example is an assembly line in a factory where each worker adds another part to the frame of an automobile. In this activity, you will brainstorm other examples in your community and the world that represent a series circuit.

What to Do

1. Work with a partner or in a small group to list examples that represent series circuits in your home, your community, and the world.

What Did You Find Out?

1. Compare your list with another group's list. Which examples did you have in common?
2. Choose one of the examples that you have in common.
   (a) What travels through the circuit?
   (b) What energy causes the motion of the objects in the circuit?
   (c) If the circuit became broken or blocked, what would happen to the motion of the objects in the circuit?

Voltage and Current in a Series Circuit

The people on the waterslide represent the electrons that flow through the circuit. A person has more potential energy at the top of the stairs than at the bottom. Suppose the staircase has 12 steps. A person who slides from the top of the slide to the bottom will "lose" all 12 steps before returning to the bottom of the stairs.

In an electric circuit, the charge that leaves a 12 V battery "loses" all 12 V before it returns to the battery. These losses occur on loads such as light bulbs or resistors, which transform the electrical energy into other forms of energy. Each load in the series circuit loses a portion of the total voltage supplied to the electrons by the battery (Figure 9.5). The sum of the voltages lost on the loads equals the total voltage supplied by the battery.

Did You Know?

When Edison was designing his light bulb, he tried more than 1600 materials for the filament. Some of these materials included thread, fishing line, coconut fibre, bamboo, and the hair from a beard. Edison finally chose carbonized cotton for the filament.

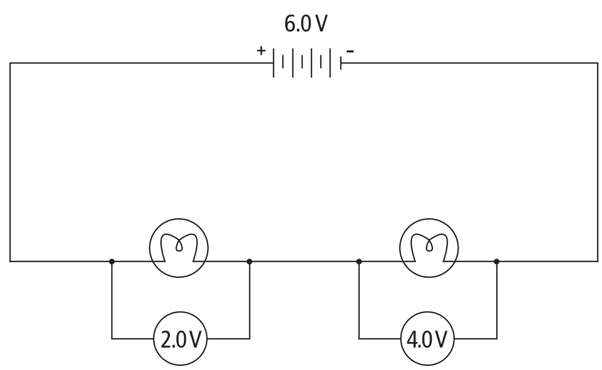


Figure 9.5 Each load in a series circuit loses a portion of the total voltage.

In an electric circuit, the electrons repel each other with the same action-at-a-distance force. Therefore, most of the electrons flowing in a circuit will remain fairly evenly spaced apart. Since there is only one path for the electrons to travel in the series circuit, the current in each part of a series circuit is equal (Figure 9.6). This is similar to a garden hose filled with water. The amount of water entering the garden hose must be the same as the amount of water leaving the same hose. All along the hose, therefore, the "current" of water is the same.

Suggested Activity

Find Out Activity 9-1D on page 314

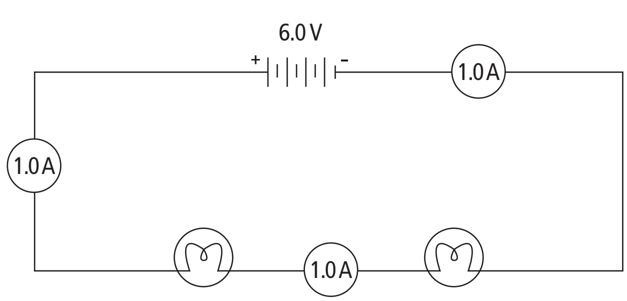


Figure 9.6 The current is the same throughout a series circuit.

Resistors in Series

Imagine if a waterslide contained a section where the water escaped and you had to slide across dry plastic. This section would have more resistance than the other parts of the slide, and therefore you would slow down. If all the people on this slide behaved like electrons and kept almost equal spacing, then everyone would slow down due to this resistance. Suppose there were another dry patch farther down the slide. This resistance would further slow down the person sliding across it and cause everyone to slow down even more. The total number of people reaching the bottom per minute would be less.

The same result occurs in an electric circuit when resistance is added. Resistors placed in series increase the total resistance of the circuit. When you place resistors in series, you increase the total resistance, and therefore the total current throughout the circuit decreases.

Reading Check

1. What do we call a circuit that has only one path?
2. What happens to the current in a series circuit when a switch is opened?
3. How does the total voltage lost on all loads compare to the total voltage supplied by the battery?
4. Why is the current at any two locations in a series circuit always the same?
5. If a resistor is added in series to an existing resistor, what happens to the total resistance?

Did You Know?

Sometimes, the largest voltages in a home are in the television set where 20 000 V is common. The electric stove in your kitchen is connected to 240 V but can take a current as large as 40 A.

More Than One Way to Go

A closed pathway that has several different paths is called a **parallel circuit**. Figure 9.7 shows a parallel electric circuit. Electrons leaving the battery have three possible ways of returning to the battery in this example. An electron can travel through bulb 1, bulb 2, or bulb 3 before returning to the battery.

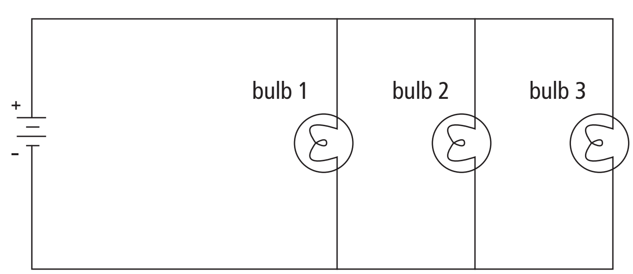


Figure 9.7 Electrons leaving the battery have three possible ways to return to the battery in this circuit.

A waterslide with more than one slide gives the rider different experiences than the single pathway waterslide (Figure 9.8). If someone decides to stop on one of the slides, the other pathways still operate. Even though there are different pathways down, everyone climbs the same stairs and everyone ends up in the same pool at the bottom of the slides.

Figure 9.8 People on this waterslide have three possible ways to reach the bottom of the slide.

9-1C More Things Are Parallel Than Lines

Think About It

A parallel circuit is a complete loop that has more than one pathway. If there is more than one way to travel between two locations, those different paths are called parallel. For example, in a busy mall there may be several escalators side by side that take you up to the next floor. Each of the escalators is parallel. In this activity, you will brainstorm situations that represent parallel paths.

What to Do

1. Work with a partner or in a small group to list examples that represent parallel paths in your home, your community, and the world.

What Did You Find Out?

1. Compare your list with another group's list. Which examples did you have in common?
2. Choose one of the examples that you have in common.
   (a) What travels through the circuit?
   (b) What energy causes the motion of the objects in the circuit?
   (c) If one pathway of the circuit became broken or blocked, what would happen to the motion of the rest of the objects in the circuit?

Voltage and Current in a Parallel Circuit

Suppose people climbed 50 stairs to reach the top of the waterslide. Regardless of which of the three slides the people travel down, they will end up in the same pool. They will "lose" all the potential energy they gained when they climbed the stairs by the time they reach the bottom. In an electric circuit, the battery supplies electric potential energy to the electrons through a potential difference. If the battery has a potential difference of 12 V, then the electrons will lose these 12 V of potential difference by the time they return to the battery. As you can see in Figure 9.9, the voltage on each of the light bulbs in parallel is the same. Loads that are in parallel have the same voltage.

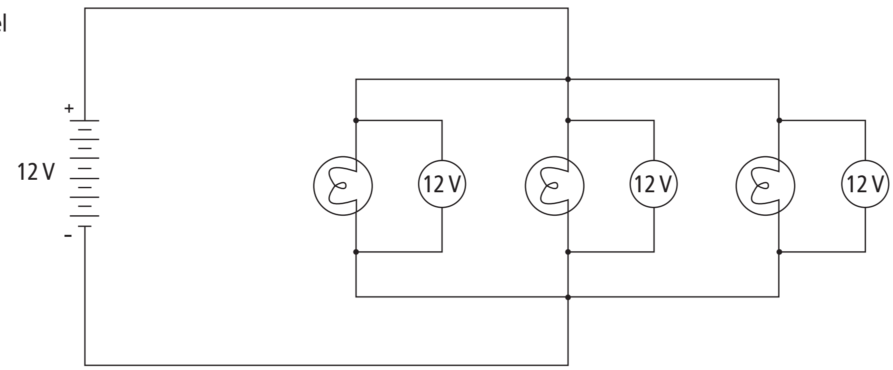


Figure 9.9 Each load in parallel must have the same voltage.

In a *series* circuit, the current is the same throughout the circuit. This is because there is only one path for the electrons to travel. In a *parallel* circuit, the current branches into different pathways that eventually rejoin. A portion of the electrons travels on each path. A pathway with less resistance will be able to have more electrons travel on it and therefore will have a greater current than a pathway with more resistance.

Figure 9.10 shows a battery connected to three different resistors connected in parallel. The total current leaving the battery divides into three possible pathways. The location where a circuit divides into multiple paths or where multiple paths combine is called a **junction point**. No current is created or destroyed by parallel paths. The current is only split up to travel different routes.

Loads of different resistance that are connected in parallel will have different currents. The total current entering a junction point must equal the sum of the current leaving the junction point.

Suggested Activity

Find Out Activity 9-1E on page 315

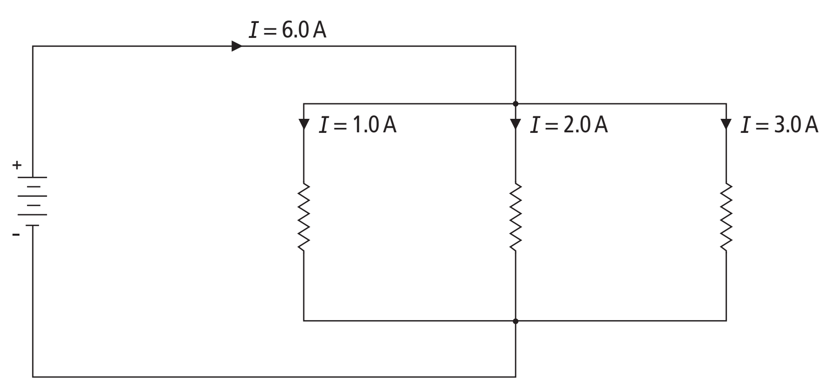


Figure 9.10 Current entering the junction point divides among the three possible paths.

Resistors in Parallel

Imagine that you are standing at the end of a long line in a grocery store. There is only one checkout open, and all customers must pass through the one checkout. This is like a series circuit since there is only one path. The cashier in this situation represents a resistor since the cashier slows down the customers. Suppose a second checkout is opened. Customers can now check out their groceries in either line. Even though the second cashier is also a resistor, the customers do not have to wait as long.

The same is true for electric circuits (Figure 9.11). When you place a resistor in parallel with another resistor, you create another pathway so the total resistance must decrease. Resistors placed in parallel will decrease the total resistance of the circuit. When the total resistance of the circuit decreases, the total current leaving the battery must therefore increase.

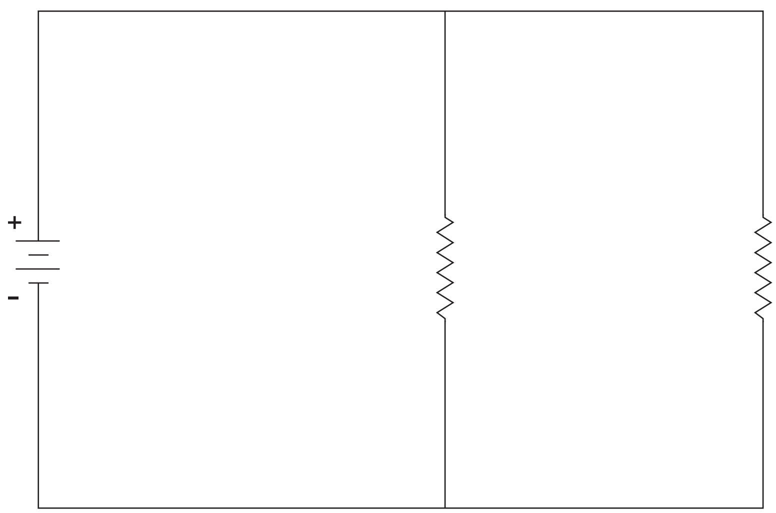


Figure 9.11 The total resistance of the circuit is decreased when resistors are placed in parallel.

Suggested Activity

Conduct an Investigation 9-1F on page 316

Reading Check

1. What name is given to a circuit that contains more than one pathway?
2. Two loads are connected in parallel. Compare the voltage across each load.
3. Two loads are connected in parallel. Must the current through one load equal the current through the other load?
4. What name is given to a location in a circuit where the circuit branches into more pathways or where pathways rejoin?
5. How does current entering a junction point compare to current leaving that same junction point?
6. If you add a resistor in parallel to an existing resistor, what happens to the total resistance in the circuit?

Explore More

The value of the total resistance of resistors connected in both series and parallel can be calculated. Find out how to calculate this total resistance. Begin your research at **www.bcscience9.ca**.

9-1D A Series of Lights

Find Out ACTIVITY

In this activity, you will construct a series circuit. Using voltmeters and ammeters, you will measure and analyze the voltage and current in this circuit. How do you think voltage and current change in a series circuit?

Safety

- If any wires become hot, disconnect the circuit.

Materials

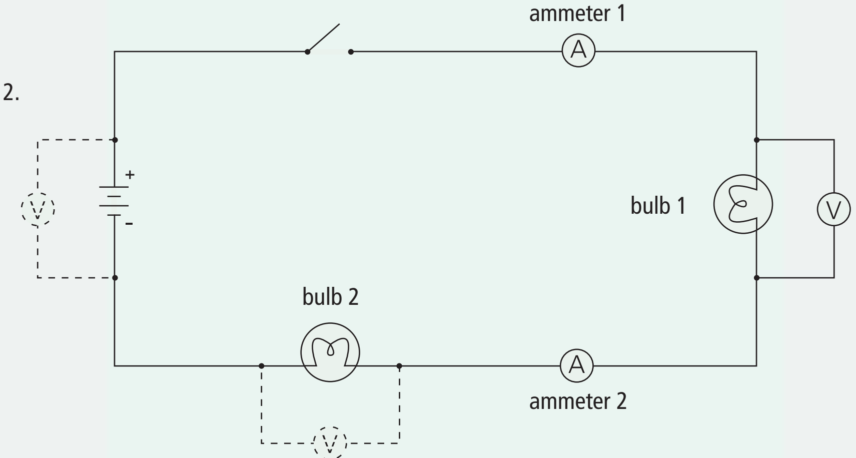
- two 1.5 V cells
- 2 different flashlight bulbs
- 2 ammeters
- voltmeter
- switch
- connecting wires

What to Do

1. Copy the following data table in your notebook. Give your data table a title.

Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
	Battery =

2. Construct the circuit shown in the diagram. The battery in this circuit is the two 1.5 V cells connected together positive to negative.



Construct this circuit for step 2.

Science Skills

Go to Science Skill 11 to learn more about how to use an ammeter and a voltmeter.

3. Close the switch and measure the current through ammeters 1 and 2. Record this measurement in your data table.
4. Using your voltmeter, measure and record the voltage across bulb 1.
5. Remove your voltmeter from bulb 1, and connect it across bulb 2. Measure and record the voltage across bulb 2.
6. Remove your voltmeter from bulb 2, and connect it across the two cells. Measure and record the voltage across the battery.
7. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Compare the current in ammeter 1 to the current in ammeter 2.
2. Compare the voltage across bulb 1 to the voltage across bulb 2.
3. Add bulb 1 voltage and bulb 2 voltage. Compare the total voltage lost on the two bulbs to the battery voltage.
4. In a short paragraph, explain how current and voltage change in a series circuit.

9-1E Parallel Lights

Find Out ACTIVITY

In this activity, you will construct a parallel circuit. Using voltmeters and ammeters, you will measure and analyze the voltage and current in this circuit. How do you think voltage and current change in a parallel circuit?

Science Skills

Go to Science Skill 11 to learn more about how to use an ammeter and a voltmeter.

Safety

- If any wires become hot, disconnect the circuit.

Materials

- two 1.5 V cells
- 2 different flashlight bulbs
- 3 ammeters
- voltmeter
- switch
- connecting wires

What to Do

1. Copy the following data table in your notebook. Give your data table a name.

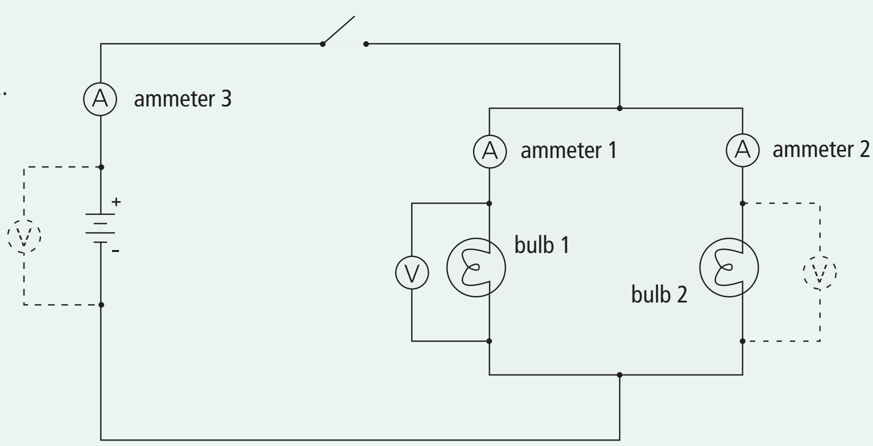
Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
Ammeter 3 =	Battery =

2. Construct the circuit shown in the diagram. The battery in this circuit is the two 1.5 V cells connected together positive to negative.
3. Close the switch, and measure the current through each of the ammeters. Record this measurement in your data table.
4. Using your voltmeter, measure and record the voltage across bulb 1.
5. Remove your voltmeter from bulb 1, and connect it across bulb 2. Measure and record the voltage across bulb 2.
6. Remove your voltmeter from bulb 2, and connect it across the two cells. Measure and record the voltage across the battery.
7. Clean up and put away the equipment you have used.

What Did You Find Out?

1. Compare the voltage across bulb 1 and bulb 2.
2. Compare the current through bulb 1 (ammeter 1) to the current through bulb 2 (ammeter 2).
3. Add the current in ammeter 1 and ammeter 2. Compare this total to the current leaving the battery (ammeter 3).
4. In a short paragraph, explain how current and voltage change in a parallel circuit.

Construct this circuit for step 2.



9-1F Resistors in Series and Parallel

SkillCheck

- Observing
- Measuring
- Explaining systems
- Evaluating information

Resistors slow down the flow of charge and change electrical energy into other forms of energy. By connecting resistors in different configurations, you can control both current and energy in the circuit. In this investigation, you will build both series and parallel circuits involving resistors. By measuring the current and voltage, you can use Ohm's law to calculate resistance.

Safety

- If any components become hot, open the switch immediately.
- If a power supply is being used instead of batteries, be sure to turn off the power supply while constructing the circuit.

Materials

- 6.0 V lantern battery or power supply
- 3 resistors of different sizes (100 Ω–1000 Ω)
- ammeter
- voltmeter
- switch
- connecting wires

Science Skills

Go to Science Skill 11 to learn more about how to use an ammeter and a voltmeter.

Question

How does the total resistance of a circuit change when resistors are connected in series and in parallel?

Procedure

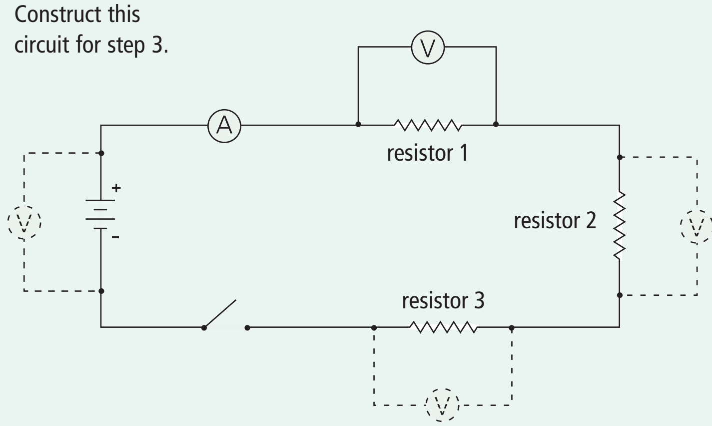
Part 1 Resistors in Series

1. Copy the following data table in your notebook. Give your table a title.

Resistance (Ω)	Voltage (V)	Current (A)
Resistor 1 =	Voltage across resistor 1 =	Total current leaving the battery =
Resistor 2 =	Voltage across resistor 2 =	
Resistor 3 =	Voltage across resistor 3 =	
	Voltage across battery =	

2. Using the resistor colour code, determine the resistance of each resistor. Record these values in your data table.
3. Construct the circuit shown in the diagram.

Construct this circuit for step 3.



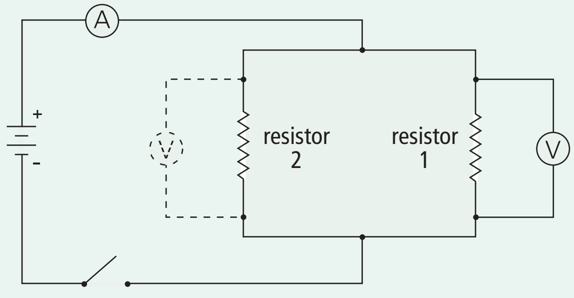
4. Close the switch, and measure the current through the ammeter. Record this current in your data table. If your ammeter is measuring milliamperes (mA), be sure to convert this to amperes (A).
5. Measure the voltage across resistor 1. Record this in your data table.
6. Move your voltmeter, and measure the voltage across the remaining resistors and the battery. Record each measurement in your data table.
7. Open the switch, and disassemble your circuit.

Part 2 Resistors in Parallel

8. Copy the following data table in your notebook. Give your table a title.

Resistance (Ω)	Voltage (V)	Current (A)
Resistor 1 =	Voltage across resistor 1 =	Total current leaving the battery =
Resistor 2 =	Voltage across resistor 2 =	
	Voltage across battery =	

9. Using the resistor colour code, determine the resistance of any two of your three resistors. Record these values in your data table.
10. Construct the circuit shown in the diagram below, using the two resistors you have recorded.



Construct this circuit for step 10.

11. Close the switch, and measure the current through the ammeter. Record this current in your data table.
12. Measure the voltage across resistor 1. Record this in your data table.
13. Move your voltmeter, and measure the voltage across resistor 2 and the battery. Record each measurement in your data table.
14. After you have taken all measurements, open the switch.
15. Clean up and put away the equipment you have used.

Analyze

Part 1

1. Use Ohm's law ($R = \frac{V}{I}$) to calculate the total resistance of your series circuit. (Use the battery voltage and the current leaving the battery.)
2. Compare the total resistance calculated in question 1 to the individual resistors used in the circuit. Is the total resistance greater than or less than the individual resistors?
3. Compare the voltage across each resistor. Does each resistor lose the same amount of voltage?
4. Add the voltages on each of the three resistors. Compare the total voltage lost on the three resistors to the battery voltage.

Part 2

5. Use Ohm's law to calculate the total resistance of your parallel circuit. (Use the battery voltage and the current leaving the battery.)
6. Compare the total resistance calculated in question 5 to the individual resistors used in the circuit. Is the total resistance greater than or less than the individual resistors?
7. Compare the voltage across each resistor. Does each resistor lose the same amount of voltage?

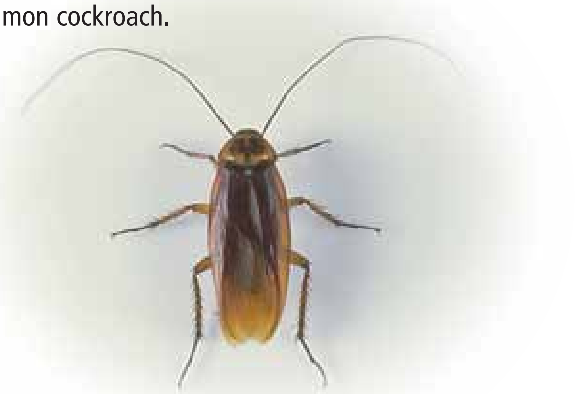
Conclude and Apply

1. Write a short paragraph that states the relationships of the following terms in a series circuit: total resistance, individual resistors, total voltage, voltage across each resistor.
2. Write a short paragraph that states the relationships of the following terms in a parallel circuit: total resistance, individual resistors, total voltage, and voltage across each resistor.

Science Watch

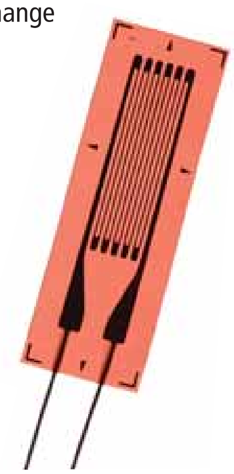
The Robotic Cockroach

Engineers are closely studying one of nature's most successful species in order to design and build better robots. Is that successful species human? No, it is the common cockroach.



Early robots were designed to have human characteristics, for example two legs. These early robots were slow and worked well only on smooth surfaces. Scientists now realize that arthropods (insects, spiders, crustaceans), for their size, possess greater strength, balance, agility, and speed than humans. The problem with a six-legged robot is co-ordinating each leg to produce the desired motion, even over rough terrain. The solution? Modern robots use a strain gauge to detect the pressure and motion of individual legs.

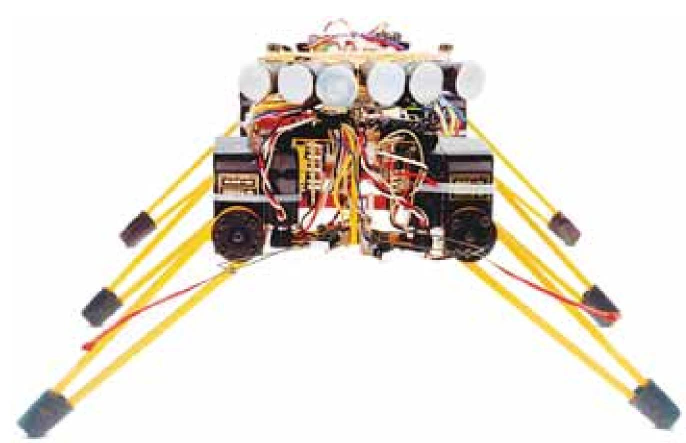
A strain gauge is a device used to measure the bend in an object. Invented in 1938, the most common strain gauge consists of a thin metallic foil or flexible semiconductor. Bending or deforming the foil causes its electrical resistance to change. This change in resistance can be used to detect pressure or motion.



A common application of a strain gauge is in an electronic bathroom scale. A strain gauge attached to a beam is bent when you step on the scale. The change in resistance due to the bend is then used to electronically calculate your weight or mass.

The idea of placing electronic strain gauges on the exterior of the robot was based on an insect design. Insects and spiders have biological strain gauges attached to their exoskeleton. These sense organs are located mostly near the joints and tips of the legs. The biological strain gauges in insects are as sensitive to motion as the receptors in the human ear are to sound. Strain gauges in insects regulate their walking movement. Robotic engineers are trying to closely copy what occurs in nature.

Recently designed six-legged robots are both quick and mobile. These robots can travel up to five body-lengths per second and can continue in a forward motion even when encountering small obstacles. Robots with such speed and balance could be useful for exploring dangerous areas such as toxic waste sites or active volcanoes and could function well on difficult terrain, such as that of the Moon or Mars.



Questions

1. Make a list of the advantages and disadvantages of a six-legged robot as compared to a two-legged robot.
2. (a) What electric property changes when a strain gauge is deformed?
   (b) What effect would this have on an electric circuit?
3. Engineers have studied insects to design better robots. Describe another technology that has been designed by studying nature.

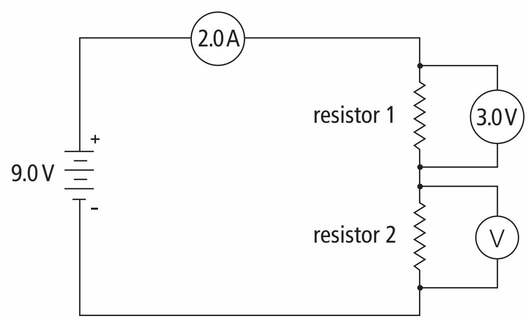
Check Your Understanding

Checking Concepts

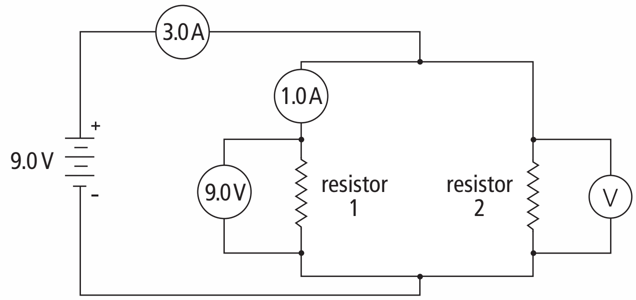
1. How is a parallel circuit different from a series circuit?
2. In a series circuit, how does the voltage supplied by the battery compare to the voltages on each load?
3. What happens to the total resistance of a series circuit when another resistor is added?
4. What happens to the total resistance of a parallel circuit when another resistor is added?
5. Two resistors are connected in parallel to a battery. What must be the voltage across these two resistors?
6. Is the current in one branch of a parallel circuit more than, less than, or equal to the total current entering the junction point of the circuit?

Understanding Key Ideas

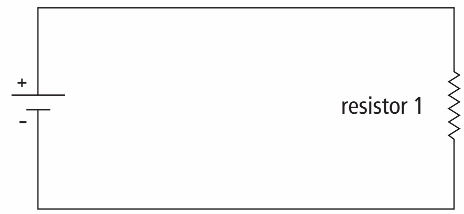
7. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2



8. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2

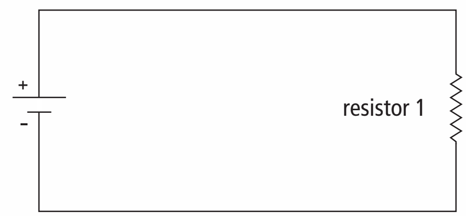


9. You are given the following circuit.



   A second resistor is now added in series with resistor 1.
   (a) Draw the new circuit diagram.
   (b) Comparing your new circuit to the original, describe the changes in:
      (i) total resistance
      (ii) current leaving the cell
      (iii) voltage across resistor 1

10. You are given the following circuit.



   A second resistor is now added in parallel with resistor 1.
   (a) Draw the new circuit diagram.
   (b) Comparing your new circuit to the original, describe the changes in:
      (i) total resistance
      (ii) current leaving the cell
      (iii) voltage across resistor 1

Pause and Reflect

Are the lights in your school connected in series or in parallel? Justify your answer using facts about series and parallel circuits.