QUAMICHAN LIGHTNING

Grade 9 Science May 20-26, 2020

Below you will find this week's science nine assignments. This week's assignment has only one student worksheet on electrivity and circuits, please read instructions carefully and finish the required worksheet. The 'extending your learning' is offered for those who want to go beyond the minimal requirements.

If you need or want assistance on the assignment provided below, we are offering 'office hours' using the platform 'Zoom' twice per week with one of the four science teachers: Mr. Kyle Conne, Ms. Alanna Skene, Mr. Aren Goodman and Mr. James Cutt. Please see the end of this document for this week's office hours. However, if you wish to speak directly with your science nine teacher, please do not hesitate to email them or ask a question on your classes Office 365 Team page at any time and they will respond in a timely manner. Submitting completed work: Please submit your completed work by May 26, 2020 via **your Office 365 Class Teams account, ideally by clicking the "Turned In" button or through email. Assignments and any relevant resources will be posted in your class' Teams Account.**

Learning Intentions:

1. Core Competencies of Communication, Thinking and Personal and Social Awareness and Curricular Competencies relating to making observations aimed at identifying students' own questions, including increasingly complex ones, about the world around them.
2. Big idea: Electric current is the flow of an electric charge
    - basic components include power source, load/resistor (lightbulbs, etc.), conductor and switch
    - types of circuits include series, parallel, short circuits
    - current flow in a circuit: alternating current (AC) and direct current (DC)
    - Voltage, current and resistance are related

Assignment Instructions:

Outline: Please access your Office.com Science Class Teams account and ensure that you can access the instructions, online videos and student worksheets. Please complete the student worksheets and turn them into your teacher.

Required materials:

- Science 9 May 20-26, 2020 Assignment # 7 Instructions
- BC Science nine textbook of chapters 8.2 and 9.1 and Electricity Datapages
- Electricity – Introduction to Circuits Student Worksheet

Criteria / Rubric:

Assessment is based on a 4-point proficiency scale:

emerging	developing	proficient	extending
The student demonstrates an initial understanding of the concepts and competencies relevant to the expected learning.	The student demonstrates a partial understanding of the concepts and competencies relevant to the expected learning.	The student demonstrates a solid understanding of the concepts and competencies relevant to the expected learning.	The student demonstrates a sophisticated understanding of the concepts and competencies relevant to the expected learning.

Assignment:

Please complete the "Electricity - Introduction to Circuits Student Worksheet". This worksheet along with the "Electricity Datapages" will introduce students to the concepts of electricity, circuits and how electrons flow through a circuit. Please follow the instructions on worksheet for each section. You will need to watch the video linked in the instructions of this assignment. You will also need to access a PhET simulation called "Circuit Construction DC Kit". Within this simulation, you will need to be able to draw or take screen shots of you work. If you are going to draw your circuits, please follow the symbols and guidelines presented in the "Eletricity Datapages". Once you have completed the worksheet, please "Turn-In" the worksheet in your Teams class account.

Extending Your Learning (Optional):

Please read the worksheet titled "Science 9 Enrichment Activity May 13-262, 2020". Student will need to read the article and watch the videos posted in the worksheet, complete the worksheet and submit it to their teacher by turning it in to their Teams class account

Office Hours: May 20-26 (via ZOOM: https://zoom.us/join):

Time - 1:00pm to 2:00pm

Thursday, May 21: Mr. James Cutt, Mrs. Alanna Skene and Mr. Aren Goodman

- Meeting ID: 916 773 99798
- Password: science

Monday, May 25: Mrs. Alanna Skene, Mr. James Cutt, and Mr. Aren Goodman

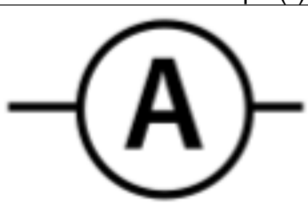
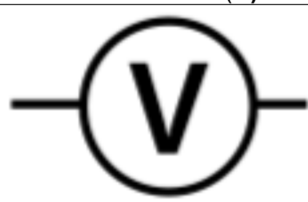
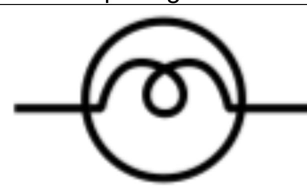
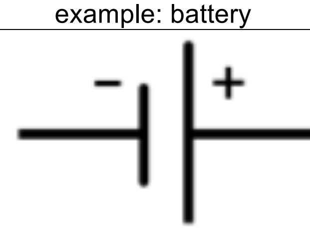
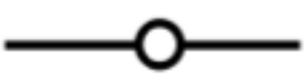
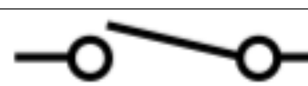
- Meeting ID: 990 8478 0100
- Password: science

ELECTRICITY REFERENCE

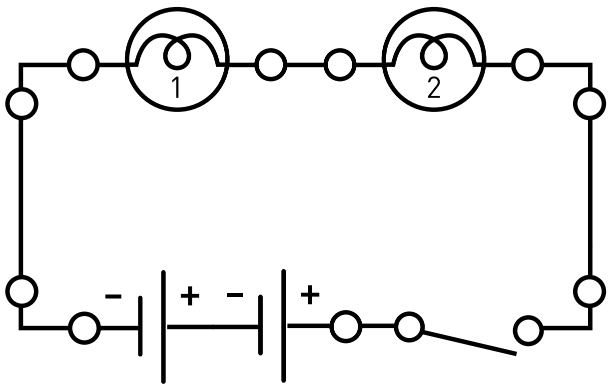
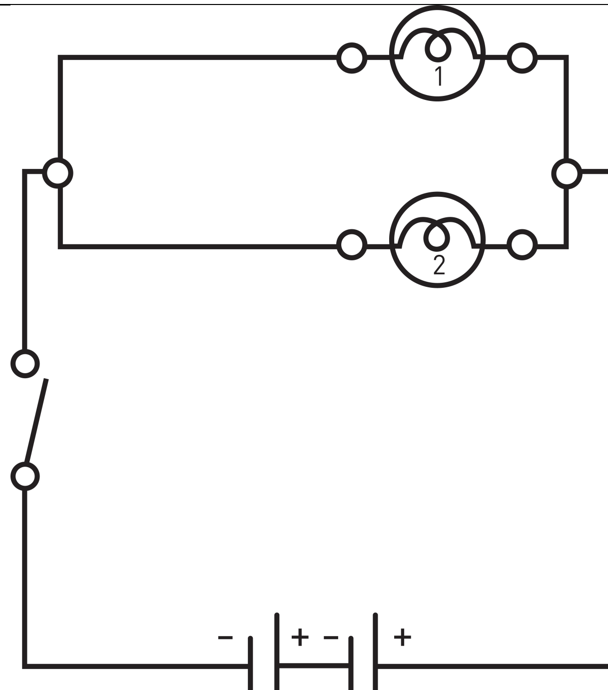
DEFINITIONS

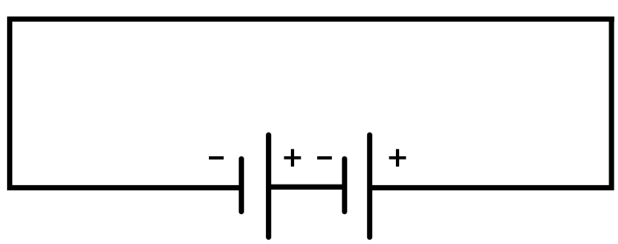
<table>
<tr><td colspan="2">Voltage
the amount of pressure/tension in a circuit
measured in Volts (V)</td><td colspan="2">Current
the flow of electrons in a circuit
measured in amps (I)</td><td colspan="2">Resistance
slows the flow of electrons (Resistor)
measure in Ohms (Ω)</td></tr>
<tr><td colspan="6">Voltage, Current and Resistance are linked together in electricity, because
voltage pushes current through resistance</td></tr>
<tr><td colspan="2">Source
Where power comes from example: battery, wall socket</td><td colspan="2">Switch
Can complete or break a circuit</td><td colspan="2">Load
Electrical component that uses electrons (power) example: light bulb, speaker</td></tr>
<tr><td colspan="3">Electric Circuit
a pathway for electrons to move
Essential components are: conductor, source, load</td><td colspan="3">Short Circuit
a circuit with no resistors/loads</td></tr>
</table>

SYMBOLS

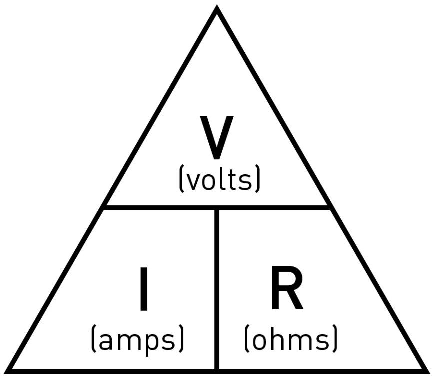
Ammeter measures current/amps (I)	**Voltmeter** measures volts (**V**)	**Load** example: light bulb	**Source** example: battery
 	 		
Connection Point	**Resistor** measured in **ohms/Ω**	**Switch**	**Wire**
			

CIRCUITS

Series Circuit	Parallel Circuit
Series Circuit a single path for electrons	**Parallel Circuit** when there is more than one path for electrons
	
SASS - Series **A**mps **S**tay the **S**ame current (I) stays the same voltage (V) changes	**PVSS - P**arallel **V**olts **S**tay the **S**ame voltage (V) stays the change current (I) changes

Short Circuit
Short Circuit a circuit with no resistors or loads


OHM'S LAW



What I Don't Know: $V = I \times R$, $I = \frac{V}{R}$, $R = \frac{V}{I}$:What I Know

CALCULATING VOLTAGE, RESISTANCE AND CURRENT

Example Word Problems
Use OHM'S LAW Formulas (above)

1. A hair dryer is connected to a 110v circuit. If the resistance is 20 ohms. How many amperes does the hair dryer draw?

What I Know	What I need to know
110v (volts) 20 ohms (resistance)	amps (I)
What formula I use	
$\mathbf{I = \frac{V}{R}}$ $I = \frac{110}{20}$ I = 5.5 amps	

2. A light bulb carries 0.5 amps when 4 volts is impressed across it. What is the resistance of the filament in the lightbulb?

What I Know	What I need to know
0.5 amps (I) 4v (volts)	R (ohms)
What formula I use	
$\mathbf{R = \frac{V}{I}}$ $R = \frac{4}{0.5}$ R = 8 ohms	

3. When a current of 2 amps is run through the coiled heating element of a water heater, the resistance of the element is 60 ohms.
   What is the voltage?

<table>
<tr><th>What I Know</th><th>What I need to know</th></tr>
<tr><td>2 amps (I)

60 ohms (R)</td><td>volts (V)</td></tr>
<tr><th colspan="2">What formula I use</th></tr>
<tr><td colspan="2">V = I x R   V = 2 x 60   V = 120 volts</td></tr>
</table>

Electricity - Introduction to Circuits Student Worksheet

Welcome to another week of virtual science at Quamichan. This week we are moving on to our physics unit. The 'Big Idea' in this unit is: Electric current is the flow of electric charge. Within the unit we will look at the components of circuits, different types of circuits (series, parallel, and short), and how the terms voltage, current, and resistance are linked.

To start, you will need to become familiar with the electricity simulation offered by PhET Interactive Simulations at the University of Colorado Boulder, under the CC-BY 4.0 license.

More specifically, this lab uses the **Circuit Construction Kit DC** simulation from PhET Interactive Simulations.

In addition, you will need to know how to take a screen shot of your work so you can include them in your assignment or you will need to be able to draw a circuit using the correct format and symbols (see textbook chapters and Electricity Datapages for assistance). If you are going to take screen shots of your work, you will need to determine how to do this with the device you are using. For example, with an iPad to take a screen shot you hold the home button and the power button at the same time (the iPad saves the image in you photos) or for a Mac computer, you can hold the command key, shift key and the number 4 key to get the screen shot icon to appear, you then highlight the area you want to save and it saves the screen shot on your desktop.

You will also require access to 'Electricity Reference Package' attached to this assignment to familiarize yourself with the different symbols and terms used in electricity.

Learning Goals

- Explore basic electricity relationships.
- Explain basic electricity relationships in series and parallel circuits.
- Use an ammeter and voltmeter to take readings in circuits.
- Provide reasoning to explain the measurements and relationships in circuits.

Part A: Initial Exploration

1. Open the 'Electricity Reference Package' and take a look at the pictures and illustrations. This is HUGELY helpful for this unit. Please become familiar with the terms, symbols and illustrations found in this reference package.

2. Please watch the following video on how to use the PhET simulation required in this assignment to show you how to use the simulation:
   https://www.youtube.com/watch?v=DcKzoOb1Ofc

3. Once you have watched the above video, please use the link below, open the Circuit Construction Kit DC simulation.

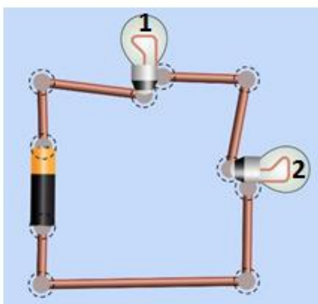
https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html

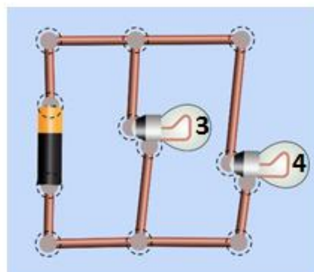
4. Select 'Intro,' and play around with what you see. Read the challenges (a-d) below, try to make some circuits in the simulation and answer the questions below. Take **two** screen shots of any of the challenges below and add these in the space directly below the challenge you attempted.
    a. Can you find the dollar bill? A dog
    b. Are you able to build a circuit that bursts into flame?
    c. Are you able to change the pictures in the left-hand menu into symbols for each picture?
    d. Are you able to change the brightness of a bulb by changing the voltage on a battery?

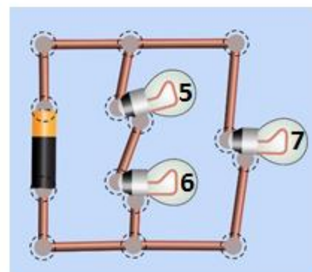
Part B: Prediction Questions

Now that you have explored the simulation, consider the pictures of each of these circuits and answer the questions below.

Series Circuit **Parallel Circuit** **Complex Circuit**







5. From the circuits above, predict which bulb (or bulbs) will be the brightest (state the number of the bulb in your answer). Why do you think this?

6. Describe what the difference is between a series circuit and a parallel circuit?

7. Current is the flow of charge (the flow of electrons, measured in coulombs/sec = amps) in a circuit. Describe how you think current will flow in the different types of circuits above (series, parallel and complex).

Part C: Develop your Understanding:

8. Explore the '**Intro**' screen of PhET Circuit Construction Kit DC
   a. Build a circuit that shows how to make a light bulb light up.
   b. Figure out how to measure current and voltage.
   c. Insert an image below of your circuit with the current **and** voltage measured.

9. Imagine you're an engineer making a string of battery powered holiday lights. If a bulb burns out current cannot flow through that bulb any longer, as if the wire at the bulb has been cut. Figure out how to hook up 2 light bulbs and a battery so that when one bulb burns out or is disconnected the other one stays lit. Create this circuit in the PhET simulation and take a screen shot.
   a. Insert images to illustrate that your circuit works as expected.

   b. Explain why you think it works.

10. Imagine that you want to make sure the battery for your string of lights will last as long as possible. A battery will last longer if it powers a circuit with low current. Using the PhET simulator, find a way to hook up a battery and 2 light bulbs so the least amount of current flows through the battery. Use the measurement tools in the simulation to check your design and take a screen shot to show your work.

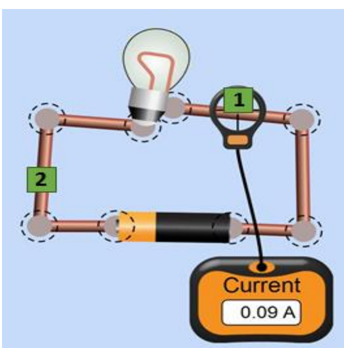
    a. Insert images to illustrate that your circuit works as expected.

    b. Explain why you think it works.

Part D: Measuring Current and Voltage in Different Types of Circuits:

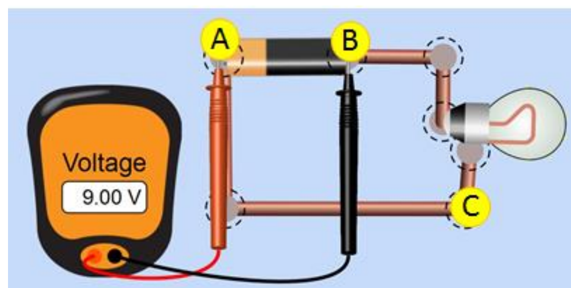
Instructions: Your goal is to write rules to describe how patterns of current and voltage in a circuit relate to the structure of the circuit. You will need to measure current and voltage in multiple places on several different circuits.

<table>
<tr><td>Examples:</td><td></td></tr>
<tr><th>Measuring Current</th><th>Measuring Voltage</th></tr>
<tr><td>“Current” is the flow of charge (flow of electrons), measured in Amps (Coulombs/s). An ammeter measures the current past a single point in the circuit. To measure current, you will need to “cut” the circuit and place the leads in between the cuts you have made.



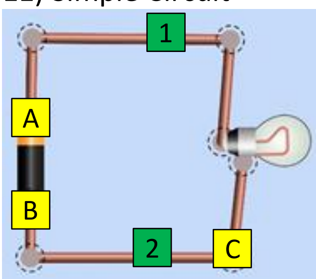
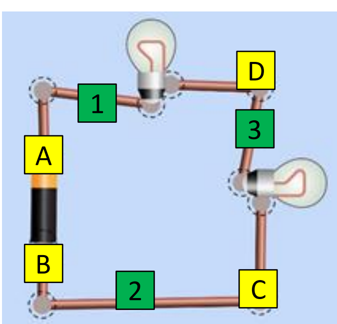
The current flowing through point 1 can be written as:

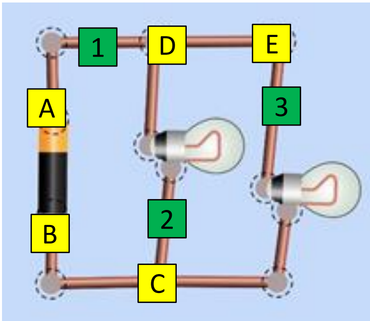
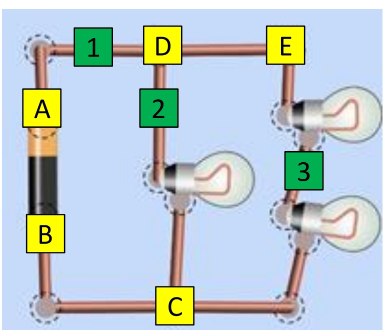
$I_1 = 0.09$.</td><td>“Voltage” is a measure of the difference in electric potential between two points (the amount of pressure). The voltmeter measures this difference by placing the two leads (pronounced “leeds”) at two different points in the circuit.



The voltage between points A and B can be written as $V_{AB} = 9$ V.</td></tr>
</table>

Use the table below to record your measurements and patterns you notice. Please take the measurements at the indicated places (Numbers = measure current/amps, Letters = measure voltage) . Please use a battery voltage of 9.0 Volts for each circuit in the table.

Circuit	Current Measurements (Amps)	Voltage Measurements (Volts)	What patterns do you notice?
11) Simple Circuit  	$I_1 =$ _______ A $I_2 =$ _______ A	$V_{AB} =$ _______ V $V_{AC} =$ _______ V $V_{BC} =$ _______ V	Where is the current the same? Where is the current different? Where does the voltage change? Where doesn't voltage change?
12) Series Circuit  	$I_1 =$ _______ A $I_2 =$ _______ A $I_3 =$ _______ A	$V_{AB} =$ _______ V $V_{AD} =$ _______ V $V_{DC} =$ _______ V $V_{BC} =$ _______ V	Where is the current the same? Where is the current different? Where does the voltage change? Where doesn't voltage change?

13) Parallel Circuit 	I_1 = _______ A I_2 = _______ A I_3 = _______ A	V_{AB} = _______ V V_{AD} = _______ V V_{DE} = _______ V V_{DC} = _______ V V_{BC} = _______ V	Where is the current the same? Where is the current different? Where does the voltage change? Where doesn't voltage change?
14) Complex circuit 	I_1 = _______ A I_2 = _______ A I_3 = _______ A	V_{AB} = _______ V V_{AD} = _______ V V_{DE} = _______ V V_{DC} = _______ V V_{BC} = _______ V	Where is the current the same? Where is the current different? Where does the voltage change? Where doesn't voltage change?

Part E: Summarize your Understanding:

15. Compare the patterns you see in a series circuit to the ones you see in series and parallel circuits. Write rules about voltage and current for each type of circuit. Refer to your answers in the 4th column of the table above ("What Patterns do you Notice") to help you. You must state rules about current, and voltage for each type of circuit.

    For example, "In a series circuit, I see that the current ….., whereas in a parallel circuit I see the current… ".

    a) Rules for Current:

    b) Rules for Voltage:

8.2 Electric Current

Current electricity is the flow of charged particles in a complete circuit. The unit for measuring electric current is the ampere (A), which is defined as one coulomb of charge passing a given point per second. An ammeter is a device used to measure current. To have a continuous flow of charge, the circuit must contain at least one source of voltage. In a circuit, electric potential energy is transformed into other forms of energy. Circuit diagrams are drawn to represent electric circuits.

Words to Know

amperes
circuit diagrams
current electricity
electric circuit
electric current
electric load

Did You Know?

A typical tiny computer chip contains more than a million circuits.

If you looked inside your computer or an old television or stereo, you would see many wires and components (Figure 8.7). All these wires and electronic components form pathways for transforming electrical energy into other forms of energy. A complete pathway that allows electrons to flow is called an **electric circuit**.

Figure 8.7 Inside a computer

8-2A Lighting It Up

Find Out ACTIVITY

In this activity, you will investigate ways to make a circuit using a battery, conducting wire, and a light bulb.

Safety

- If the wire becomes hot, disconnect it immediately.

Materials

- D cell
- 10 cm of insulated wire with both ends bare
- one 2.0 V flashlight bulb

What to Do

1. Using the flashlight bulb, wire, and battery, try to make the bulb light up. Once you are successful, disconnect the battery. Make a sketch of how these three materials were connected.
2. Rearrange the three materials and find a different way to make the bulb light up. Make a sketch of this second circuit.
3. Make a sketch that includes the three objects in such a way that the bulb will not light up. Then, using the materials, check if your sketch is correct.

What Did You Find Out?

1. Explain the difference between the sketches in steps 1 and 2 and the sketch in step 3.
2. Which of your sketches show a complete circuit?
3. Give an example of something in your home or community that represents a complete circuit.

Energy Around a Circuit

Any device that transforms electrical energy into other forms of energy is called an **electric load**. Some examples of a load are a light bulb, a buzzer, a heater, and a motor. Figure 8.8 illustrates a simple circuit containing a battery, conducting wires, and a buzzer. Chemical energy in the battery gives the electrons on the negative terminal electric potential energy. These electrons are attracted to the positive terminal of the battery. Since there is a pathway for them to travel, electrons leave the negative terminal and are pushed by the energy from the battery through the conducting wires to the buzzer. In the buzzer, the electrons' electric potential energy is transformed into sound energy. Electrons travel back to the battery through the complete circuit.

You can picture a waterslide (Figure 8.9) to help you think about an electric circuit.

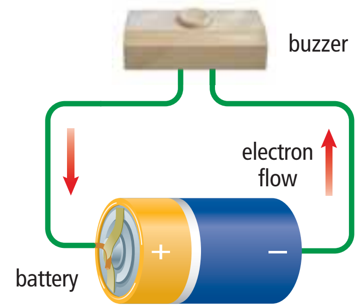
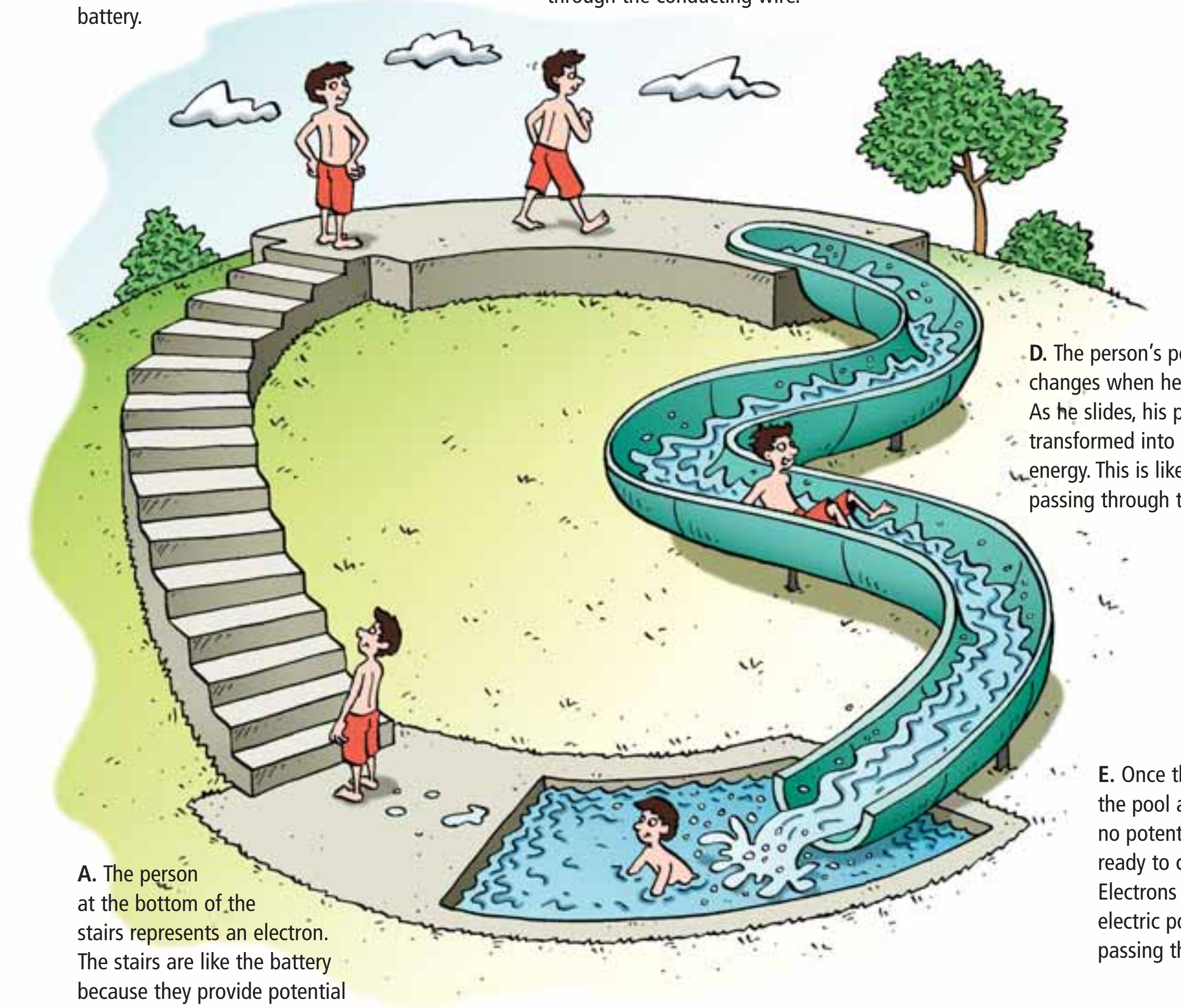


Figure 8.8 A battery provides the voltage that allows the electrons to travel through the circuit.



A. The person at the bottom of the stairs represents an electron. The stairs are like the battery because they provide potential energy. In order for the person to gain potential energy, he must climb the stairs.

B. Once the person is at the top of the stairs, he has potential energy. The number of stairs he climbed represents the voltage of the battery.

C. As the person walks horizontally along the top platform, he is not changing his potential energy. This is similar to the electrons passing through the conducting wire.

D. The person's potential energy changes when he descends the slide. As he slides, his potential energy is transformed into other forms of energy. This is like the electrons passing through the load.

E. Once the person stops in the pool at the bottom, he has no potential energy, and he is ready to climb the stairs again. Electrons in a circuit have zero electric potential energy after passing through the load.

Figure 8.9 One difference between the swimmer and the electron is that a single electron does not keep going around the circuit, whereas the swimmer may make many return trips down the slide!

Circuit Components and Diagrams

Even the most complex circuits are made of only four basic types of parts or components:

- *Source:* the source of electrical energy
- *Conductor:* the wire through which electric current flows
- *Load:* a device that transforms electrical energy into other forms of energy
- *Switch:* a device that can turn the circuit on or off by closing or opening the circuit

Suppose that you needed to have someone build an electrical circuit for you. You could describe what you needed using words, you could make an artist's sketch of the circuit, or you could take a photograph. Alternatively, you could make a circuit diagram. **Circuit diagrams** are diagrams that use symbols to represent the different components of the circuit. Figure 8.10 shows some common circuit symbols used in circuit diagrams.

Suggested Activities

Find Out Activity 8-2C on page 285
Conduct an Investigation 8-2E on page 287

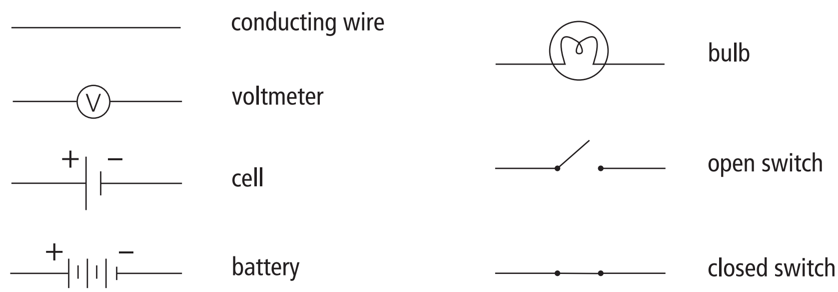


Figure 8.10 Circuit symbols help simplify complex circuits.

Circuit diagrams give an organized representation of the actual circuit. In order to make your circuit diagrams simple to read, be sure to meet the following criteria.

- Draw your diagrams using a ruler.
- Make all connecting wires and leads straight lines with 90° (right-angle) corners.
- If possible, do not let conductors cross over one another.
- Your finished drawing should be rectangular or square.

Figure 8.11 shows a sketch of a simple circuit and its circuit diagram. Check that the diagram meets all four of the criteria listed above.

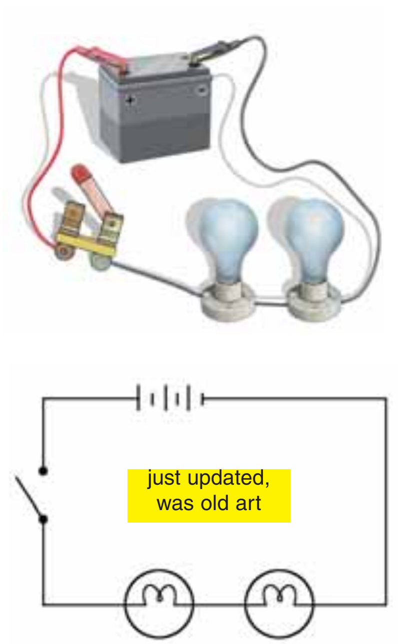


Figure 8.11 Drawing a circuit diagram is a quick and accurate way to model an electric circuit.

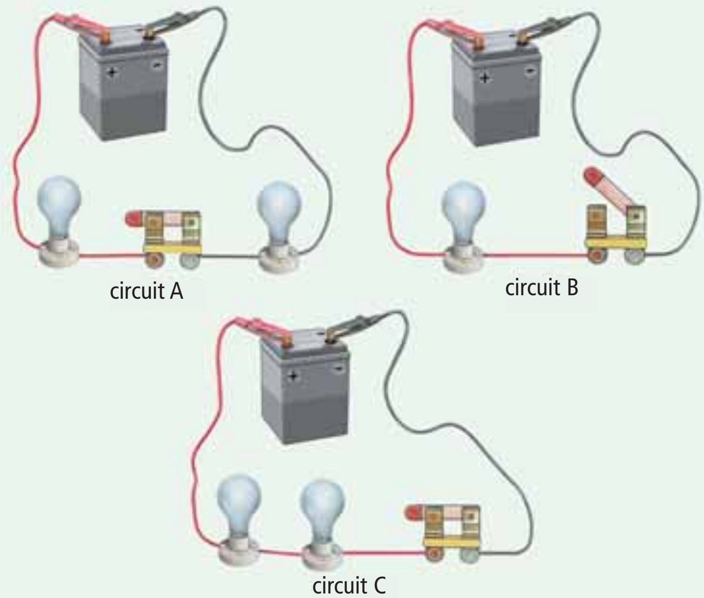
Reading Check

1. What other forms of energy can electrical energy be converted into by a load?
2. What is an electric circuit?
3. Explain how electrons in a circuit are like people on a waterslide.
4. What are the four basic components of a circuit?
5. What is the purpose of a circuit diagram?

8-2B Drawing Circuit Diagrams

Think About It

In a closed circuit, there can be no breaks in the path of electrons. An open circuit does not allow a flow of electrons because there is a break in the path. In this activity, you will draw and analyze circuit diagrams and decide which are open and which are closed.



What to Do

1. For each of the following circuit illustrations, draw its corresponding circuit diagram.

What Did You Find Out?

1. Which circuit(s) are closed circuits?
2. Which circuit(s) are open circuits?
3. In any of your closed circuits, identify the device that
   (a) is the source of electric potential energy
   (b) converts the electrical energy to other forms

Electrons Are So Pushy

In the circuits you have analyzed so far in this section, a battery supplies the energy to push electrons. Electrons are pushed from the negative terminal of the battery, along conducting wires through a load, for example a light bulb, and end up on the positive terminal of the battery. As soon as the battery is connected to the circuit, and the circuit is closed, electrons in every part of the circuit are pushing. That is why the light bulb goes on immediately.

This concept is similar to water in a hose connected to a tap, as shown in Figure 8.12. If the hose is already filled with water, as soon as you turn on the tap, water flows from the other end of the hose. The electrons leaving the negative terminal push the electrons ahead of them, just like water leaving the tap pushes on the water in front. You may remember from Chapter 7 that electrons do not need to touch in order to push other electrons. Electrons apply an action-at-a-distance force.

Figure 8.12 Electrons are pushed through a circuit in a similar way to how water is pushed through a hose.

Current Electricity and Static Electricity

Recall from Chapter 7 that static electricity is charge that remains stationary on an insulator. The charge in a battery is *not* an example of static electricity, even though the charge remains very nearly fixed on the battery terminals when the battery is not connected to a closed circuit. Once a battery is connected to a complete circuit, charge will flow continuously through the circuit. The continuous flow of charge in a complete circuit is called **current electricity**.

Did You Know?

On average, electrons travel only about 0.5 mm/s in a circuit.

Current: The Measure of Flow

You might have used the term "current" to describe the flow of water. How does the current in the Fraser River compare to the current in a small stream? Even though the water in the stream might move faster, the total volume of water in the Fraser River passing a point every second would be greater (Figure 8.13).

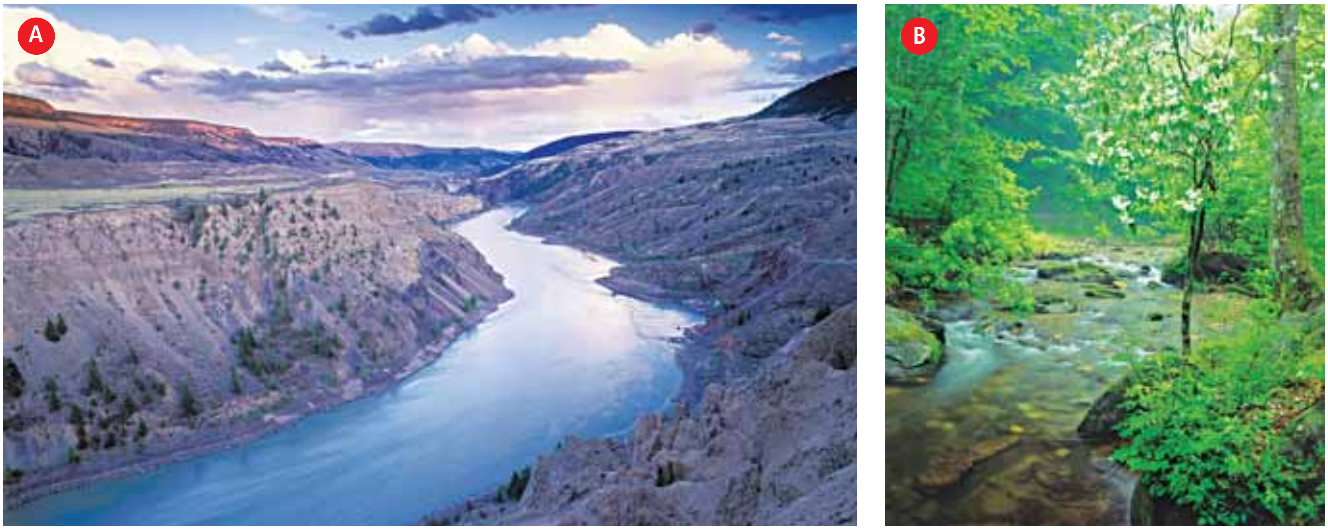


Figure 8.13 The volume of water flowing in the Fraser River (A) is greater than that of a stream (B). Therefore the river is said to have more current.

Scientists think about electric current as charge flowing in a conductor. **Electric current** is defined as the amount of charge passing a point in a conductor every second. Electric current is measured in **amperes** (A). This unit is named in honour of the French physicist André-Marie Ampère who studied the relationship between electricity and magnetism (Figure 8.14). Small currents are measured in milliamperes (mA); 1.0 A=1000 mA. An **ammeter** is a device used to measure the current in a circuit. An ammeter symbol on a circuit diagram looks like this:

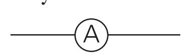


Figure 8.14 André-Marie Ampère (1775–1836)

Suggested Activity

Find Out Activity 8-2D on page 286

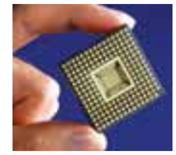
Conventional Current

In 1747, Benjamin Franklin wrote about charged objects as being electrified "positively" and "negatively," meaning that the positively charged objects contained more electric fluid (a greater, or positive amount) than the negatively charged objects (a lesser, or negative amount). This suggests that whenever electricity flows, it moves from positive to negative. Notice that a flow of charge from positive to negative is the opposite of the idea that we use today. For historical reasons, Franklin's idea is named *conventional current*. The concept of conventional current is still used to describe and calculate potential difference in a circuit. The concept of electron flow to describe current was not accepted by scientists until the late 1800s, after the discovery of the electron.

Reading Check

1. From which terminal of a battery are electrons pushed?
2. When a battery is connected to a circuit, all the electrons throughout the circuit immediately start to move. How is this possible considering that most of the electrons in the circuit are far from the battery?
3. Why is the charge in a battery not an example of static electricity?
4. What is the difference between static electricity and current electricity?
5. Define electric current.
6. What are the units of electric current?
7. What is the purpose of an ammeter?
8. How is electron flow different from conventional current?

Explore More



The design of a computer chip that contains millions of electric circuits is an example of nanotechnology. Nanotechnology is technology on a very small scale, usually of one micron or less. Find out more about nanotechnology and electrical components. Start your search at **www.bcscience9.ca.**

8-2C Pushing Electrons

Find Out ACTIVITY

When a battery is connected to a circuit, electrons in the conductor "push" or repel the other electrons nearby. The force between electrons is an action-at-a-distance force. In this activity, you will make a model for the motion of electrons in an electric circuit.

Materials

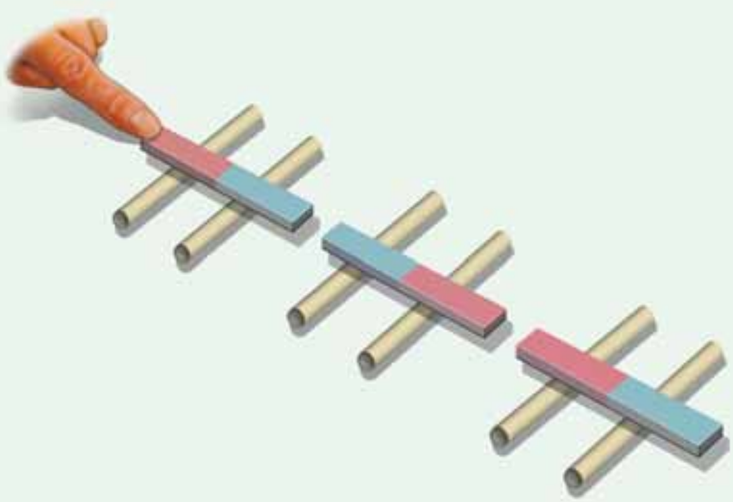
- 6 plastic drinking straws
- 3 bar magnets

What to Do

1. Using the straws as rollers, line up the magnets as shown in the illustration. Make sure the north and south ends of the magnets are oriented as shown.
2. Carefully push the end magnet and observe the motion of the other two magnets.

What Did You Find Out?

1. In a short paragraph, explain how this model demonstrates the motion of electrons in a circuit.
2. Your finger provided the "push" to start the magnets moving. In an electric circuit, what device "pushes" the electrons through the circuit?
3. Suppose the magnets of this model were replaced with wooden blocks the same size as the magnets. Why would the wooden block model not be as useful a model as the magnet model?



Carefully observe what happens to the magnets.

8-2D Measuring Current

Find Out ACTIVITY

In this activity, you will construct a circuit from a circuit diagram and use an ammeter to correctly measure current. If you need to convert the units for the current, remember that 1.0 A = 1000 mA.

Safety

- Make sure that the positive terminal of the ammeter is connected to the positive terminal of the battery, and the negative terminal of the ammeter is connected to the negative terminal of the battery.
- Never connect an ammeter directly across the terminals of a battery.
- There must be a load, like a light bulb, in the circuit to limit the flow of electrons.
- If the wires get hot, disconnect them immediately.

Materials

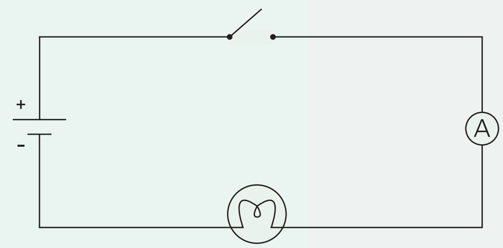
- 1.5 V cell
- various flashlight bulbs (1.5 V, 3.0 V, 6.0 V)
- connecting wires
- knife switch
- ammeter

What to Do

1. Copy the following table into your notebook. Give your table a title.

Bulb Type (V)	Measured Current (mA)

2. Using one of the light bulbs, connect the circuit as shown in the circuit diagram below.



In step 2, connect the circuit but leave the switch open.

Science Skills

Go to Science Skill 11 for information on using an ammeter.

3. Close the switch briefly and measure the current. Open the switch. Record the measurement in your data table.
4. Repeat step 3 with the remaining light bulbs.

What Did You Find Out?

1. (a) Which circuit had the largest current?
   (b) Which circuit had the smallest current?
2. Why is it important to connect the positive lead of the ammeter to the positive side of the battery?
3. What is the purpose of the switch in this circuit?
4. When you measure an unknown current, you should start with the meter set to a large current scale and then decrease the scale. Explain the purpose of starting with a higher setting.

8-2E Make a Model Circuit

Conduct an INVESTIGATION

Problem-Solving Focus

SkillCheck

- Communicating
- Modelling
- Explaining systems
- Working co-operatively

Criteria

- Your circuit needs to represent:
  - battery
  - electrical load
  - conducting wires
  - electrons
- You must show how energy is transformed by passing through the load.
- Electrons need to flow through your circuit for at least a minute or two.
- Your props are limited to a few small objects, such as tennis balls or bean bags.

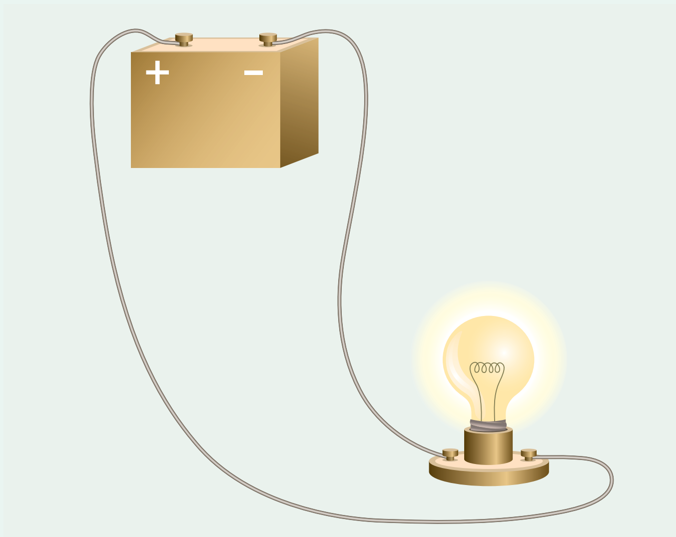
Using models to explain an idea or concept is a key skill in science. In this activity, you will make a human model of an electric circuit.

Problem

How can you design and build a human model of an electric circuit?

Design and Construct

1. Meet together with group members and make a group flowchart or other drawing of what happens in an electric circuit. Include as much detail as possible.
2. Discuss how the group could model the circuit. Be sure to include everyone's ideas and input.
3. Decide whether you will need any simple props.
4. Practise your presentation and refine your model.
5. Perform your presentation for other groups.



Make a human model to represent electrons flowing in an electric circuit.

Evaluate

1. How did your group show the change in potential energy in different parts of the circuit?
2. How did your group show how energy was transformed?
3. What was the most difficult part about making a human model of an electrical circuit?
4. In what ways was your model an inaccurate representation of an electric circuit?
5. How could you refine your model based on ideas from other groups' presentations?

Science Watch

The Faraday Cage

Most commercial airplanes avoid turbulent thunderstorms by flying over them or around them. But even with these precautions, it is estimated that every commercial airplane in Canada is hit by lightning at least once a year. How is it that the passengers and equipment on these planes avoid being damaged by this huge voltage? The answer to this was already known in 1836, long before planes were even invented.

Michael Faraday (1791–1867) was a brilliant chemist and physicist. During his studies of electricity, Faraday realized that excess charges were spread evenly over a conducting surface. Faraday hypothesized that if an object were totally enclosed by conducting material, any excess charge placed on the surface would not have an effect on the object inside. Every point on the conducting surface would be at the same electric potential and therefore there would be no potential difference (voltage) inside the enclosure.

To test his hypothesis, Faraday built a room covered with metal foil. A large Van de Graaff generator was used to apply a "lightning bolt" to the room. Inside the room, Faraday held an electroscope to detect static charge. As Faraday had predicted, the large voltage applied to the exterior of the room had no effect on objects inside the room. An enclosure of conducting material is now called a Faraday cage.

Since airplanes have a complete outer covering of conducting metal, they act as a Faraday cage. The charge from a lightning strike spreads evenly over the surface without creating voltage inside the aircraft. Sensitive instruments onboard the plane are protected by their own separate Faraday cage.

An automobile can also act as a Faraday cage, and therefore it is a relatively safe place to be during a thunderstorm. During a thunderstorm, you can turn the motor off and remain in the car without touching any of its metal parts until the storm has passed.

Faraday cages can even be used as clothing, allowing trained electricians to safely work near high voltage transmission cables without turning off the power. These workers wear a suit of heavy fabric that contains about 25 percent conducting metal fibres. This suit directs almost all the current around the body rather than through it.

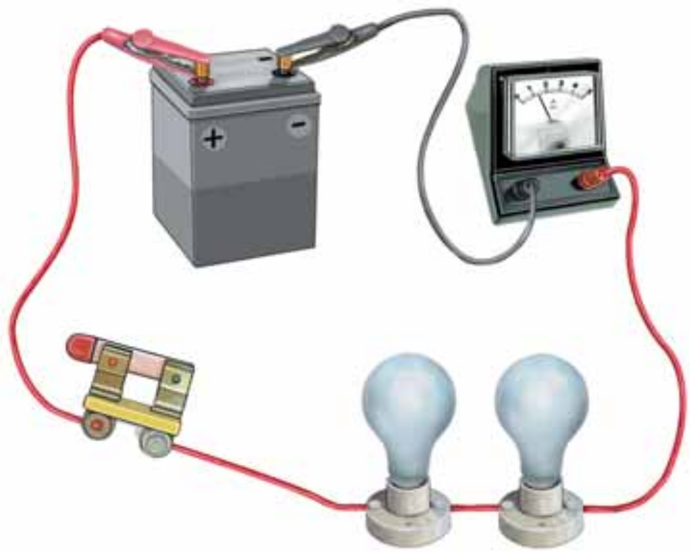
Check Your Understanding

Checking Concepts

1. What is the function of the battery in an electric circuit?
2. What is the function of the load in an electric circuit?
3. What are three different examples of loads?
4. Draw and label each of the following circuit symbols:
   (a) conducting wire
   (b) cell
   (c) battery
   (d) light bulb
   (e) open switch
   (f) closed switch
   (g) voltmeter
   (h) ammeter
5. What is the amount of charge passing a given point every second called?
6. State the correct units of electric current.
7. What device is used to measure electric current?

Understanding Key Ideas

8. What is the difference between electron flow and conventional current?
9. Explain the difference between static electricity and current electricity.
10. A circuit contains a 3.0 V battery and a light bulb. Suppose the battery were replaced by a 6.0 V battery. Would the electrical energy transformed in the light bulb increase or decrease? Use the example of a waterslide to explain your answer.
11. Explain how electrons are "pushed" through a conductor without having to touch other electrons.
12. Explain how two conductors could have different current even though the electrons in each conductor are travelling at the same speed.
13. Draw a circuit diagram for the circuit shown.



Pause and Reflect

In this chapter, a waterslide was used as an analogy, or a comparison, for the energy transfer in an electric circuit. In that analogy, the stairs represented the battery, the person represented the charges, and the slide represented the loss of electrical energy on a load. What other analogy can you develop for an electric circuit? In your description, identify the battery, the load, and the charge.

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

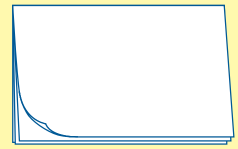
In this chapter, you will

- **measure** current and voltage in both series and parallel circuits
- **model** series and parallel circuits
- **evaluate** energy consumption of common electric devices

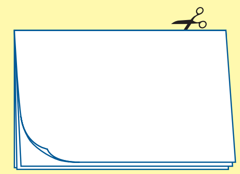
FOLDABLES™
Reading & Study Skills

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

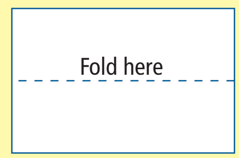
STEP 1 **Fold** two vertical sheets of paper in half horizontally.



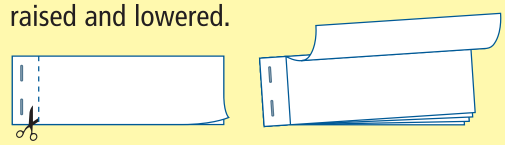
STEP 2 **Cut** along the fold lines, making four half sheets. (**Hint:** Use as many half sheets as necessary for additional pages in your book.)



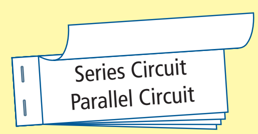
STEP 3 **Fold** each half sheet in half horizontally.



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

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

Safety

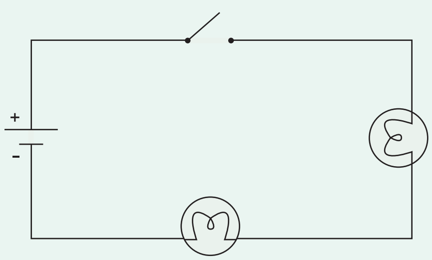
- Disconnect the circuit if any wires become hot.

Materials

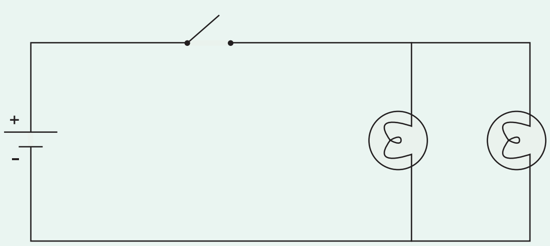
- 1.5 V cell
- two 2.0 V light bulbs
- switch
- connecting wires

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.

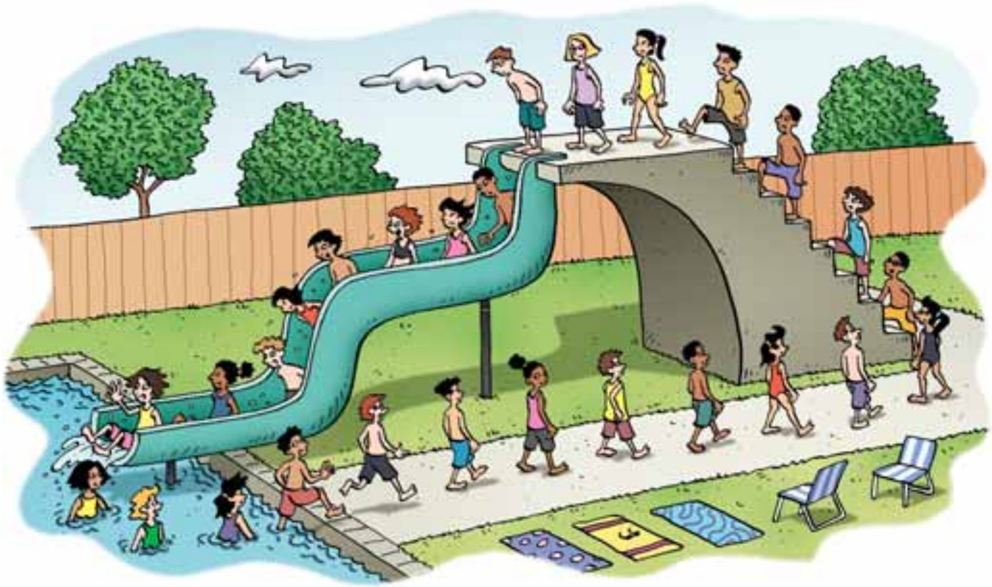


Figure 9.3 Everyone who uses this slide follows the same path.

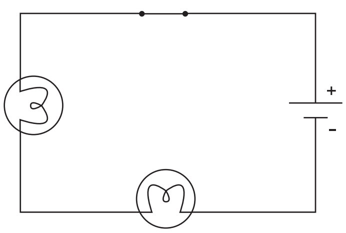


Figure 9.4 Electrons leaving the negative terminal of the battery in this circuit have only one path to return to the battery at the positive terminal.

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.

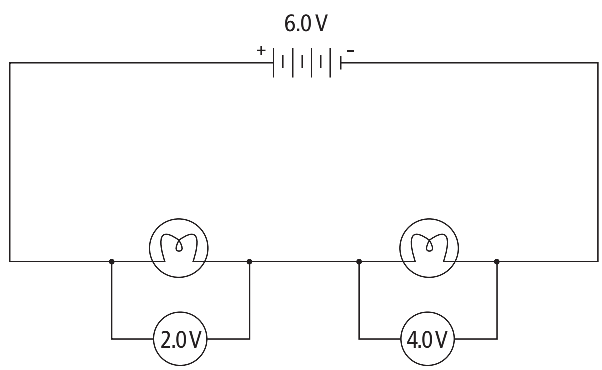


Figure 9.5 Each load in a series circuit loses a portion of the total voltage.

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

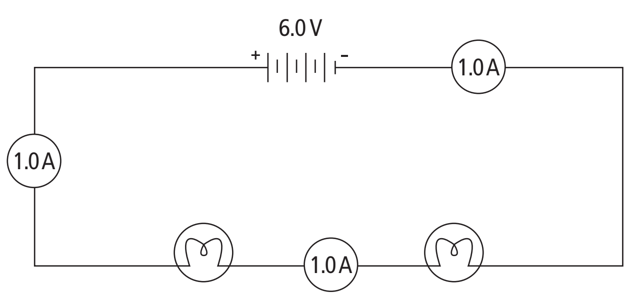


Figure 9.6 The current is the same throughout a series circuit.

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.

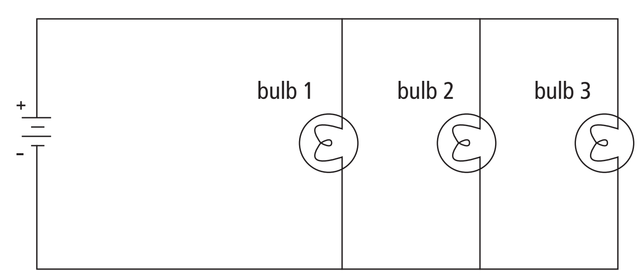


Figure 9.7 Electrons leaving the battery have three possible ways to return to the battery in this circuit.

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.

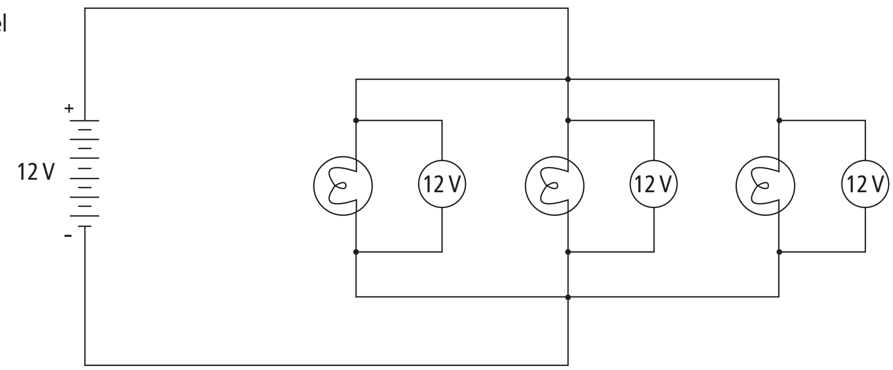
What Did You Find Out?

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.

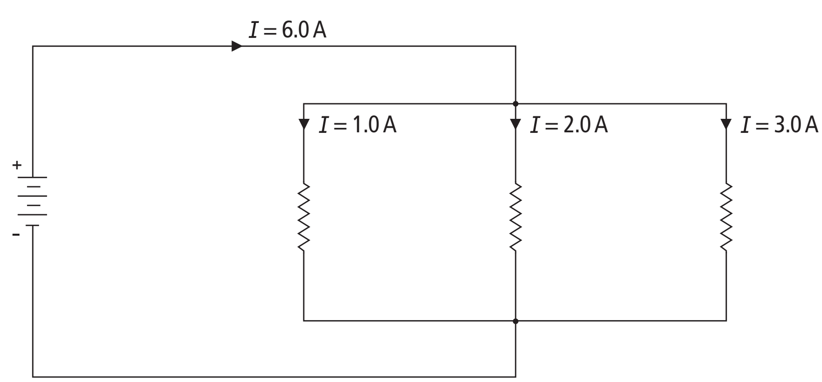
Figure 9.10 shows a battery connected to three different resistors connected in parallel. The total current leaving the battery divides into three possible pathways. The location where a circuit divides into multiple paths or where multiple paths combine is called a **junction point**. No current is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

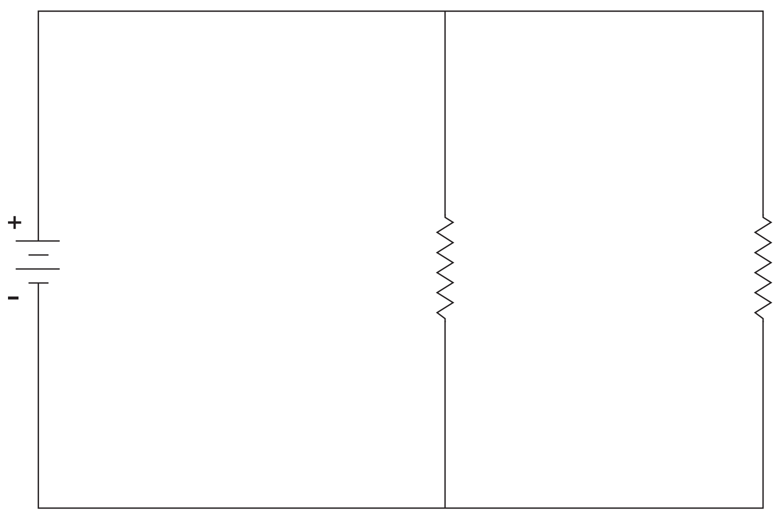


Figure 9.11 The total resistance of the circuit is decreased when resistors are placed in parallel.

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?

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
- 2 ammeters
- voltmeter
- switch
- connecting wires

What to Do

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

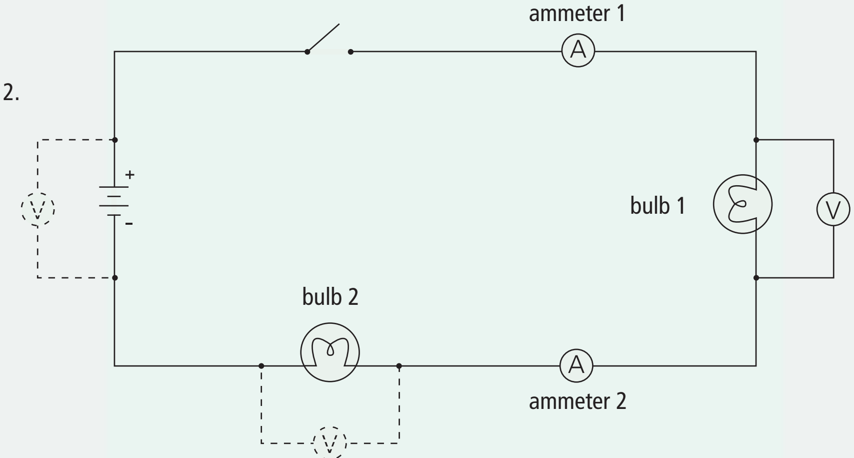
Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
	Battery =

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.
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.

Construct this circuit for step 2.



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?

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

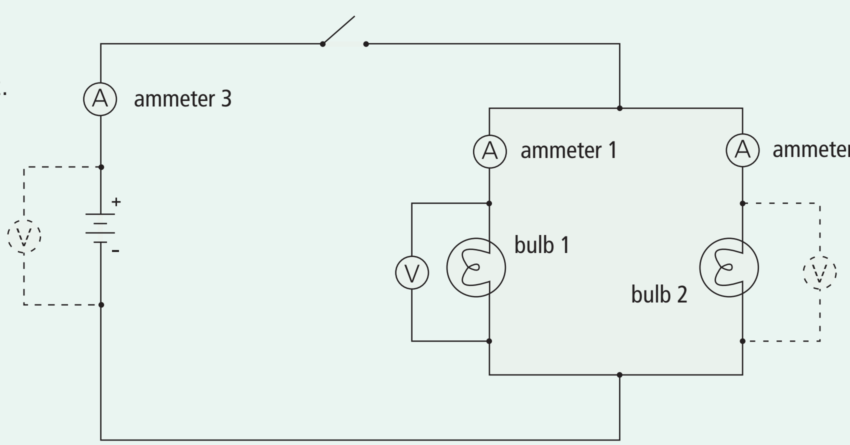
What to Do

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.

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 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.

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.

Question

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

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.

Procedure

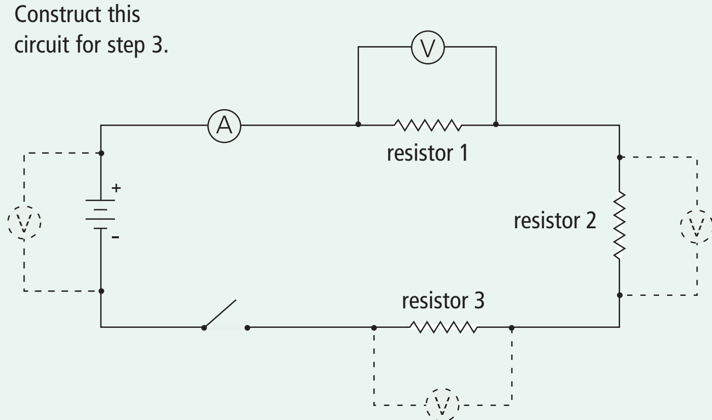
Part 1 Resistors in Series

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.



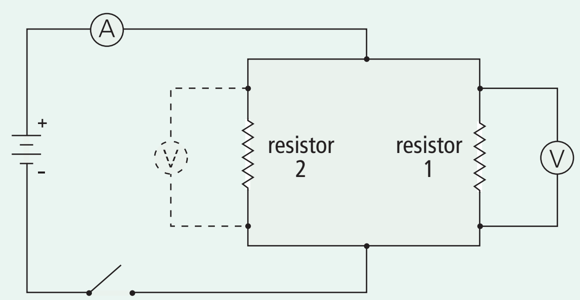
4. Close the switch, and measure the current through the ammeter. Record this current in your data table. If your ammeter is measuring milliamperes (mA), be sure to convert this to amperes (A).
5. Measure the voltage across resistor 1. Record this in your data table.
6. Move your voltmeter, and measure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

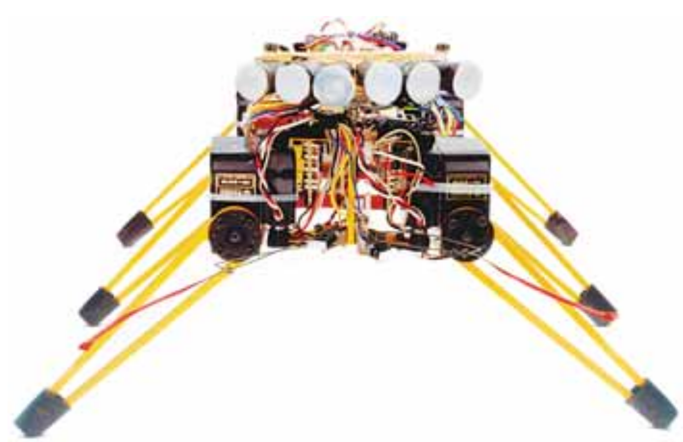
Early robots were designed to have human characteristics, for example two legs. These early robots were slow and worked well only on smooth surfaces. Scientists now realize that arthropods (insects, spiders, crustaceans), for their size, possess greater strength, balance, agility, and speed than humans. 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.

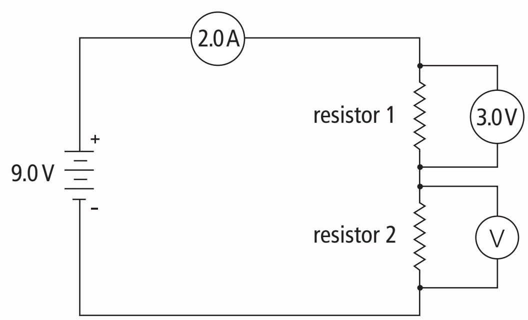
Check Your Understanding

Checking Concepts

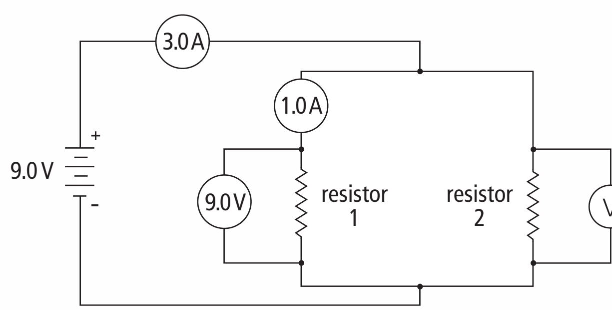
1. How is a parallel circuit different from a series circuit?
2. In a series circuit, how does the voltage supplied by the battery compare to the voltages on each load?
3. What happens to the total resistance of a series circuit when another resistor is added?
4. What happens to the total resistance 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

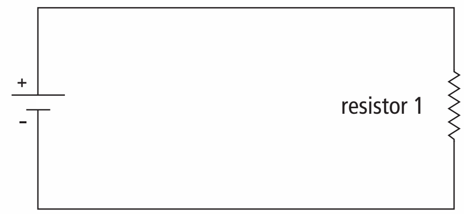
7. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2



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

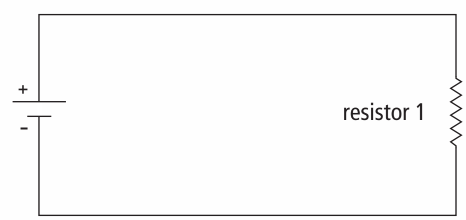


9. You are given the following circuit.



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.