QUAMICHAN LIGHTNING

Grade 9 Science May 27- June 2, 2020

Below you will find this week's science nine assignments. This week's assignment has only one student worksheet on electricity, circuits and Ohm's Law, 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 June 2, 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
    - Ohm's Law (V=IR)
    - Relative dangers of current and voltage

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 27 – June 2, 2020 Assignment # 8 Instructions
- BC Science nine textbook of chapters 8.2 and 8.3 (and 9.1 from Assignment #7) and Electricity Datapages
- Electricity – Circuits Review and Ohm's Law 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 - Circuits Review and Ohm's Law Student Worksheet". This worksheet along with the "Electricity Datapages" will introduce students to the concepts of electricity, circuits, how electrons flow through a circuit and how resistance, current and voltage are related through Ohm's Law. 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.

<u>Extending Your Learning (Optional):</u>

Please read the worksheet titled “Science 9 Enrichment Activity May 13-26, 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. This Enrichment activity’s due date has been extended.

<u>Office Hours: May 27 – June 2 (via ZOOM: https://zoom.us/join):</u>

<u>Time - 1:00pm to 2:00pm</u>

Thursday, May 28: Mr. James Cutt, Mrs. Alanna Skene and Mr. Aren Goodman

- Meeting ID: 916 773 99798
- Password: science

Monday, June 1: Mrs. Alanna Skene, Mr. James Cutt, and Mr. Aren Goodman

- Meeting ID: 990 8478 0100
- Password: science

Electricity – Circuits Review and Ohm's Law Student Worksheet

Welcome to week eight (has it actually been 2 months since we had regular school....). This week we are continuing our exploration of electricity, with a focus now on Ohm's Law.

Part A: Review (Chemistry)

Please write the formula or name corresponding to the given name or formula for the following ionic compounds. You can use the "subscript"  button in the "Home" bar to make small numbers.

Hints:

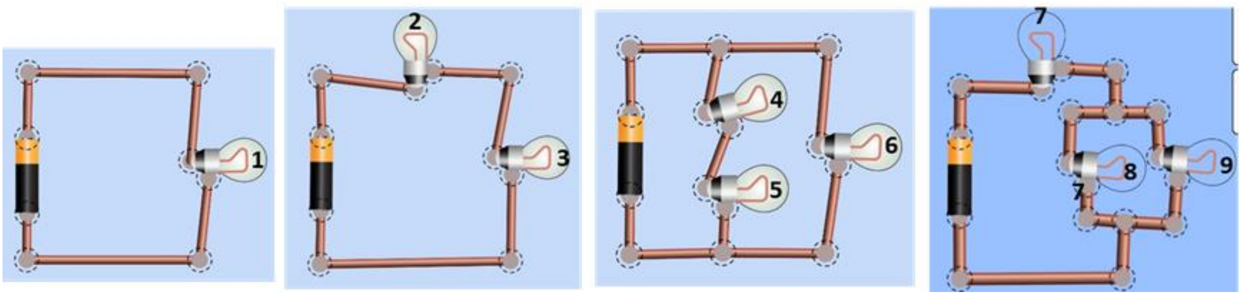
1. *For every question ask yourself, "Is this covalent or ionic?".*
2. *If the question is covalent, use prefixes and DO NOT BALANCE charges. If you need help, use the flow chart for covalent compounds found on the back of the chemistry reference package.*
3. *If the question is ionic, you need to draw a t-chart to balance the charges. DO NOT use prefixes. If you need help, use the flow chart for ionic compounds found on the back of the chemistry reference package.*
4. *If an element ends in something other than 'ide' it might be polyatomic. Treat these as ionic compounds. We have created these in **bold** below.*

Ammonium phosphide	B_3P_5
Manganese (II) sulfide	$Cr_3(PO_4)_2$

Part B: Review (Circuit Knowledge - Test your Understanding)

Please review your answers for Assignment # 7 to make your predictions below.

1. Predict from your rules above, the order of the light bulbs in these circuits from brightest to dimmest. Some bulbs might be the same brightness.



a) Order the bulbs by increasing brightness (dimmest to brightness).

b) After you make your rankings, build circuits to check your answers and list the correct ranking below. **Insert images** from the PhET simulation to support your sequence.

c) Did your rules allow you to correctly rank the bulb brightness? If not, correct your rules in #15.

d) Did you use any meters to help you make your list? If so, explain why.

2. In this question, you will need to make a flashlight that has two batteries and a lightbulb.

a) Predict how you would hook them up to make the brightest flashlight and explain why.

b) Build circuits in the PhET simulator to check your answer and insert images from the simulation for evidence.

Part C: Relationship between Current, Voltage and Resistance:

Voltage, current, and resistance are key terms in electricity. As you are watching the following video decide on a single word you could use to describe voltage, a single word to describe current and a single word to describe resistance.

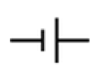
Video: What are Volts, Ohms, and Amps? Daniel Sullivan

https://www.bing.com/videos/search?q=volts%2c+ohms+and+amps&docid=608027284167067004&mid=669E5EF83B99D710E2D3669E5EF83B99D710E2D3&view=detail&FORM=VIRE

3. In the following table, write a single word to describe each of the following electricity terms.

Electricity term	Definition	Single word to describe the electricity term.
voltage	The amount of pressure/tension in a circuit.	
current	The flow of electrons in a circuit.	
resistance	Slows the flow of electrons	

Using the information you gathered in the simulations from last week's assignment (Assignment #7), and the 'Electricity Reference Package,' build the following circuits. Note, you must use symbols for the parts of the circuits, not the actual images.

For example: Use the symbol for battery,  not a picture of a battery. 

a. Build a series circuit with one battery (set to 3V), 2 bulbs, and a switch that controls all the bulbs. Place a screen shot below.

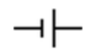
b. What happens to the brightness of the bulbs when you add another bulb in series?

c. Build a parallel circuit with one battery (set to 3V), 2 bulbs, a switch that controls one of the bulbs, and a switch that controls all the bulbs. Place a screen shot below.

d. What happens to the brightness of the bulbs as you add another bulb in parallel?

Voltage, current and resistance are related in electricity. This can be summed up in the phrase: **voltage pushes current through resistance**. Complete the following to discover this relationship.

4. For the following circuit, select the images (actual pictures) of the components.

(Example: Use the picture of a battery,  **not** the symbol for a battery 

- a. Build a series circuit using PHET with one battery (set to 9V), one bulb and one ammeter (this measures current).
- b. Click on the bulb so the 'resistance' sliding bar appears at the bottom of the screen.
- c. What happens when you lower the resistance of the bulb to zero?
- d. What happens in 'c' above is called a 'short circuit' and is the cause of many house fires. Why do you think this happens?
- e. Move the resistance sliding bar. Record what happens:
    - a. As you increase the resistance, what happens to the brightness of the bulb?
    - b. As you increase the resistance, what happens to the value on the ammeter?
    - c. Set the resistance to 20 ohms. What is the value on the ammeter (in other words, what is the current flowing through the circuit?)?
    - d. Multiply the value on the ammeter (current) by the resistance of the bulb. What value did you get?
    - e. The above value should equal the voltage of the battery. Is this true?

Part D: Ohm's Law:

You just proved voltage pushes current through resistance. But you can also do this with a math equation using the formula V=IR, where V=voltage, I=current, and R=resistance. This is called Ohm's Law.

5. Look at your 'Electricity Datapages' and read the 'Ohm's Law' section. There are three examples, each one calculating either voltage (V), current (I), or resistance (R). Use the examples to solve the following problems.

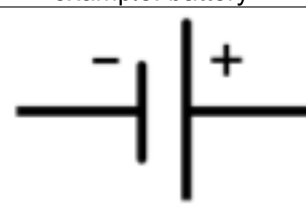
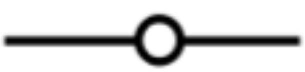
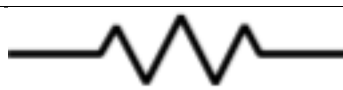
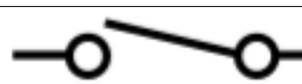
   a. If V= 10 V and R = 5Ω, what is the current (I)?
   b. If V = 3.5V and R = 10Ω, what is the current?
   c. If V = 10V and I = 2A, what is the resistance?
   d. If V = 3.5V and I = 0.5A, what is the resistance?
   e. If I = 11A and R = 3Ω, what is the voltage?
   f. If I = 7A and R = 4.5Ω, what is the voltage?
   g. A toaster has resistance of 8.6Ω and a current of 14A. What is the voltage?
   h. A coffee machine has a voltage of 120V and a resistance of 100Ω. What is the current?
   i. An iron has a voltage of 120V and a current of 4.6A. What is the resistance?

ELECTRICITY REFERENCE

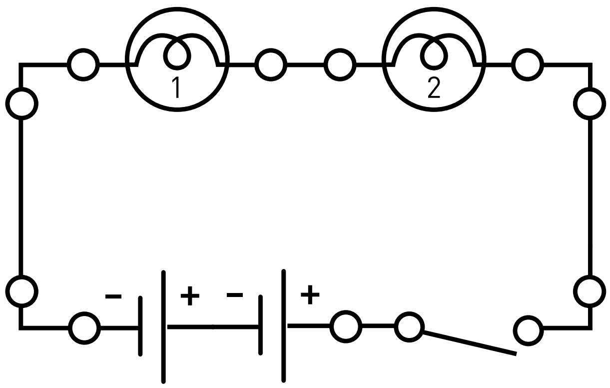
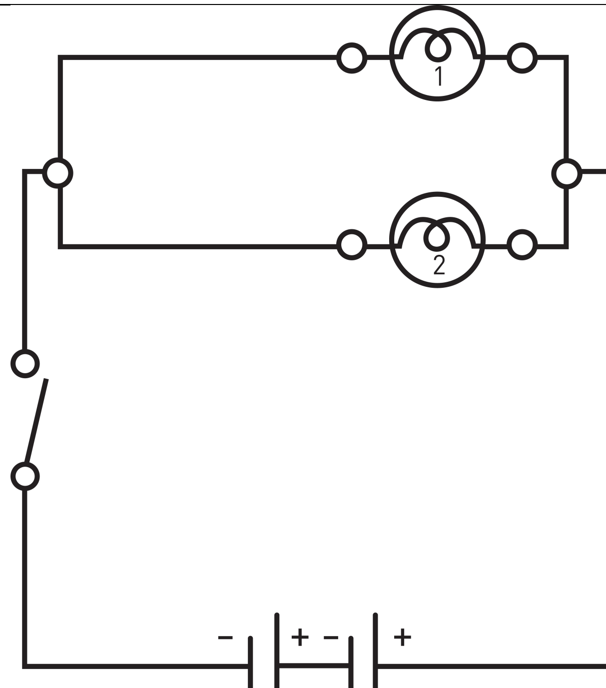
DEFINITIONS

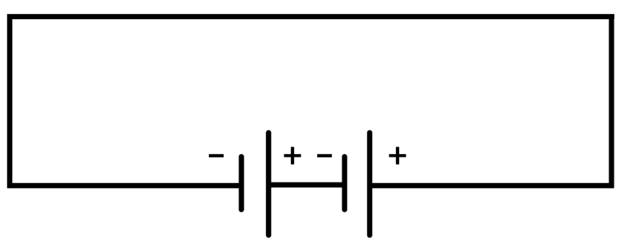
<table>
<tr>
<td colspan="2">Voltage
the amount of pressure/tension in a circuit
measured in Volts (V)</td>
<td colspan="2">Current
the flow of electrons in a circuit
measured in amps (I)</td>
<td colspan="2">Resistance
slows the flow of electrons (Resistor)
measure in Ohms (Ω)</td>
</tr>
<tr>
<td colspan="6">Voltage, 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

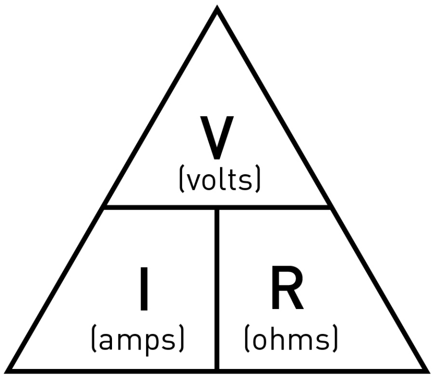
<table>
<tr>
<td>Ammeter
measures current/amps (I)</td>
<td>Voltmeter
measures volts (V)</td>
<td>Load
example: light bulb</td>
<td>Source
example: battery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection Point</td>
<td>Resistor
measured in ohms/Ω</td>
<td>Switch</td>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

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 a circuit with no resistors or loads


OHM'S LAW



What I Don't Know $\left\{ \begin{array}{c} V = I \times R \\ I = \dfrac{V}{R} \\ R = \dfrac{V}{I} \end{array} \right\}$ **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?

<table>
<tr><th>What I Know</th><th>What I need to know</th></tr>
<tr><td>110v (volts)

20 ohms (resistance)</td><td>amps (I)</td></tr>
<tr><th colspan="2">What formula I use</th></tr>
<tr><td colspan="2">$\mathbf{I = \dfrac{V}{R}}$ $I = \dfrac{110}{20}$ I = 5.5 amps</td></tr>
</table>

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?

<table>
<tr><th>What I Know</th><th>What I need to know</th></tr>
<tr><td>0.5 amps (I)

4v (volts)</td><td>R (ohms)</td></tr>
<tr><th colspan="2">What formula I use</th></tr>
<tr><td colspan="2">$\mathbf{R = \dfrac{V}{I}}$ $R = \dfrac{4}{0.5}$ R = 8 ohms</td></tr>
</table>

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?

What I Know	**What I need to know**
2 amps (I) 60 ohms (R)	volts (V)

What formula I use		
V = I x R	V = 2 x 60	V = 120 volts

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.

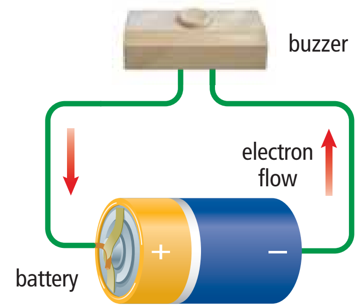


Figure 8.8 A battery provides the voltage that allows the electrons to travel through the circuit.

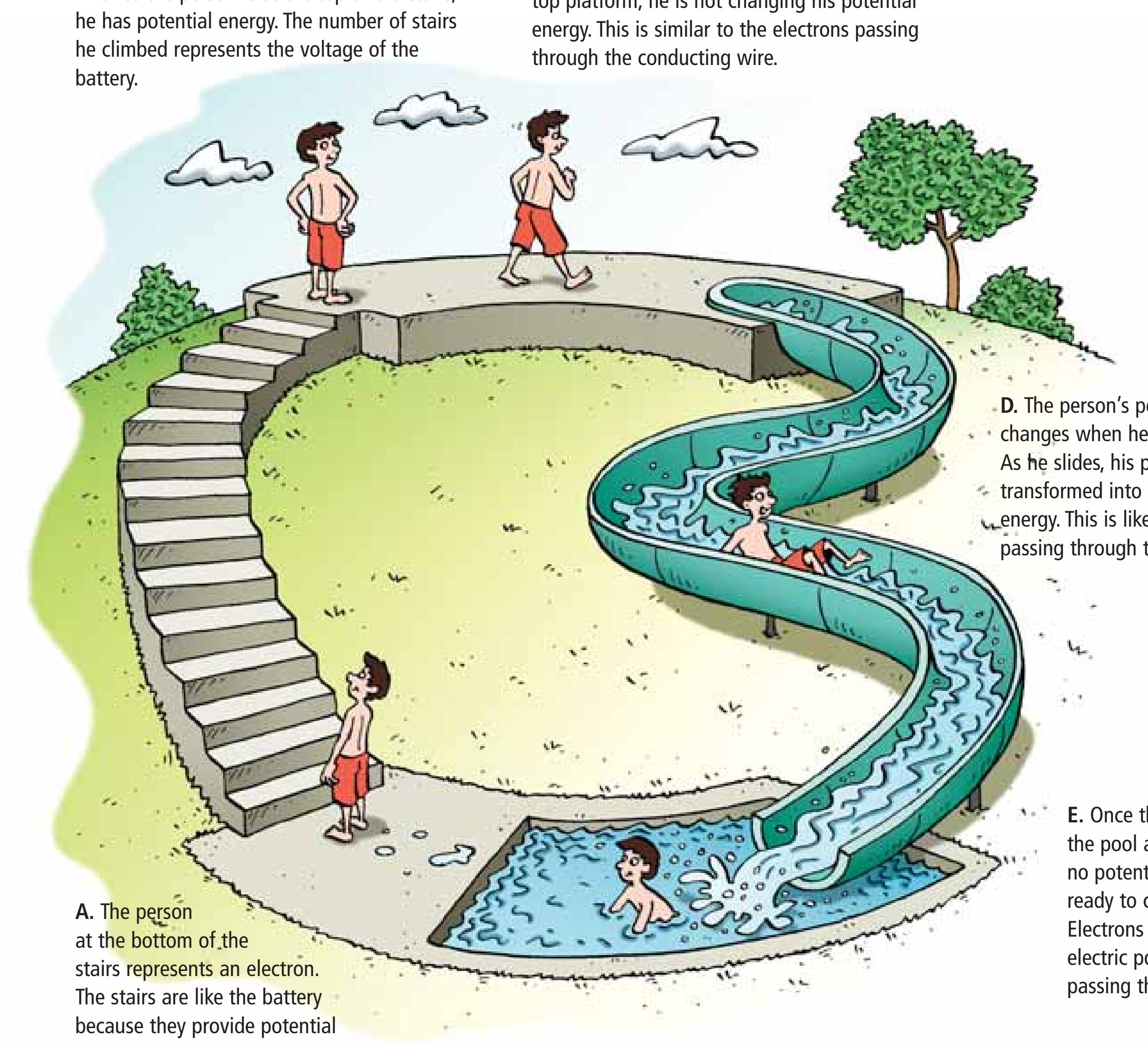


Figure 8.9 One difference between the swimmer and the electron is that a single electron does not keep going around the circuit, whereas the swimmer may make many return trips down the slide!

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

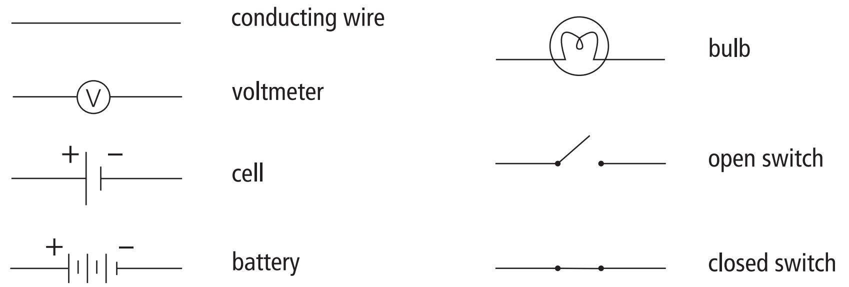


Figure 8.10 Circuit symbols help simplify complex circuits.

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.

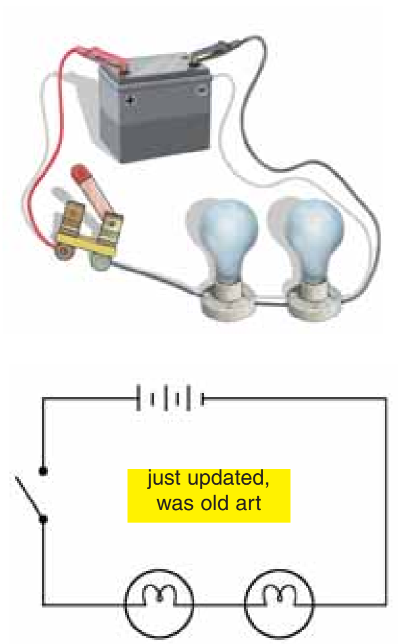


Figure 8.11 Drawing a circuit diagram is a quick and accurate way to model an electric circuit.

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?

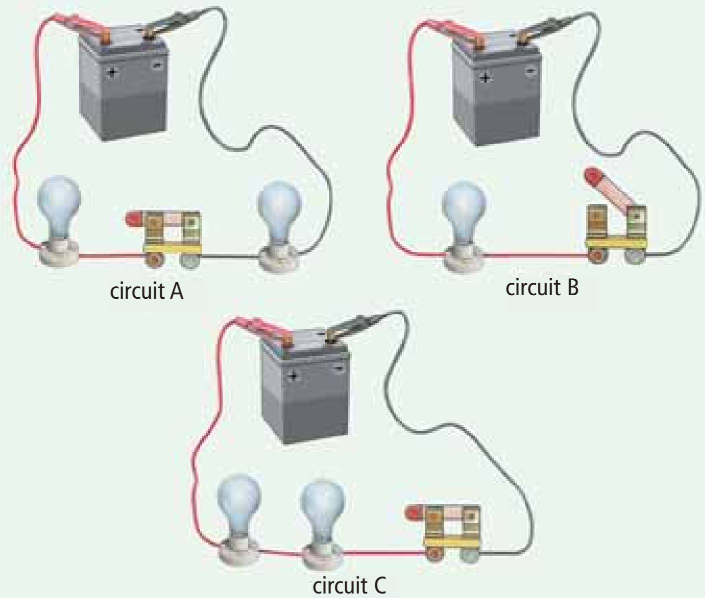
8-2B Drawing Circuit Diagrams

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).

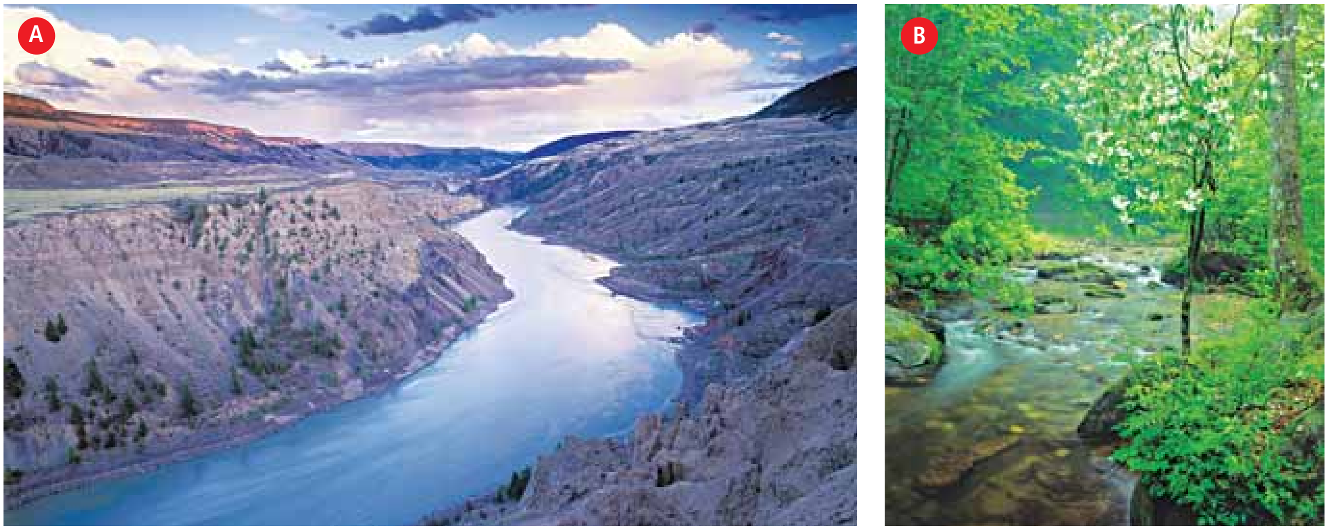


Figure 8.13 The volume of water flowing in the Fraser River (A) is greater than that of a stream (B). Therefore the river is said to have more current.

Suggested Activity

Find Out Activity 8-2D on page 286

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:

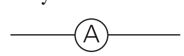


Figure 8.14 André-Marie Ampère (1775–1836)

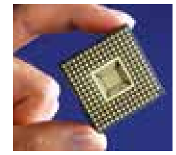
Conventional Current

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

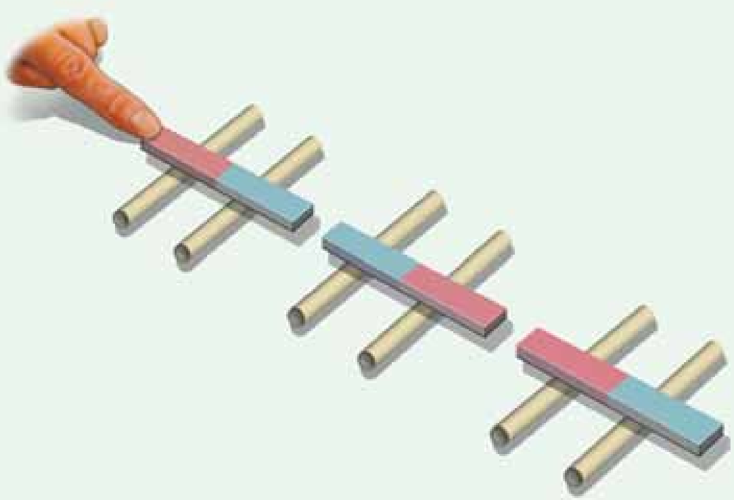
- 6 plastic drinking straws
- 3 bar magnets

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

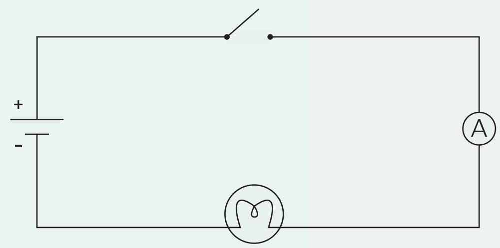
- 1.5 V cell
- various flashlight bulbs (1.5 V, 3.0 V, 6.0 V)
- connecting wires
- knife switch
- ammeter

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.

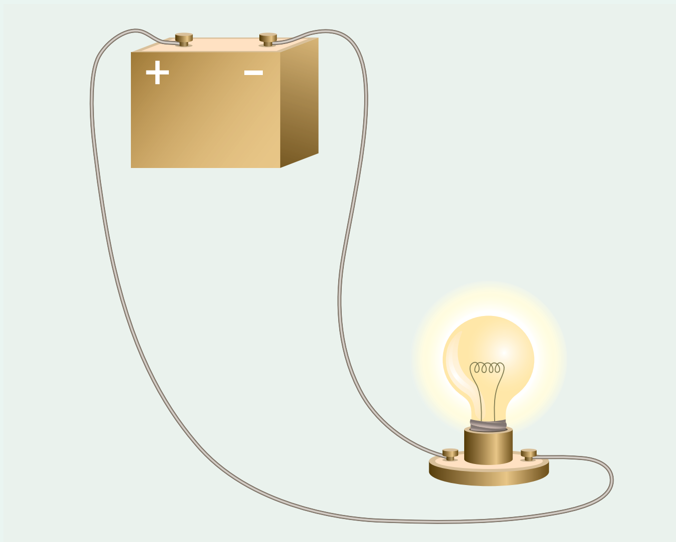
Using models to explain an idea or concept is a key skill in science. In this activity, you will make a human model of an electric circuit.

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.

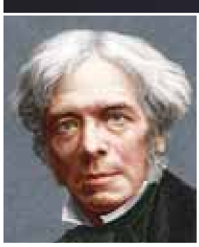
Evaluate

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.

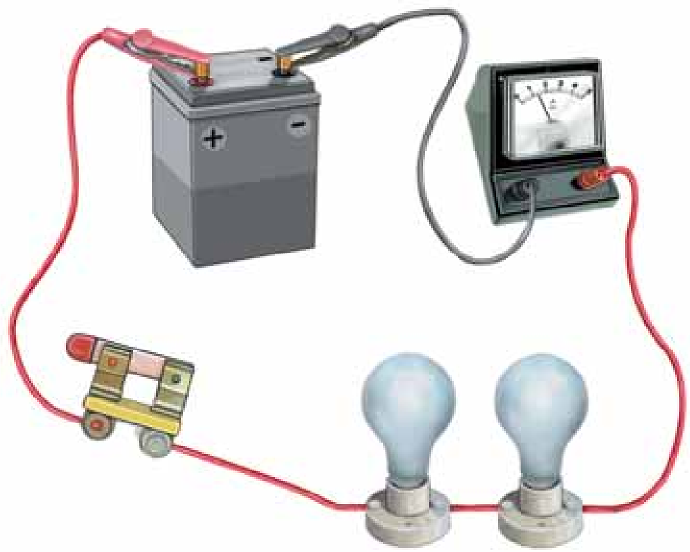
Check Your Understanding

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.

8.3 Resistance and Ohm's Law

Resistance slows down the flow of electrons and transforms electrical energy. Resistance is measured in ohms (Ω). We calculate resistance by applying a voltage and measuring the current. Ohm's law states that the relationship of voltage (V), current (I), and resistance (R) is given by: $V = IR$. Resistors are electrical components used in circuits to decrease current and convert electrical energy into other forms of energy.

Words to Know

electrical resistance
ohm
Ohm's law
resistance
resistor

Summertime in British Columbia means long road vacations for many families. Perhaps you can remember some trips on busy highways when you were excitedly waiting to arrive at your destination. Suddenly, to your dismay, a sign announced "Road Construction, Single Lane Traffic Only." As the cars merged into one lane, the flow of traffic slowed down. Maybe you were also slowed down when the road became gravel instead of pavement or was full of potholes.

Resistance and the Flow of Electrons

The flow of cars in the situation above is similar to the flow of electrons in a circuit. For example, the load in the circuit might be a light bulb as shown in Figure 8.15 on the next page. The filament of the light bulb resists the flow of the electrons and therefore slows down the current. **Resistance** is the property of any material that slows down the flow of electrons and converts electrical energy into other forms of energy. The filament's high resistance causes the electrons' electrical energy to be converted into heat and light energy. The wire that connects the battery to the light bulb has very little resistance, and therefore the electrons travelling through this wire lose almost no electrical energy.

Did You Know?

The electrical resistance of your hands when the skin is dry is 100 times greater than if your hands are wet.

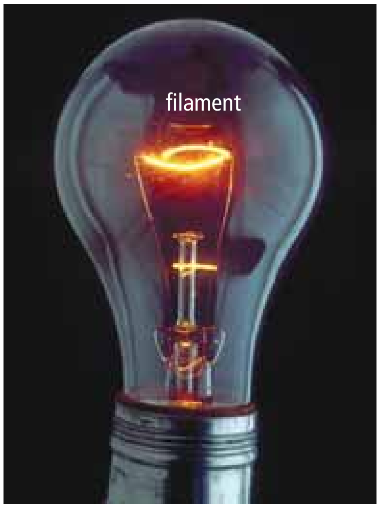


Figure 8.15A Electrons move through the filament in a light bulb.

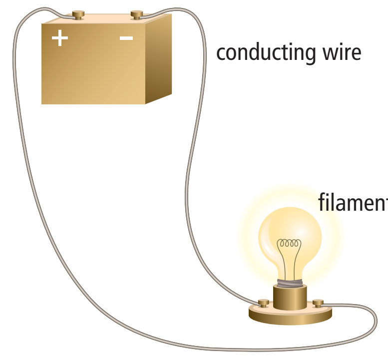


Figure 8.15B The filament has more resistance than the conducting wire. As the electrons "squeeze" through the filament, heat and light energy are produced.

8-3A Resist Your Thirst

Find Out ACTIVITY

In this activity, you will investigate how resistance affects the flow of a fluid through a straw.

Safety

- Do not share straws, cups, or water.

Materials

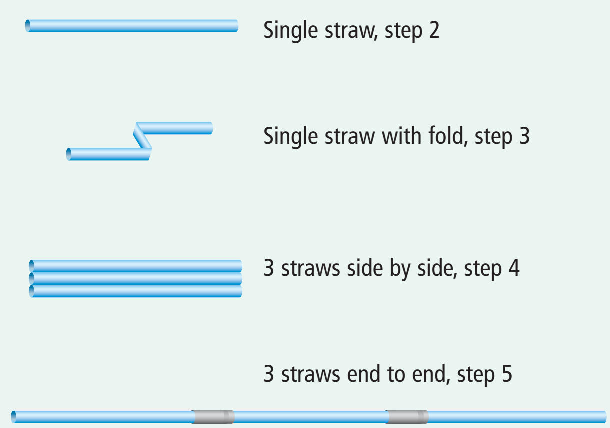
- water
- plastic disposable cup
- 4 drinking straws
- stopwatch
- clear adhesive tape

What to Do

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

Description of Straws	Time (s)
Single straw	
Single straw with folds	
3 straws side by side	
3 straws end to end	

2. Measure 100 mL of water into a cup. Have your partner time how long it takes you to drink the 100 mL of water using a single straw. Record this time.
3. Make an accordion fold in the straw as shown in the diagram. Repeat step 2 using the folded straw.
4. Repeat step 2 using three straws side by side.
5. Insert the ends of the three straws to make one long straw. Be sure to tape the joints so that the joints are sealed. Repeat step 2 using the long straw.



What Did You Find Out?

1. List the four straw types, from your data table, in order from least resistance to most resistance.
2. State the relationship between the amount of resistance and the time required to drink the fluid.
3. What factors do you think influence the amount of resistance?

Resistance and Current

Marbles in a tube can represent electrons being pushed through a circuit. Suppose you have a hollow tube filled with identical-sized marbles. If you hold the tube level, the marbles will leave both ends of the tube (Figure 8.16A). That is, there will not be a "current" of marbles all flowing the same direction. In order to have all the marbles flow out of one end of the tube you must lift one end so that the two ends of the tube are at different heights or "potentials." The higher you lift one end of the tube the greater the number of marbles flowing out of the tube (Figure 8.16B).

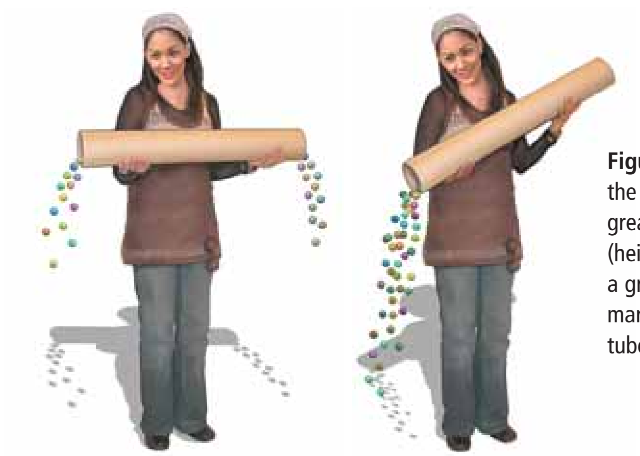


Figure 8.16A Both ends of the tube are at the same potential (height). The marbles in the tube do not all flow in the same direction.

Figure 8.16B The ends of the tube in (B) have a greater potential difference (height) than in (A). There is a greater "current" of marbles in tube (B) than in tube (A).

Voltage is the difference in potential energy per unit of charge between one point in the circuit and another point in the circuit. When you increase the voltage connected to the circuit, the current will also increase. In other words, voltage is directly proportional to current.

Georg Ohm, a German physicist (Figure 8.17), studied the relationship between voltage and current and realized that there was another factor involved. Two *different* tubes filled with identical marbles tipped the same amount do not have to have the same current. Figure 8.18 shows a tube with a large diameter and a tube with a smaller diameter both held at the same angle. The number of marbles leaving the larger tube is greater than that of the smaller tube. Even though both tubes have the same potential difference, they have different "currents" of marbles. The smaller tube does not allow the marbles to flow as freely as the larger tube. In other words, the smaller tube has more resistance.

If a battery is connected to an electric circuit that has a large resistance, less current will flow than if the same battery is connected to a lower resistance circuit.

Figure 8.17 Georg Ohm (1789–1854)

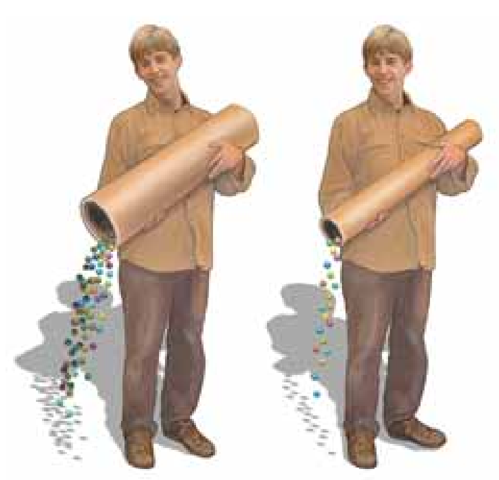


Figure 8.18 Even though both tubes have the same potential difference, the tube on the left has a greater "current" of marbles.

Ohm's Law

By measuring the amount of current that a given voltage produces, Ohm was able to calculate the circuit's resistance. **Electrical resistance** is the ratio of the voltage to the current. The unit of measurement for electrical resistance is the **ohm** (Ω). The mathematical relationship comparing voltage (V), current (I), and resistance (R) is called **Ohm's law** and is written as:

$$R = \frac{V}{I}$$

Ohm's law is more commonly written in the form:

$$V = IR$$

You can use Ohm's law to calculate resistance.

Read the question:

What is the resistance of a flashlight bulb if there is a current of 0.75 A through the bulb when connected to a 3.0 V battery?

Use the formula:

$$R = \frac{V}{I}$$

$$= \frac{3.0\ \text{V}}{0.75\ \text{A}}$$

$$= 4.0\ \Omega$$

State your answer:

The resistance of the flashlight bulb is 4.0 Ω.

Word Connect

The symbol for the unit of the ohm is the Greek letter omega (Ω) instead of the first letter of ohm (O). This is because the (O) might be confused as the number zero. The symbol "I" for current stands for "intensity."

Practice Problems

Try the following Ohm's law problems. Show each step of your solution.

1. The current through a load in a circuit is 1.5 A. If the potential difference across the load is 12 V, what is the resistance of the load?
2. The resistance of a car headlight is 15 Ω. If there is a current of 0.80 A through the headlight, what is the voltage across the headlight?
3. A 60 V potential difference is measured across a load that has a resistance of 15 Ω. What is the current through this load?

Answers

1. 8.0 Ω
2. 12 V
3. 4.0 A

Converting prefixes

Prefixes are used to indicate the magnitude of a value.

milli (m) represents one-thousandth (example: 25 mA = $\frac{25}{1000}$ A = 0.025 A)

kilo (k) represents one thousand (example: 5.0 kΩ = 5000 Ω)

mega (M) represents one million (example: 12 MV = 12 000 000 V)

When solving a problem where some of the units contain prefixes, first convert the prefixes before you do your calculation.

Read the question:

What is the voltage across a 12 kΩ load that allows a current of 6.0 mA?

Use the formula:

$$
\begin{aligned}
V &= IR \\
&= (6.0\ \text{mA})(12\ \text{k}\Omega) \\
&= (0.0060\ \text{A})(12\ 000\ \Omega) \\
&= 72\ \text{V}
\end{aligned}
$$

State your answer:

The voltage across a 12 kΩ load is 72 V.

Practice Problems

Try the following Ohm's law problems. Show each step of your solution. Remember to convert prefixes before calculating.

1. A 15 mA current flows through a 400 Ω lamp. What is the voltage across the lamp?
2. A 12 kΩ load is connected to a 90 V power supply. What is the current through the load in milliamperes (mA)?
3. A device draws a current of 1.2 mA when connected to 120 V. What is the resistance of this device? Give your answer in both ohms and kilo-ohms.

Answers
1. 6.0 V
2. 7.5 mA
3. 100 000 Ω; 100 kΩ

Determining the Resistance

There are several methods you can use to determine the resistance.

Method 1: To experimentally measure the resistance of a device or load, the load must be connected to a source of potential difference, such as a battery. You can use a voltmeter to measure the voltage across the load and an ammeter to measure the current through the load. Then you can use Ohm's law to calculate the resistance.

To obtain more accurate results, you can place several different voltages across the load. You then measure the current through the load for each voltage. Using Ohm's law, you can calculate the load's resistance for each set of data. These resistances can then be compared.

Method 2: In your classroom, you may have used a digital multimeter to take your voltage and current measurements. Most multimeters also have a setting for measuring resistance. An **ohmmeter** is a device that measures resistance. When a multimeter is used as an ohmmeter, the meter uses its internal battery to provide a voltage across the load. The meter measures the current leaving the battery and calculates the resistance. This calculated resistance is then shown on the display screen.

Did You Know?

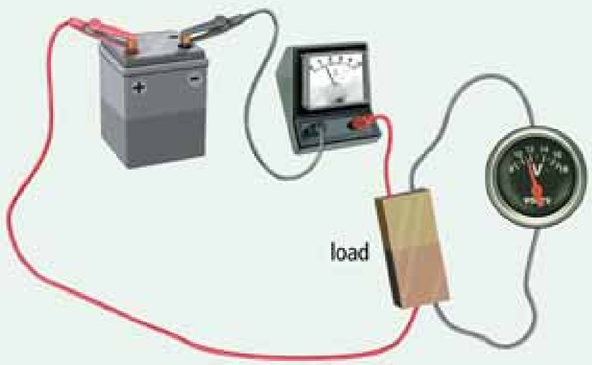
The current flowing in an MP3 player is very small, perhaps one-thousandth of an ampere. The current produced by a car's battery to start the car is almost 100 A.

Calculating Resistance

The resistance of a load can be determined by analyzing the relationship between the voltage across the load and the current. In this activity, you will use voltage and current data obtained from an experiment to calculate the resistance of the load.

What to Do

1. A battery is connected to a load as shown. The voltage across the device and the current through the device is measured.



A battery is connected to a load, and the voltage and current are measured.

2. Different batteries are connected to this same load and the following data is obtained. Copy this data table into your notebook. Give it a title.

Voltage (V)	Current (A)	Resistance (Ω)
3.0	1.2	
4.5	1.7	
6.0	2.5	
9.0	3.6	
12.0	5.0	

3. Using Ohm's law, calculate the resistance for each set of voltage-current data.
4. Calculate the average resistance of your five calculated resistances. To find the average, add the five resistances and divide the sum by 5. Record the average resistance. Include correct units.

What Did You Find Out?

1. How did the resistances you calculated for the sets of data compare? Were they exactly the same, close, or very different?
2. Given that the same load was used, explain why you think the values calculated might not be exactly the same for each set of data.

The Resistor

Any electrical component that has electrical resistance slows down current and transforms electrical energy into other forms of energy. A **resistor** is an electrical component that has a specific resistance. Resistors (Figure 8.19) can be used to control current or potential difference in a circuit to provide the correct voltage and current to the other components of the circuit. The circuit symbol for a resistor is shown below in Figure 8.20.

Figure 8.20 The circuit symbol for a resistor

Figure 8.19 Resistors are used to control current and voltage in electrical circuits.

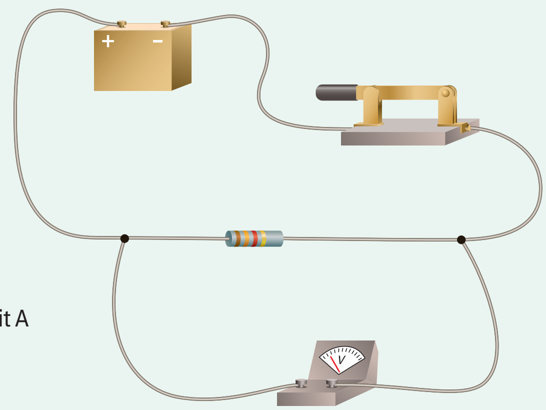
8-3C Circuit Diagrams with Resistors

Think About It

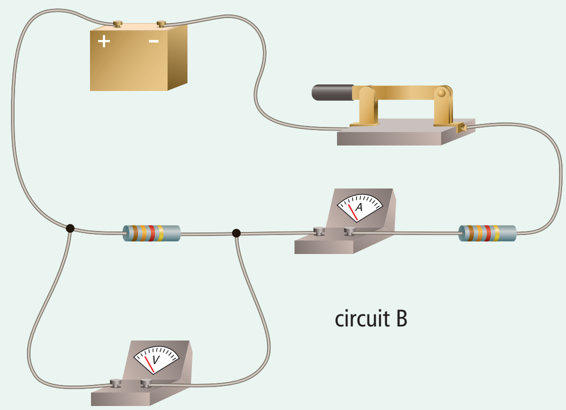
In this activity, you will draw circuit diagrams for circuits that contain resistors.

What to Do

1. Draw the corresponding circuit diagrams for circuit A and circuit B.



circuit A



circuit B

What Did You Find Out?

1. Compare your circuit diagrams with those of a classmate. List any similarities and differences.
2. Explain the advantage of the circuit diagram you drew as compared to the original illustration in this student book.

Resistance Is a Big Loser

It takes less effort to slide a heavy box across a smooth polished floor compared to pushing the same box across a rough floor (Figure 8.21). The rough floor provides resistance to the motion of the box. This resistance, or friction, of the rough floor produces much more heat than the smooth floor.

There is a similar effect when a battery tries to "push" electrons through a circuit. When the charge encounters resistance, some of the electrical energy stored in the electrons is transformed into other forms of energy, such as heat. When we say that energy is lost in a resistor, it really means that electrical energy has been transformed to other forms of energy. These other forms of energy do not easily get changed back into electrical energy.

Did You Know?

The resistance of the tungsten wire in a light bulb is 400 times greater than the resistance of the copper wire leading to the light bulb. This is why the tungsten wire heats up more than the copper wire.

Figure 8.21 Since the rough floor provides more resistance, more energy is transferred into heat by the friction.

Resistor Colour Code

Resistors are marked with coloured bands. These stripes are not for decoration but instead indicate the resistance of the resistor. Table 8.2 gives the numeric values associated with each colour.

Table 8.2 Colour Coding on Resistors

Colour	Numeric Value
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
grey	8
white	9

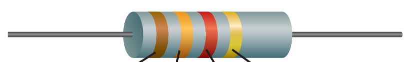


Figure 8.22 The resistor in this illustration would have the first digit 1, the second digit 3, the power of 10 to the second power, and an accuracy within 5 percent. Therefore this resistor's value would be 13×10^2 or 1300 Ω and is accurate within 5 percent.

Suggested Activity

Conduct an Investigation 8-3D on page 298

Figure 8.22 displays the colour code of a resistor. The first band is the first digit of the resistance. The second band is the second digit of the resistance. The third band represents the multiplier or power of 10 factor of the resistance (the number of zeros that follow the second digit in the resistance value). If the resistor has a fourth band, it represents the percentage of accuracy between the indicated value and actual value (gold 5 percent, silver 10 percent, no colour 20 percent).

Reading Check

1. How does resistance affect current?
2. What will happen to the current in a circuit if the voltage applied to that circuit is increased?
3. State Ohm's law, which is the relationship of voltage (V), current (I), and resistance (R).
4. What are the units of electrical resistance?
5. What happens to the electrical energy when electrons flow through a resistor?
6. What does it mean when we say that energy is "lost" in a resistor?
7. How do manufacturers of resistors indicate the value of the resistance?

Explore More

Decreasing the resistance allows more current with less energy lost to heat. Scientists have produced materials that have almost zero resistance. These materials are called superconductors. Find out how superconductors are produced and what applications they may have. Begin your research at **www.bcscience9.ca.**

8-3D Resistors and Ohm's Law

SkillCheck

- Observing
- Measuring
- Controlling variables
- Evaluating information

Safety

- If any of the wires or resistors become hot, open the switch immediately.
- Make sure that the positive terminal of the ammeter is connected to the positive terminal of the battery. The negative terminal of the ammeter should be connected to the negative terminal of the battery.
- Never connect an ammeter directly across the terminals of a battery.
- There must be a load, in this case the resistor, in the circuit to limit the flow of electrons.

Materials

- 2 different resistors (100–300 Ω)
- ammeter
- voltmeter
- conducting wires
- four 1.5 V cells
- switch

In Part 1 of this activity, you will construct a circuit from a circuit diagram and measure voltage and current using a voltmeter and ammeter. In Part 2, you will calculate resistance.

Question

How do the calculated value and measured value of resistors compare?

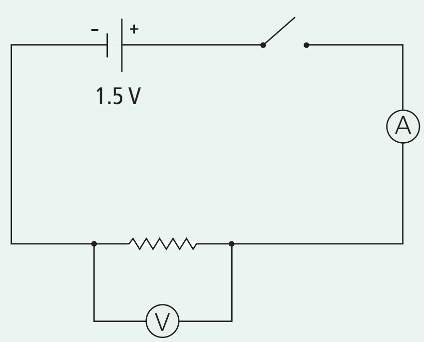
Procedure

Part 1 Measuring Voltage and Current

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

Resistor Value (Ω)	Voltage (V)	Current (A)	Calculated Resistance (Ω)
#1			
#2			

2. Using the resistor colour code, record the value of each of your resistors in your data table.
3. Construct the following circuit using one of your resistors and one 1.5 V cell. Be sure to leave the switch open until instructed by your teacher to close the switch.



Construct this circuit in step 3.

Inquiry Focus

Science Skills

Go to Science Skill 11 for information about how to use an ammeter and voltmeter.

4. Close the switch briefly and measure the voltage and current. Open the switch as soon as you have measured your values. Record these values in your data table. If your ammeter is measuring in milliamperes, be sure to convert this to amperes.
5. Replace your 1.5 V cell with two 1.5 V cells connected together. Make sure the cells are connected positive (+) to negative (−). When instructed by your teacher, repeat step 4.
6. Connect three 1.5 V cells together, again positive to negative. When instructed by your teacher, repeat step 4.
7. Connect four 1.5 V cells together, again positive to negative. When instructed by your teacher, repeat step 4.
8. Remove your first resistor and replace it with your second resistor. Repeat steps 4 to 7.
9. Clean up and put away the equipment you have used.

Part 2 Calculating Resistance

10. Using your measured voltage and current, calculate the resistance for each set of data. Record these values in the "Calculated Resistance" column of your data table.

Analyze

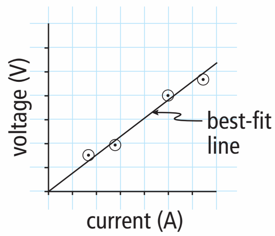
1. Using the calculated resistances for resistor #1, calculate the average resistance. Record this value. Include correct units.
2. Using the calculated resistances for resistor #2, calculate the average resistance. Record this value. Include correct units.

Conclude and Apply

1. For each resistor, compare the average value of the resistance to the value obtained from the colour code.
2. Give a possible reason for the calculated value and colour code value not being exactly the same.
3. As the current through an individual resistor is increased, what happens to the voltage across that same resistor?

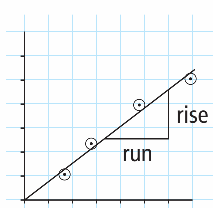
Using a Line Graph to Analyze Voltage and Current Data

Measurements taken during scientific investigations are not always perfectly accurate. This could be due to the inaccuracy of the measuring device or the inability to observe the exact value. When you plot your data on a line graph, the points may not line up perfectly on a line. The line that is drawn is therefore called a best-fit line. Think of the data points you have plotted as being good approximations of the exact values. The best-fit line should show the trends and therefore might not hit every point exactly.



In the graph above, you can see that as the voltage increases (vertical axis) the value of the current (horizontal axis) also increases. Using a mathematical tool called slope, you can obtain even more information from your graph line. The slope of a line is very similar to the slope of a hill or ramp. If you were hiking up a hill that had a large slope, the hill would be very steep. If the hill had a small slope, the hill would be less steep.

Mathematics defines slope of a line as "rise over run." Slope is the ratio of how much the line rises (vertical axis) as compared to how much change there is on the horizontal axis.



$$\text{slope} = \frac{\text{rise}}{\text{run}}$$

The rise on the voltage and current graph indicates the change in voltage. The run indicates the change in current. Therefore, by finding the slope, you are calculating the ratio of voltage to current.

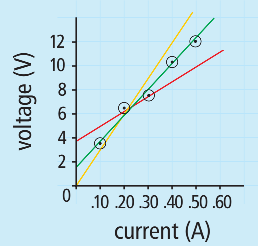
Slope = rise/run

Slope = voltage/current

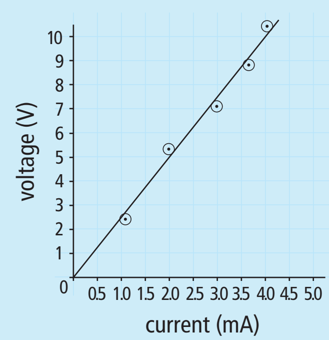
According to Ohm's law: $R = \frac{V}{I}$. Therefore, on a voltage vs. current graph, the slope of the line is the resistance of the load. If the data from two different loads were plotted on the same graph, the line with the steeper slope would indicate a higher resistance.

Questions

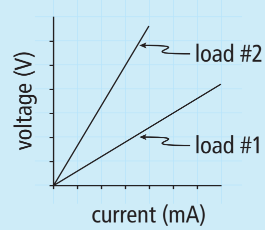
1. Which of the following lines represents the best-fit line for the plotted data points?



2. Using the best-fit line, what would be the current through the load if it were connected to 5.0 V?



3. The data for two different loads are plotted on the following graph. Which load has the higher resistance? Explain your answer.



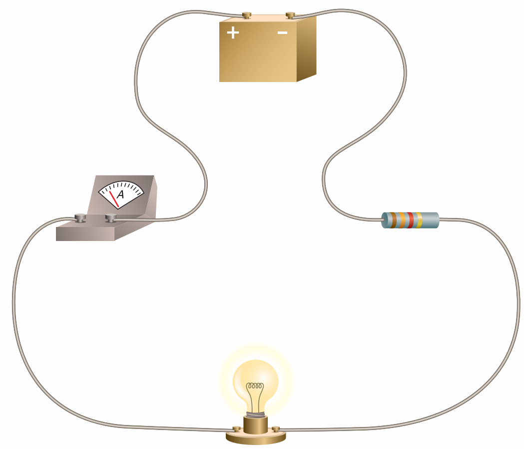
Check Your Understanding

Checking Concepts

1. What is the name of the property of a material that slows down current and converts electrical energy into other forms of energy?
2. Using Ohm's law, state the relationship of current, resistance, and voltage.
3. What two values do you need in order to calculate resistance?
4. (a) What is the unit of resistance?
   (b) What is its symbol?
5. What is used to control current and potential difference in a circuit?
6. Explain how manufacturers indicate the value of resistance on each resistor.
7. Draw the symbol used to represent a resistor in a circuit diagram.

Understanding Key Ideas

8. A 1.2 A current flows through a 250 Ω resistor. Calculate the voltage across this resistor.
9. A 120 Ω resistor is connected to a 12 V battery. Calculate the current through the resistor.
10. An unknown resistor transforms 2.0 mA of current when connected to a 9.0 V battery. Calculate the value of this resistor.
11. A classmate hands you a resistor that has the following colour bands: yellow, orange, red, and silver. What is the resistance of this resistor?
12. A light bulb is connected to a battery and the brightness of the light is observed. A resistor is then connected between the battery and the light bulb and the brightness of the light decreases. Explain this observation using what you know about energy and circuit components.
13. Draw a circuit diagram for the following circuit.



Pause and Reflect

Suppose you are given several batteries, an ammeter, voltmeter, connecting wires, and a resistor that has no coloured bands indicating its value. How could you determine an accurate value for this resistor?

Chapter 8

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated the relationship between current, voltage, and resistance. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 12 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Electrical Energy
2. Current
3. Voltage
4. Resistance and Ohm's Law
5. Circuits

Checking Concepts

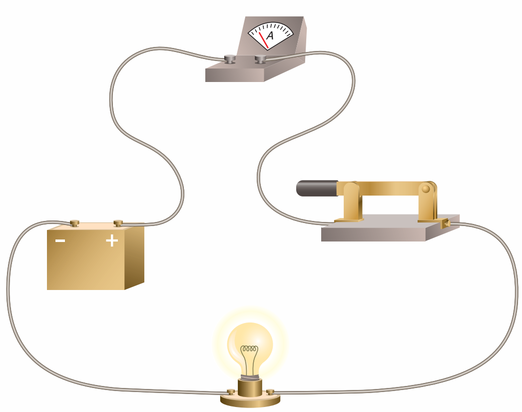
1. What is the purpose of a battery?
2. In a battery, what form of energy is converted into electric potential energy?
3. What is the relationship of electric potential energy, charge, and potential difference (voltage)?
4. What materials are needed to produce an electrochemical cell?
5. List five methods of producing electric energy.
6. What unit is used for measuring voltage?
7. What is the purpose of a voltmeter?
8. What is the purpose of an ammeter?
9. Copy and complete the following table in your notebook.

	Symbol	Unit	Unit Symbol
Voltage	V		
Current		amperes	
Resistance			Ω

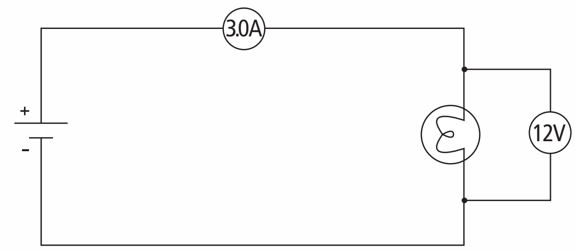
10. Draw the following circuit symbols.
    (a) battery
    (b) bulb
    (c) resistor
    (d) voltmeter
    (e) ammeter
    (f) switch
11. What is the relationship between amperes (A) and milliamperes (mA)?
12. What is the difference between conventional current and electron flow?
13. What are the four basic components of an electric circuit?
14. Explain the relationship between resistance and resistor.
15. State the relationship of voltage (V), current (I), and resistance (R).
16. When an electron passes through a resistor, what happens to its electric energy?
17. What is the purpose of an ohmmeter?
18. Resistors have a maximum of four coloured bands stamped on their surface. What does each band represent?

Understanding Key Ideas

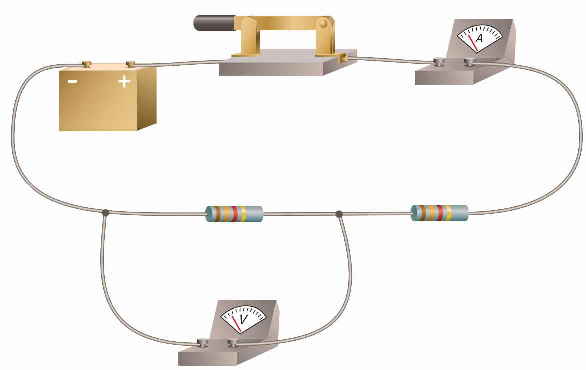
19. In order for skiers to have potential energy, they must travel to the top of the hill. Explain how this is similar to electrons in an electrochemical cell.
20. A voltmeter is connected to the (+) and (−) terminals of a battery and measures 6.0 V. If the lead on the (−) terminal is removed and now touches the (+) terminal, what would now be the reading on the meter? Explain your answer.
21. Explain how two 9.0 V batteries could have different amounts of electric potential energy.
22. Explain the difference between static electricity and current electricity.
23. By looking at an electrical set-up, explain how you would determine if it is a complete circuit.
24. You enter a dark room and press the light switch on the wall. The ceiling light turns on immediately. Explain why you do not have to wait for the electrons at the switch to travel to the ceiling light before the light goes on.
25. Draw a circuit diagram for the circuit below.



26. Convert each of the following:
    (a) 400 mA = ______ A
    (b) 18 kΩ = ______ Ω
    (c) 12 MV = ______ V
27. The current through a 120Ω resistor is 2.0 A. Calculate the voltage across this resistor.
28. The current through a load is 75 mA. If the potential difference across the load is 12 V, what is the resistance of the load?
29. Calculate the resistance of the bulb in the following circuit:



30. A fellow student hands you a resistor and the bands of colour are brown, black, and orange. What is the resistance of this resistor?
31. Draw a circuit diagram for the circuit shown below.

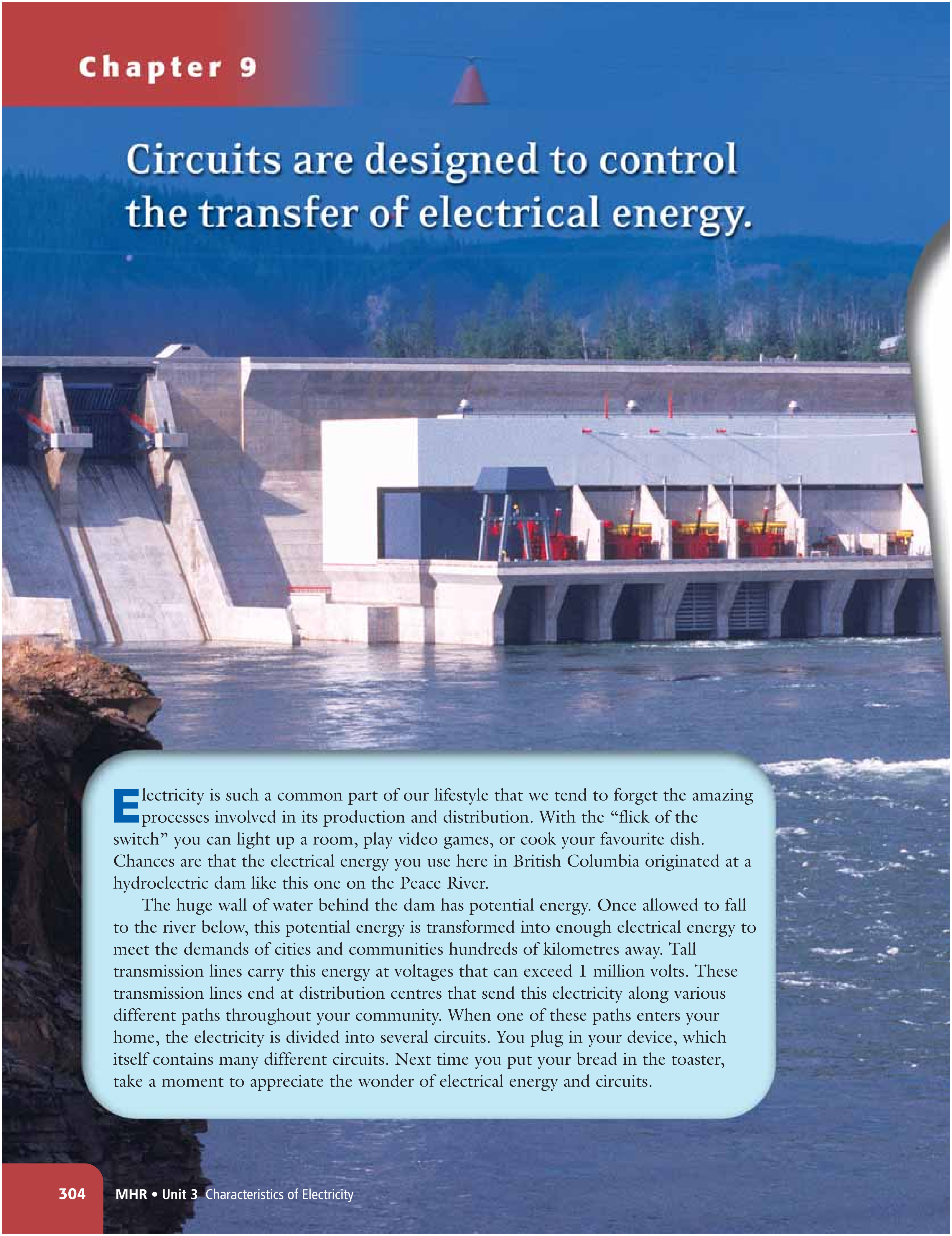


Pause and Reflect

A common flashlight contains a battery, a light bulb, and a switch. Draw a possible circuit diagram for the flashlight. In your circuit diagram, does it matter where the switch is located? Explain your answer.

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.

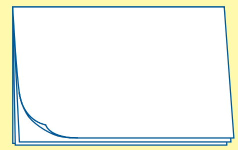
Skills You Will Use

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

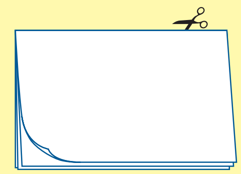
FOLDABLES™
Reading & Study Skills

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

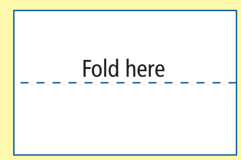
STEP 1 **Fold** two vertical sheets of paper in half horizontally.



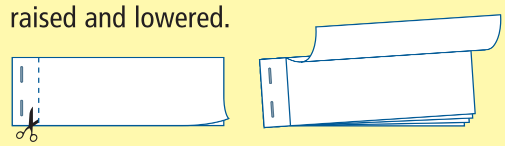
STEP 2 **Cut** along the fold lines, making four half sheets. (**Hint:** Use as many half sheets as necessary for additional pages in your book.)



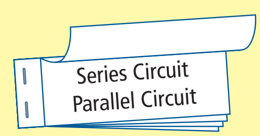
STEP 3 **Fold** each half sheet in half horizontally.



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

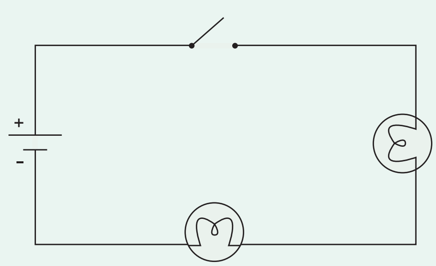
- Disconnect the circuit if any wires become hot.

Materials

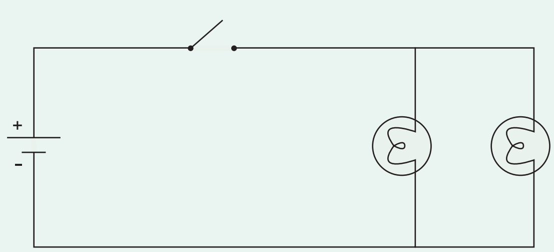
- 1.5 V cell
- two 2.0 V light bulbs
- switch
- connecting wires

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.

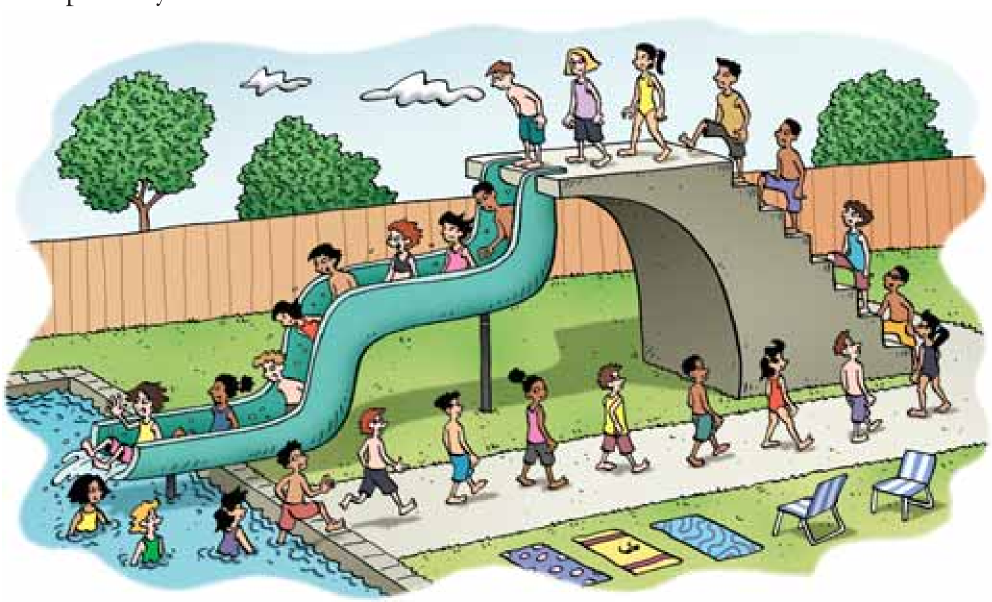


Figure 9.3 Everyone who uses this slide follows the same path.

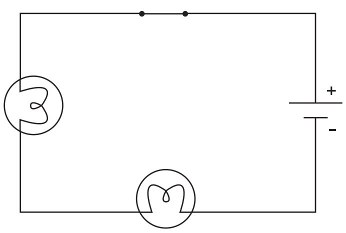


Figure 9.4 Electrons leaving the negative terminal of the battery in this circuit have only one path to return to the battery at the positive terminal.

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.

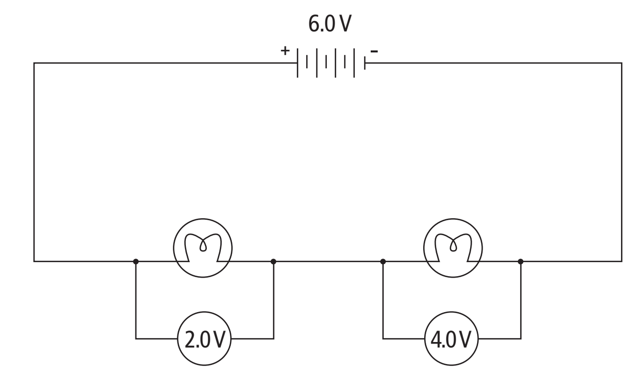


Figure 9.5 Each load in a series circuit loses a portion of the total voltage.

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

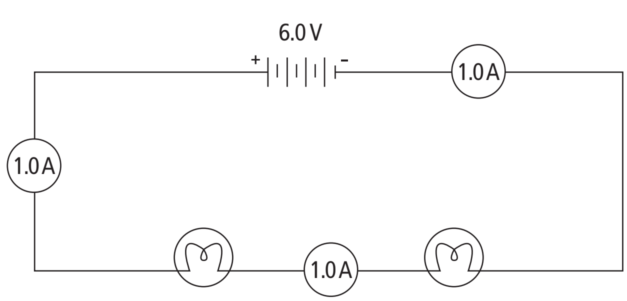


Figure 9.6 The current is the same throughout a series circuit.

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.

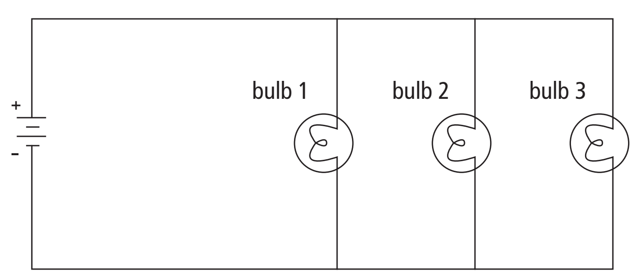


Figure 9.7 Electrons leaving the battery have three possible ways to return to the battery in this circuit.

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.

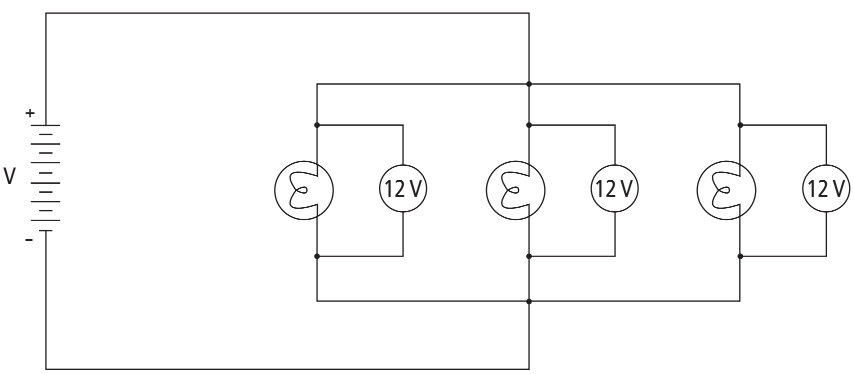
What Did You Find Out?

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.

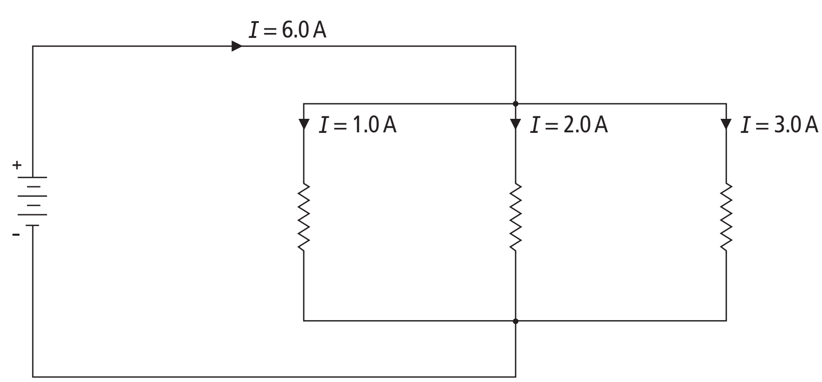
Figure 9.10 shows a battery connected to three different resistors connected in parallel. The total current leaving the battery divides into three possible pathways. The location where a circuit divides into multiple paths or where multiple paths combine is called a **junction point**. No current is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

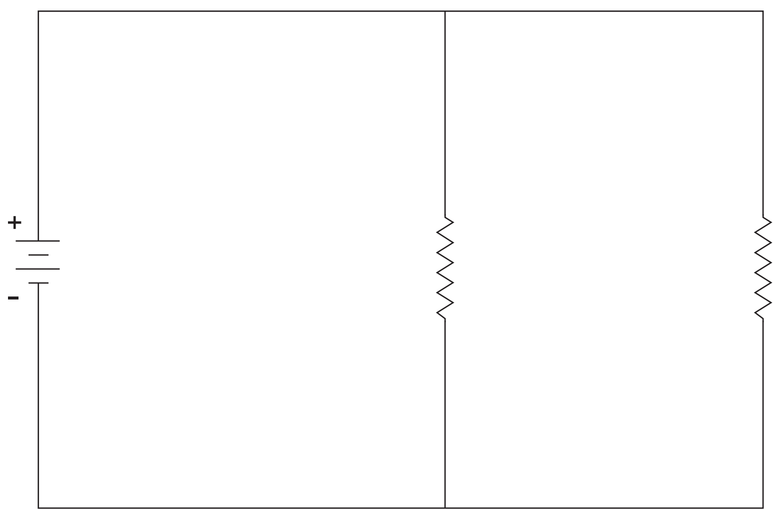


Figure 9.11 The total resistance of the circuit is decreased when resistors are placed in parallel.

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?

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.

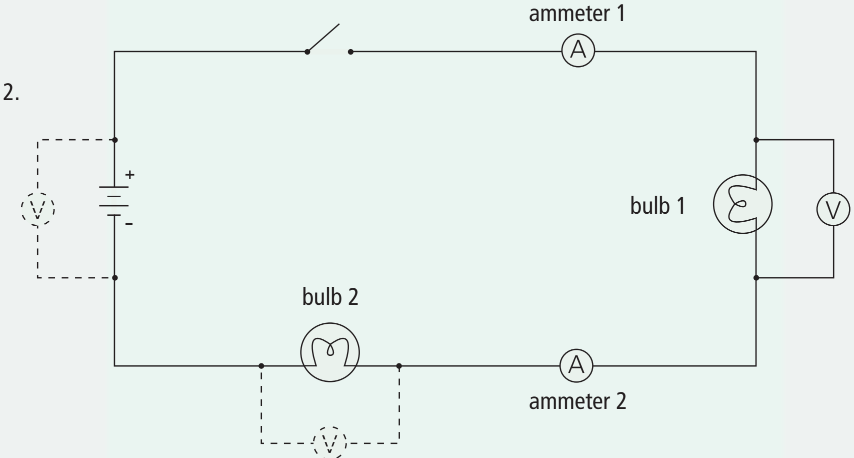
Current (mA)	Voltage (V)
Ammeter 1 =	Bulb 1 =
Ammeter 2 =	Bulb 2 =
	Battery =

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

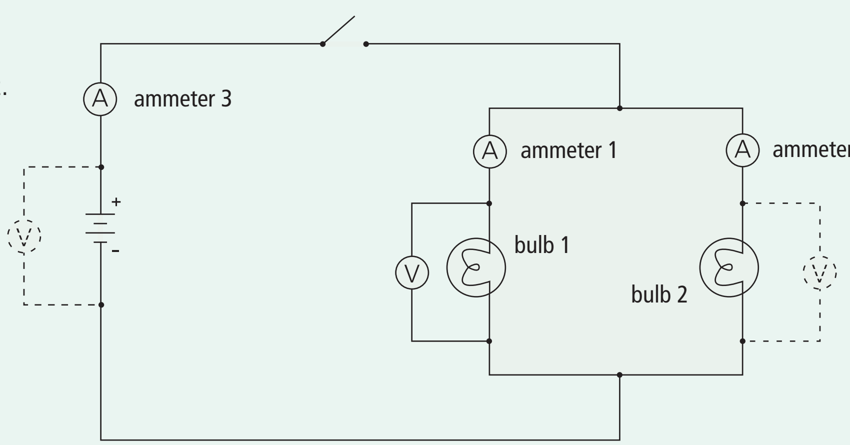
What to Do

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

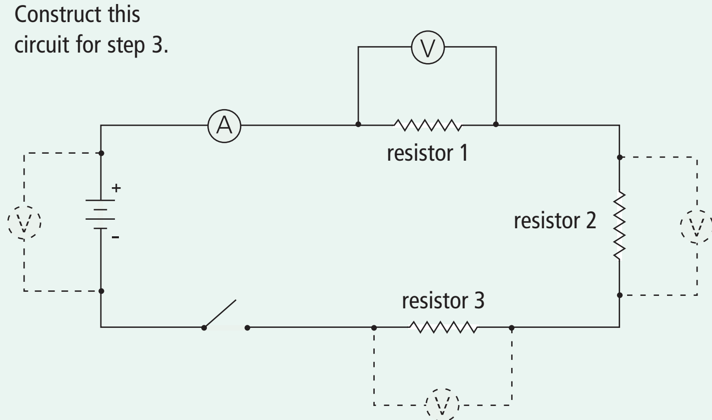
Part 1 Resistors in Series

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.



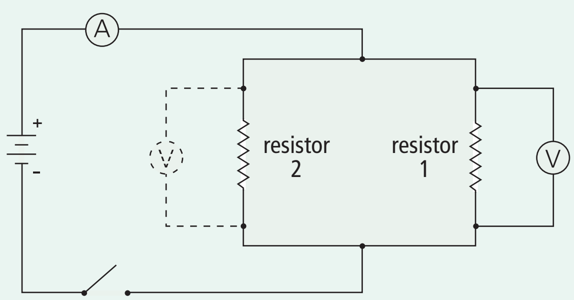
4. Close the switch, and measure the current through the ammeter. Record this current in your data table. If your ammeter is measuring milliamperes (mA), be sure to convert this to amperes (A).
5. Measure the voltage across resistor 1. Record this in your data table.
6. Move your voltmeter, and measure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

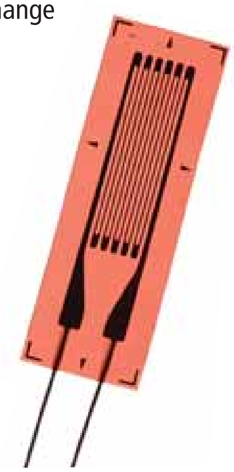
Science Watch

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.

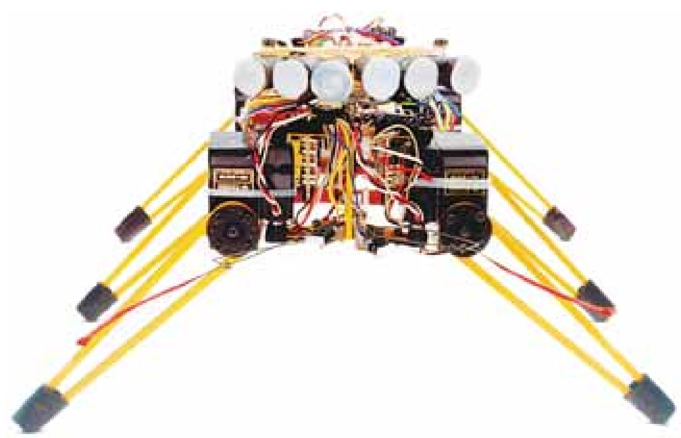
A strain gauge is a device used to measure the bend in an object. Invented in 1938, the most common strain gauge consists of a thin metallic foil or flexible semiconductor. Bending or deforming the foil causes its electrical resistance to change. This change in resistance can be used to detect pressure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

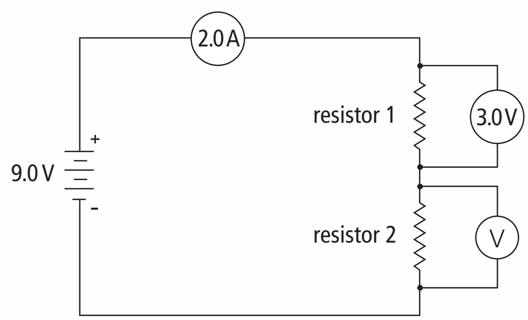
1. Make a list of the advantages and disadvantages of a six-legged robot as compared to a two-legged robot.
2. (a) What electric property changes when a strain gauge is deformed?
   (b) What effect would this have on an electric circuit?
3. Engineers have studied insects to design better robots. Describe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

Checking Concepts

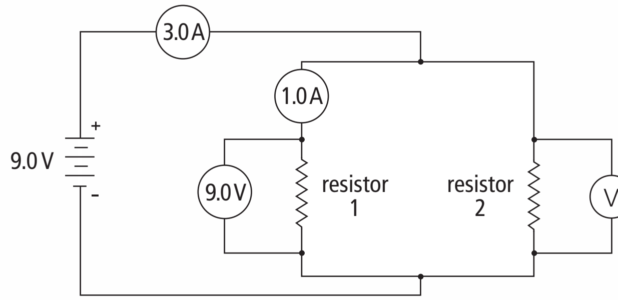
1. How is a parallel circuit different from a series circuit?
2. In a series circuit, how does the voltage supplied by the battery compare to the voltages on each load?
3. What happens to the total resistance of a series circuit when another resistor is added?
4. What happens to the total resistance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

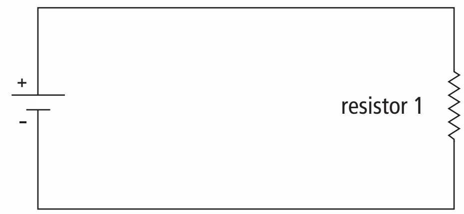
7. For the following circuit, find:
   (a) the current through resistor 2
   (b) the voltage across resistor 2



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

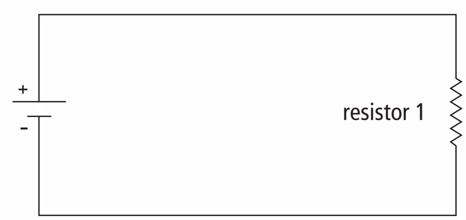


9. You are given the following circuit.



   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.