CK-12 Physical Science For Middle School Teacher's Edition

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1.1 Chapter 1: The World of Science

Chapter Overview

Science is way of learning about the natural world that is based on evidence and logic. A diversity of people has contributed to science for hundreds of years. Physical science is the study of matter and energy, and it includes chemistry and physics. There are many careers in physical science.

Online Resources

See the following Web sites for appropriate laboratory activities:

This interesting lab activity demonstrates the nature of science, which is the focus of Lesson 1.1. It shows, for example, that scientific knowledge is tentative and subject to revision, scientific explanations cannot be proven with certainty, and human values influence science.

- http://www.indiana.edu/~ensiweb/lessons/chec.lab.html

Have students do this lab activity (or present it to the class as a demonstration) when you introduce the concept of matter in Lesson 1.2. The lab will help overcome the common misconception that gases are not matter.

- http://galileo.phys.virginia.edu/outreach/8thgradesol/GasesRealFrm.htm

These Web sites may also be helpful:

This Web site offers many resources for helping students understand science and how science really works.

- http://undsci.berkeley.edu/teaching/68.php

You can find brief biographies of many notable physical scientists at this URL:

- http://www.infoplease.com/spot/scibio6.html

This video answers the question "What is physical science?" It also provides an overview of physical science topics. It is a good way to introduce the subject of physical science to your students.

- http://www.youtube.com/watch?v=Q_-yF-g84ug

Pacing the Lessons

TABLE 1.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
1.1 What Is Science?	2.0
1.2 The Scope of Physical Science	1.0

1.2 Lesson 1.1 What Is Science?

Key Concept

Science is a way of learning about the natural world that is based on evidence and logic. The hallmark of scientific thinking is induction. Scientific theories and laws have been developed over many centuries by a diversity of people, including women and people of color.

Standards

- MCR.6-8.SCI.11.1, 2; MCR.6-8.SCI.12.2, 7; MCR.6-8.SCI.13.1, 5
- NSES.5-8.A.1.5, 6; NSES.5-8.A.2.5, 6; NSES.5-8.E.2.2; NSES.5-8.F.5.4; NSES.5-8.G.2.1, 2; NSES.5-8.G.3.1, 2, 3
- AAAS.6-8.1.A.3, 4; AAAS.6-8.1.C.1, 2; AAAS.6-8.9.E.1; AAAS.6-8.12.A.2

Lesson Objectives

- Define science.
- Explain how scientists use induction.
- Distinguish between scientific theories and laws.
- Describe milestones in the history of science.
- Identify contributions of women and minorities to science.

Lesson Vocabulary

- **induction**: drawing general conclusions from many individual observations
- **science**: way of learning about the natural world that is based on evidence and logic
- **scientific law**: statement describing what always happens under certain conditions in nature
- **scientific theory**: broad explanation that is widely accepted because it is supported by a great deal of evidence

Teaching Strategies

Introducing the Lesson

Engage students in physical science with a fun activity. Bring a few glow sticks to class and hand them out to volunteers. Darken the classroom as much as possible, and have students activate the glow sticks according to package instructions. Ask the class why they think glow sticks produce light. Encourage a diversity of responses. Then explain that glow sticks produce light because of chemical reactions. Tell students they will learn in this course not only how glow sticks work, but the science behind many things in their daily lives.

Building Science Skills

Point out that logical thinking is the basis of science, and then give students a chance to apply it. Tell students that chemical reactions occur more quickly at higher temperatures. Then challenge them to use logic to predict how heating a glow stick might affect its ability to produce light. (Warmer glow sticks will have more chemical reactions occurring at the same time, so they will glow more brightly. However, the chemical reactions will be over soon, so the light won't last as long.)

Differentiated Instruction

Pair English language learners with native English speakers, and ask pairs to make a cluster diagram to organize lesson concepts. They should start with "Science" in the center circle of their diagram and then add surrounding circles for main topics in the lesson (e.g., scientific theory, scientific law, history of science, diversity of scientists).

Enrichment

Have a few students take a survey of a sample of the student body, asking respondents to give their understanding of the terms *scientific theory* and *scientific law*. Ask the students to present the results of their survey to the class and point out any misconceptions they found. (One common misconception is that as evidence accumulates in support of a scientific theory, it may be "upgraded" to a scientific law.) In their presentation, have students review the correct meanings of *scientific theory* and *scientific law* and give examples of each.

Science Inquiry

Introduce students to the process of science while continuing with the glow sticks theme. Ask students to brainstorm how they could test the effects of temperature on glow sticks. Guide students in developing a research plan. Lead them in identifying the relevant variables and how they would measure them and also in identifying factors they should control. Discuss the results they might obtain and the conclusions they could logically draw from them.

Common Misconceptions

There are many common misconceptions about the nature of science. For example, students might believe that:

1. Science is just a collection of facts.
2. Science is complete, absolute, and unchanging.
3. Science proves ideas.

Explain why the misconceptions are incorrect. You can find these and many other misconceptions about the nature of science and the scientific process at the following URL. The Web site also explains why the misconceptions are false.

- http://undsci.berkeley.edu/teaching/misconceptions.php

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define science.
   - [Science is a way of learning about the natural world that is based on evidence and logic.]
2. What is induction?
   - [Induction is a way of reasoning in which general conclusions are drawn from many individual observations.]
3. State the contributions of Thales and Aristotle to the evolution of science.
   - [Thales proposed that natural events have natural, rather than supernatural, causes. He is called the "father of science" for this idea. Aristotle argued that truth about the natural world can be learned through observations and induction. This is called empiricism. It laid the foundation for the methods of modern science.]
4. What was the Scientific Revolution?
   - [The Scientific Revolution occurred in Europe during the mid-1500s to late 1600s. This was the beginning of Western science. Many scientific advances were made during this time. For example, Copernicus proposed that the sun is the center of the solar system, and Newton proposed the law of gravity.]
5. Use induction to draw a logical conclusion based on the **Table** below.
   - [Answers may vary but should be logical inductions based on the data in the table. *Sample answer:* If you add substances to pure water, it lowers the freezing point of the water.]

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Lesson Quiz

Check students' mastery of the lesson with Lesson 1.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Most of the scientists mentioned in this lesson are physical scientists.

- Based on their work, what do you think is the subject matter of physical science?

***Sample answer*: I think physical science is the science of all the basic parts and processes of the universe, such as atoms**

- What are some questions that physical scientists might investigate?

Questions might include: What particles make up atoms? Which elements are radioactive? What causes gravity? How

1.3 Lesson 1.2 The Scope of Physical Science

Key Concepts

Physical science is the study of matter and energy. It includes chemistry and physics. There are many physical science careers.

Standards

- MCR.6-8.SCI.13.3
- NSES.5-8.F.5.5
- AAAS.6-8.1.B.1; AAAS.6-8.1.C.4

Lesson Objectives

- Define physical science.
- Explain the relevance of physical science to everyday life.
- Describe examples of careers in physical science.

Lesson Vocabulary

- **chemistry**: study of the structure, properties, and interactions of matter
- **physical science**: study of matter and energy
- **physics**: study of energy and how it interacts with matter

Teaching Strategies

Introducing the Lesson

Pique student interest in physical science and physical science careers by describing a "cool" career in physical science. The URL below describes several, including robotic engineer. For example, a robotics engineer profiled at the Web site is collaborating with a biologist to develop a robot that imitates the cockroach, an insect with superior locomotion. Tell students that there are hundreds of other careers in physical science, some of which they will learn about in this lesson.

- http://www.pbs.org/safarchive/5_cool/53_career.html

Using Visuals

Have students look at the images in the lesson of common activities that involve matter and energy. Call on volunteers to try to explain how or why the activities involve matter and energy (see caption question and sample answer below). Ask other students whether they agree with the answers. After the discussion, tell the class they will learn the science behind these and many other common activities as they read the *CK–12 Physical Science for Middle School* FlexBook® resource.

Question: All these activities involve matter and energy. Can you explain how or why?

Answer: A bike lets you travel faster and farther because it is a complex machine that multiplies the force you apply to it. The air conditioner turns on when you lower the thermostat because the thermostat sends an electric signal to the air conditioner when the temperature rises above the new set point. A microwave heats food very quickly by sending electromagnetic radiation (microwaves) through the food, which absorbs the energy of the microwaves. Lenses correct vision problems by focusing light so images fall on the light-sensing cells in the retina of the eyes. Mixing different colors of paint produces new colors because primary pigments can be combined to produce all the colors of visible light.)

Differentiated Instruction

From the lesson, select some of the figure questions relating to chemistry and physics (see questions and sample answers below). Write each question on a large sheet of paper, and post the questions around the room. Have groups of students walk around the room to read and discuss the questions. Make sure any English language learners are grouped with native speakers of English. Give each group a different colored marker to answer the questions on the sheets. After the activity, discuss the answers and relate them to the scope of physical science.

Question: Why does a mud puddle dry up in the sun? Where does the water go?

Answer: The water evaporates and goes into the air as water vapor.

Question: What happens to a candle when it burns? Is its matter destroyed?

Answer: Its matter is not destroyed. The candle changes to other kinds of matter when it burns, including carbon dioxide and water vapor.

Question: How do icicle-like stalactites form in caves? What are they made of?

Answer: They are made of rock. They form when tiny particles of dissolved rock come out of solution as water drips down from the roof of a cave.

Question: Why do certain baked goods rise in the oven? Would they rise if they weren't baked?

Answer: No, they wouldn't rise if they weren't baked, or at least they wouldn't rise as high. An elevated temperature is needed for chemical reactions that release gas and cause the batter or dough to rise.

Question: How do different cleaning products work? Why are some products better for cleaning clothes whereas others are better for washing dishes or scrubbing bathtubs?

Answer: Different cleaning products have different compositions, which give them different properties.

Question: How does a rainbow form? What role does rain play?

Answer: A rainbow forms when raindrops act like tiny prisms. They diffract and separate rays of visible light into the full spectrum of colors.

Question: How do waves move? Does the water in a wave travel to shore?

Answer: The energy of a wave moves through the water, but the individual particles of water do not travel along with the energy to shore. They just vibrate in place.

Question: How do musical instruments make sounds? Do different instruments make sound the same way?

Answer: All musical instruments make sound the same basic way, by causing something to vibrate, which starts sound waves traveling through the air.

Question: Why do satellites orbit Earth? Why don't they either fall to Earth or fly out into space?

Answer: Satellites literally fall around Earth because of the combination of their own forward motion and their acceleration toward Earth because of gravity.

Question: How does a light bulb turn electricity into light? Do all light bulbs work the same way?

Answer: There are a variety of ways that light bulbs can turn electricity into light. The light bulb in the picture turns electricity into light by fluorescence.

Enrichment

Ask interested students to select a physical science career that interests them and interview a professional in that career. They can choose a career that is described in the lesson or any other physical science career (e.g., chemist, electrician, physics teacher, engineer). Tell students to inquire about the education and training required for the career, the work setting and nature of the work, and any other questions they may have. After students complete their interviews, give them a chance to share what they learned with the rest of the class.

Science Inquiry

Divide the class into several groups, and assign groups to find photos of common situations, conditions, or events that they think can be explained by concepts in chemistry or physics. Have groups share their photos and state how they think they are related to chemistry or physics. Tell students to look for the relevant concepts as they read the *CK–12 Physical Science for Middle School* FlexBook® resource.

Common Misconceptions

Students tend to have many misconceptions about matter and energy. They are two of the most fundamental concepts in physical science, and both are introduced in this lesson. Make sure that students start out with as few misconceptions about these concepts as possible. Present the class with the following common misconceptions (and/or others from the URL below), and then ask students whether they think the statements are true or false. After students have weighed in on the misconceptions, briefly explain why each statement is false.

- http://www.eskimo.com/~billb/miscon/opphys.html

1. Gases aren't matter because they are invisible.
2. Mass and volume represent the same property of matter.
3. Energy can be "used up."
4. Energy is the same thing as force.
5. Objects at rest have no energy.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define physical science.
   - [Physical science is the study of matter and energy.]
2. What is the focus of chemistry?
   - [The focus of chemistry is matter. It is the study of the structure, properties, and interactions of matter.]
3. Describe an example of a career in physical science.
   - [Answers may vary. *Sample answer:* An example of a career in physical science is pharmacist. A pharmacist prepares and dispenses medicines and advises patients. Pharmacists work in drug stores, hospitals, and other settings.]
4. What practical question might be answered with physics concepts?
   - [Answers may vary, but they should be questions relating to energy. *Sample answers:* What is the best way to heat a home? How can I use electricity safely?]
5. Energy is needed to make matter move. Explain how you use energy to ride a bike uphill. What force allows you to coast downhill without peddling?
   - [You provide energy with your muscles when you push the pedals. The pedals move gears and chains that turn the wheels. The turning wheels move the bike uphill. The force of gravity allows you to coast downhill without peddling.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 1.2 Quiz in *CK-12 Physical Science for Middle School Assessments*.

Points to Consider

A figure in the lesson describes several careers in physical science. Other careers in physical science include research scientist and engineer.

- What do you think research scientists do?

***Sample answer*: I think research scientists do experiments and collect data to further knowledge of physical science.**

- How do you think the work of engineers differs from that of research scientists?

***Sample answer*: I think that engineers use scientific knowledge to make things or solve practical problems, rather than**

Chapter 2 TE Scientific Research and Technology

Chapter Outline

2.1 Chapter 2: Scientific Research and Technology

Chapter Overview

Steps of a scientific investigation generally include asking a question, forming a hypothesis, gathering and analyzing evidence, deciding whether the evidence supports the hypothesis, drawing conclusions, and communicating results. Important science skills range from making measurements in SI units to following safety rules. Technology is the application of scientific knowledge to real-world problems.

Online Resources

See the following Web sites for appropriate laboratory activities:

The penny lab at the following URL is a great way to introduce and teach the scientific method.

- http://sciencespot.net/Media/pennylab.pdf

The URL below has links to many labs and other activities that will help students develop science process skills.

- http://www.myteacherpages.com/webpages/mri/science.cfm?subpage=917446

Many grade-appropriate technology and engineering activities are available at this URL:

- http://www.pbs.org/wgbh/nova/teachers/resources/subj_13_03.html

These Web sites may also be helpful:

Before you discuss scientific investigation in Lesson 2.1, you may want to read the short article and see the animation at the following URLs for a full view of the complexity of scientific investigation.

- http://undsci.berkeley.edu/article/0_0_0/howscienceworks_01
- http://undsci.berkeley.edu/article/0_0_0/howscienceworks_02

Before students do any lab procedures in physical science, make sure they know the safety rules presented in Lesson 2.2. The video below outlines lab safety rules with a student-friendly flash animation.

- http://www.youtube.com/watch?v=d-YBq2PX-4o

This is a good resource for you or your students when you teach technology in Lesson 2.3. It is an interactive timeline that covers some of America's technological innovations and inventions, from Benjamin Franklin's lightning rod to the Hubble Space Telescope.

- http://www.pbs.org/wgbh/amex/telephone/timeline/index.html

Pacing the Lessons

TABLE 2.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
2.1 Scientific Investigation	2.0
2.2 Scientific Skills	3.0
2.3 Technology	1.0

2.2 Lesson 2.1 Scientific Investigation

Key Concept

A scientific investigation generally involves some or all of the following steps: ask a question, form a hypothesis, gather and analyze evidence, decide whether the evidence supports the hypothesis, draw conclusions, and communicate results. Scientific investigations also must be guided by ethical rules.

Standards

- SCI.CA.8.IE.9.a, b, c
- MCR.6-8.SCI.12.1, 2, 3, 4, 5, 7, 8, 9
- NSES.5-8.A.1.1, 2; NSES.5-8.A.2.1, 2, 6, 7; NSES.5-8.G.2.1, 3
- AAAS.6-8.1.A.1, 2; AAAS.6-8.1.B.1, 2, 3, 5, 6; AAAS.6-8.1.C.5, 6, 8; AAAS.6-8.12.A.1; AAAS.6-8.12.D.6

Lesson Objectives

- List the steps of a scientific investigation.
- Relate ethics to scientific research.

Lesson Vocabulary

- **control**: variable in an experiment that is held constant so it will not influence the outcome
- **ethics**: rules for deciding between right and wrong
- **experiment**: controlled scientific study of a limited number of variables
- **field study**: investigation of a problem in a real-world setting
- **hypothesis**: potential answer to a question that can be tested by gathering information
- **manipulated variable**: factor that is changed, or manipulated, by a researcher in a scientific experiment
- **observation**: any information that is gathered with the senses
- **replication**: getting the same results when an investigation is repeated
- **responding variable**: factor in an experiment that is expected to change, or respond, when the manipulated variable changes

Teaching Strategies

Introducing the Lesson

Introduce scientific investigation with a demonstration of Oersted's well-known accidental discovery of electromagnetism. Use a battery and wire to form a simple circuit and place a compass near it so the needle of the compass is attracted to the wire. Connect and disconnect the wire from the battery so students can observe that the needle of the compass moves toward the wire only when current is flowing through it. Ask students what they can conclude from the demonstration. (A wire with electric current flowing through it acts like a magnet.) Explain that this is how electromagnetism was actually discovered. Relate this example to the serendipitous nature of scientific investigation to help students avoid the misconception that scientific investigation is like following a recipe in a cookbook.

Discussion

For an entertaining discussion of the steps of a scientific investigation, present students with science experiments involving everyone's favorite member of the phylum Porifera, SpongeBob SquarePants. The URL below provides several examples that you can share and discuss with your students. Read the description of each experiment, and then challenge students to use their knowledge of scientific investigation to answer the questions.

- http://sciencespot.net/Media/scimthdexps.pdf

Differentiated Instruction

Pair less proficient readers and English language learners with students who excel in science. Then ask partners to work together to create an illustrated diagram of the steps in a scientific investigation. Illustrations could be their own sketches or images they find online. Students should add their diagram to their science notebook.

Enrichment

Ask a few students to make crossword puzzles using lesson vocabulary terms. Distribute copies of their puzzles to the rest of the class to solve as a review of lesson vocabulary.

Science Inquiry

Continue the SpongeBob theme and give students an opportunity to identify variables and controls in scientific investigations. Make and distribute copies of one or both worksheets (except for the answers pages) at the URLs below. Have students complete the worksheets alone, in pairs, or in small groups. Call on volunteers to report their answers until correct answers have been given.

- http://sciencespot.net/Media/scimethodconvar.pdf
- http://sciencespot.net/Media/scimethodconvar2.pdf

Common Misconceptions

A frequently held misconception is that there is a single scientific method that all scientists follow. Explain that the commonly taught "scientific method" is a simple way to understand the basics of scientific investigation, but it is an oversimplified representation of how scientists actually do research. In reality, the process of science is exciting, complex, and unpredictable. It involves many different people, engaged in many different activities, and in many different sequences. Students can see an animation showing the complexity of scientific investigation at this URL: http://undsci.berkeley.edu/article/0_0_0/howscienceworks_02 .

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. List the steps of a typical scientific investigation.
   - [The steps of a typical scientific investigation include: identify a research question or problem, form a hypothesis, gather evidence to test the hypothesis, analyze the evidence, decide whether the evidence supports the hypothesis, draw conclusions, and communicate the results.]
2. State why communication is important in scientific research.
   - [Communication is important in scientific research because, by sharing their results, researchers may be able to get helpful feedback from other scientists. Reporting on research also lets other scientists repeat the investigation to see whether the results can be replicated. If the results can be replicated, it means they are more likely to be correct.]
3. Identify three ethical rules for scientific research.
   - [Students may list any three ethical rules for scientific research. *Sample answer*: Scientific research must be reported honestly; scientific researchers should avoid being biased by the results they expect or want to get; researchers studying human subjects must tell their subjects about any potential risks of the research.]
4. Write a hypothesis based on this question: Do vinegar and water freeze at the same temperature? Make a prediction based on your hypothesis.
   - [Answers may vary. *Sample answer*: Vinegar freezes at a lower temperature than water. If I put the same amount of vinegar and water in the freezer at the same time, the water will freeze first.]
5. Describe an experiment you could do to test your prediction in question 4. Identify the variables and controls in your experiment. Include a list of materials. With your teacher's approval, conduct your investigation.
   - [Answers will vary depending on the hypothesis and prediction in the answer to question 4. Students should identify manipulated and responding variables and controls. They should also provide a list of materials needed to carry out the experiment.]
6. In Tara's experiment with the magnet, she measured and recorded the data in the **Table** below.

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Lesson Quiz

Check students' mastery of the lesson with Lesson 2.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Scientific investigations often involve measuring. For example, Tara measured the temperature of a magnet with a thermometer. Thermometers may have different scales. You may be most familiar with the Fahrenheit and Celsius scales.

- Do you know how the Fahrenheit and Celsius scales differ? For example, what are the freezing and boiling points of water on each scale?

The scales differ in the freezing and boiling points of water and the number of degrees separating them. The freezing a

- Do you know how to convert a temperature from one scale to the other?

Students may or may not know the conversion formulas, which are given in Lesson 2.2.

2.3 Lesson 2.2 Science Skills

Key Concept

Most scientists use the SI system of units. Important science skills include making measurements that are accurate and precise, keeping good records, calculating derived quantities, using significant figures and scientific notation, using descriptive statistics and graphs, creating models, and following safety rules.

Standards

- SCI.CA.8.IE.9.e, f
- MCR.6-8.SCI.12.6
- NSES.5-8.A.2.1, 3, 4; NSES.5-8.G.2.1
- AAAS.6-8.1.C.3, 8; AAAS.6-8.2.B.1; AAAS.6-8.9.B.3; AAAS.6-8.9.C.3; AAAS.6-8.11.B.1, 5, 6; AAAS.6-8.12.B.1, 2, 3, 4, 5, 8, 9, 10, 11; AAAS.6-8.12.C.3; AAAS.6-8.12.D.1, 2, 4

Lesson Objectives

- Explain how measurements are made in scientific research.
- Describe how to keep good records in scientific investigations.
- Demonstrate how to use significant figures and scientific notation.
- Calculate descriptive statistics and use data graphs.
- Identify the role of models in science.
- Describe how to stay safe when doing scientific research.

Lesson Vocabulary

- **accuracy**: closeness of a measurement to the true value
- **Kelvin scale**: SI scale for measuring temperature in which the freezing point of water is 273 K and the boiling point of water is 373 K
- **mean**: average value of a set of measurements that is calculated by summing the individual measurements and then dividing the total by the number of measurements
- **precision**: exactness of a measurement
- **range**: total spread of values in a set of measurements that is calculated by subtracting the smallest value from the largest value
- **scientific notation**: way of writing very large or very small numbers that uses exponents in the format $a \times 10^b$
- **SI**: International System of Units, which is used by most scientists
- **significant figures**: correct number of digits in an answer that is based on the least precise measurement used in the calculation

Teaching Strategies

Introducing the Lesson

Ask students to imagine flying in a jumbo jet at an altitude of 12.5 km (about 7.7 mi) and running out of fuel half way to your destination. Explain that this actually happened in 1983 to passengers on an Air Canada 747 jet. The amount of fuel needed for the flight was miscalculated because standard English units were used instead of newly adopted metric units. Amazingly, the pilot was able to glide the jet safely to the ground, and no one was seriously injured. Relate the incident to the importance of having a standard system of measurement units. Tell students they will learn in this lesson about the standard system of measurement units that is used in science.

Demonstration

Demonstrate to the class the correct way to use a graduated cylinder to measure the volume of liquids and the correct way to use a beam balance to measure the mass of solids. After your demonstration, give groups of students a chance to use the instruments to make sample measurements. Discuss the difference between mass and volume, the two fundamental properties of matter.

Activity

The URL below describes several lab safety scenarios for students to identify safety issues and apply science safety rules. Read each scenario to the class, and call on students to identify the problem and the correct alternative.

- http://mjksciteachingideas.com/pdf/SafetyGame.pdf

Differentiated Instruction

Start a word wall for physical science. Pair English language learners with native English speakers, and have partners select three of the lesson vocabulary words and post them on the word wall along with definitions and examples.

Enrichment

Ask a few students to collaborate on writing a rap about staying safe in science. Their rap should include several of the safety rules given in the lesson. Invite the students to present their rap to the class.

Science Inquiry

Divide the class into several groups, and give each group a copy of the following **Table** 2.2. Tell students to decide within their group which type of graph (bar, circle, or line) would be most appropriate for the data and then graph the data. Have groups display their graphs and explain their choice of type of graph. (A line graph is most appropriate for showing changes over time.) Call on volunteers to summarize in words what their graph shows. Use the example to discuss with the class how a graph helps to visualize data better than a table does.

TABLE 2.2: Moose Population in Franklin County

Year	Number of Moose
2000	6

TABLE 2.2: (continued)

Year	Number of Moose
2001	8
2002	10
2003	14
2004	12
2005	11

Math Connection

Expand on the discussion of derived quantities in the lesson. Point out that many physical science quantities are derived quantities that require math calculations. Write the following example on the board:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Tell students that equations like this one can be rearranged to solve for different variables, and this is often necessary to solve physical science problems. Show students how to rearrange the speed equation to solve for distance or time:

$$\text{Distance} = \text{Speed} \times \text{Time}$$
$$\text{Time} = \frac{\text{Distance}}{\text{Speed}}$$

Then challenge students to do the following problems. Call on volunteers to put their solutions on the board.

- Emily rode her bicycle at a speed of 20 km/h for $\frac{1}{4}$ h. How far did she go? (Answer: 5 km)
- Miguel walked at a speed of 2.5 miles per hour and covered a distance of 5 miles. How long did it take him to walk that distance? (Answer: 2 hours)

Answers to You Try It!

Problem: Rod needs to buy 1 meter of wire for a science experiment. The wire is sold by the yard, not the meter. If he buys 1 yard of wire, will he have enough? (*Hint*: How many inches are there in 1 yard? In 1 meter?)

Solution: Rod needs 39.37 inches (1 m) of wire and a yard is only 36 inches, so if he buys 1 yard of wire he won't have enough.

Problem: The weather forecaster predicts a high temperature today of 86 °F. What will the temperature be in Celsius?

Solution: The temperature will be (86 °F –32) ÷ 1.8 = 30 °C.

Problem: Write the number 46,000,000 in scientific notation.

Solution: 4.6×10^7

Reinforce and Review

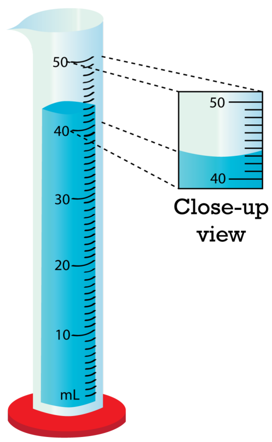
Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are the basic SI units for length, volume, and mass?
    - [The basic SI units for length, volume, and mass are the meter, cubic meter, and gram, respectively.]
2. How much liquid does this graduated cylinder contain?



    - [The graduated cylinder contains 43 mL of liquid.]
3. Define the mean and range of a data set. How are they calculated?
    - [The mean is the average value. It is calculated by summing the individual measurements and dividing by the total number of measurements. The range is the total spread of values. It is calculated by subtracting the smallest value from the largest value.]
4. What is a model? How are models used in science?
    - [A model is a representation of an object, system, or process. Models are used in science to investigate things that are too small, large, complex, or distant to investigate directly.]
5. What hazard does each of these symbols represent?

    - [From left to right, the hazards represented by the symbols are sharp instrument, heat, and glassware.]
6. Do the following calculations:

(a) Write the number 0.0000087 in scientific notation.
   - [$0.0000087 = 8.7 \times 10^{-6}$]

(b) Convert 50 °C to °F.
   - [50 °C = 122 °F]

(c) Find the volume of a cube that measures 5 cm on each dimension (length, width, and height).
   - [volume = 125 cm^3]

7. Make a safety poster to convey one of the lab safety rules in this lesson.
   - [Posters will vary but should convey one of the lab safety rules in the lesson.]
8. Compare and contrast accuracy and precision of measurements in science.
   - [The accuracy of measurements in science is the closeness of the measurements to the true values. The precision of measurements is their exactness. A measurement may be accurate but not precise, or a measurement may be precise but not accurate. Ideally, scientific measurements are both accurate and precise.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Most of the skills described in this lesson are important in technology as well as science.

- What is technology?

***Sample answer*: Technology is the use of scientific knowledge to solve practical problems or make things that are usefu**

- How do you think technology differs from science?

***Sample answer*: Technology uses scientific knowledge but it doesn't add to scientific knowledge as scientific research do**

2.4 Lesson 2.3 Technology

Key Concept

Technology is the application of knowledge to real-world problems by professionals called engineers. The development of new technology is known as technological design. Technology, science, and society are all interrelated.

Standards

- MCR.6-8.SCI.13.3, 6; MCR.6-8.TECH.1, 2, 3, 4, 6
- NSES.5-8.A.2.4; NSES.5-8.E.1.2; NSES.5-8.E.2.1, 3, 4, 5; NSES.5-8.F.5. 3, 5, 6, 7
- AAAS.6-8.1.C.7; AAAS.6-8.3.A.2, 3; AAAS.6-8.3.B.1; AAAS.6-8.3.C.3, 4, 6, 7, 8; AAAS.6-8.6.A.3, 4, 6

Lesson Objectives

- Define technology.
- Outline the technological design process.
- Explain how science and technology are related.
- Describe how technology and society influence each other.

Lesson Vocabulary

- **engineer**: professional in technology
- **technological design**: development of new technology
- **technology**: application of knowledge to real-world problems

Teaching Strategies

Introducing the Lesson

Mars One is a private enterprise plan to settle people permanently on Mars by 2023. The plan is to be financed by making the entire endeavor a reality TV show. Although some people think Mars One might be a hoax, it is a very interesting vehicle for introducing technology. Share with students the Mars One proposal (see URL below), and show them the video about the project so they can learn about the technological challenges and proposed solutions. Tell students they will learn how engineers solve technological challenges such as these in this lesson.

- http://mars-one.com/en/

Activity

Students can apply lesson concepts with the minds-on activity "Surviving on Planet Niwrad." Teacher guidelines and a student handout are available at the URL below.

- http://www.pbs.org/wgbh/nova/teachers/activities/2201_mammoths.html

Differentiated Instruction

Help visual learners and less proficient readers see the relationship between technology and science by working with them to make a compare-contrast table (see sample **Table** 2.3). Label the rows and columns of the table, and then call on students to fill in the cells.

TABLE 2.3: **Comparing and Contrasting Science and Technology**

Properties	Science	Technology
Goal	to increase knowledge	to use knowledge for practical purposes
Method	scientific investigation	technological design

Enrichment

Ask a few students to learn more about the evolution of modern computers. Then have them create a PowerPoint presentation to share what they learn with the rest of the class and extend lesson content.

Science Inquiry

Have groups of students do the "Backpack Challenge" to design a backpack that meets multiple needs. The activity will show students that there are usually many possible solutions to a design problem and give them first-hand experience with trade-offs and constraints on technological design. At the URL below, you can find a step-by-step description of the activity and handouts for students.

- http://www.pbs.org/wgbh/nova/teachers/activities/3004_xplanes.html

Real-World Connection

Challenge students to brainstorm as many examples of technology in their daily lives as they can think of. (Examples might include cell phones, TVs, computers, lighting, microwave ovens, motor vehicles, and materials such as plastics and glass.) For each example, ask students to identify the problem or need that the technology solves. Encourage students to think about what their lives would be like without the different technologies.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define technology.
   - [Technology is the application of knowledge to real-world problems.]
2. What do engineers do?
   - [Engineers are professionals in technology. They improve technologies or develop new technologies to solve practical problems.]
3. List the steps of the technological design process.
   - [The steps of the technological design process include: identify a problem, research the problem, generate possible solutions, select the best solution, create a model of the solution, test the model, refine and retest the model as needed, and communicate the final solution.]
4. A team of engineers is designing a new type of car. What are likely to be some of the constraints on the design?
   - [Answers may vary. *Sample answer:* Constraints might include the strength of the materials used to build the car, the fuel efficiency of the car, the amount of pollution produced by the car, the safety of the car, and the cost of making the car.]
5. Compare and contrast science and technology.
   - [Technology is sometimes referred to as applied science, but it has a different goal than science. The goal of science is to increase knowledge. The goal of technology is to use knowledge for practical purposes. Although they have different goals, technology and science work closely together, and each helps the other advance. Both are also based on evidence and logic.]
6. Relate technology and society.
   - [Technology attempts to solve people's problems. Therefore, the problems of society generally set the direction that technology takes. New technologies, in turn, affect society. For example, they may make people's lives easier or healthier.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 2.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Nanotechnology manipulates atoms and molecules of matter.

- What is matter? What are its characteristics?

Matter is all the "stuff" that exists in the universe. Matter has both mass and volume.

- Do you think all matter consists of atoms and molecules?

Students may know that atoms and molecules are the basic building blocks of matter.

CHAPTER 3 TE Introduction to Matter

Chapter Outline

3.1 Chapter 3: Introduction to Matter

Chapter Overview

Matter is anything that has mass and volume. Matter has both physical and chemical properties. Elements are pure substances with unique properties. Compounds are unique substances that form when two or more elements combine chemically. Physical changes in matter are changes in physical properties. Chemical changes in matter are changes in chemical properties. Matter cannot be created or destroyed, even when it changes.

Online Resources

See the following Web sites for appropriate laboratory activities:

At the following URL, the first part of the lab is a good choice for Lesson 3.1; add the graphing part for enrichment.

- http://www.kwanga.net/chemnotes/density-lab.pdf

For Lesson 3.2, students can do the lab "Messing with Mixtures." Worksheets and background notes are provided at these URLs:

- http://sciencespot.net/Media/messingmixtures.pdf
- http://sciencespot.net/Media/messingmixturesnotes.pdf

This teacher-developed lab hones students' observational skills and really reinforces the differences between physical and chemical changes.

- http://people.wku.edu/bruce.kessler/IKE/Sciencematerials/PandCCLab.pdf

These Web sites may also be helpful:

For Lesson 3.1, teach mass and volume with the mass and volume PowerPoint presentations and worksheets at this URL: http://sciencespot.net/Pages/classmetric.html .

Students can delve more deeply into elements in Lesson 3.2 with the activity at the following URL: http://www.pbs.org/wgbh/nova/teachers/activities/3114_origins.html .

When you teach Lesson 3.3, students can explore physical and chemical changes in matter with this excellent animation: http://www.wisc-online.com/objects/ViewObject.aspx?ID=SCE204 .

Pacing the Lessons

TABLE 3.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
3.1 Properties of Matter	1.5
3.2 Types of Matter	2.5
3.3 Changes in Matter	2.0

3.2 Lesson 3.1 Properties of Matter

Key Concept

Matter is anything that has mass and volume. Mass is the amount of matter in a substance. Volume is the amount of space matter takes up. Matter has both physical and chemical properties. Physical properties can be measured or observed without matter changing to a different substance. Chemical properties of matter can be measured or observed only when matter undergoes a chemical change to become a different substance.

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.6.a; SCI.CA.8.PS.7.c; SCI.CA.8.PS.8.a, b
- MCR.6-8.SCI.10.1
- NSES.5-8.B.1.1
- AAAS.6-8.4.D.11, 15, 16; AAAS.6-8.4.G.1; AAAS.6-8.9.C.6

Lesson Objectives

- Define matter, mass, and volume.
- Identify physical properties of matter.
- List examples of chemical properties of matter.

Lesson Vocabulary

- **chemical property**: property of matter that can be measured or observed only when matter changes form and becomes something else
- **density**: amount of mass in a given volume of matter $(D = M/V)$
- **flammability**: ability of matter to burn
- **mass**: amount of matter in a substance or object
- **matter**: anything that has mass and volume
- **physical property**: property of matter that can be measured or observed without matter changing to a different kind of matter
- **reactivity**: ability of matter to combine chemically with other substances
- **volume**: amount of space that matter takes up
- **weight**: amount of space that matter takes up

Teaching Strategies

Introducing The Lesson

Introduce matter by asking the class to brainstorm examples of matter in the classroom. Students are likely to name visible objects such as books, desks, and other students. If they don't mention air, tell them that most of the matter, by volume, in the classroom is invisible, and ask them to guess what it is. Conclude by saying that they will learn about matter and its properties in this lesson.

Activity

Put a variety of different small objects in a brown paper bag. For example, you might include a cotton ball, toothpick, pen, shoelace, lemon, orange, eraser, playing card, dry pasta, and paper clip. Include at least two objects, such as a lemon and an orange, that are difficult to distinguish by touch alone. Carry the bag around the classroom, and ask several different students to try to identify the objects by just reaching into the bag and feeling them. Use the activity to launch a discussion of physical properties of matter.

- **Question**: What physical properties of matter did you use to identify the objects in the bag?
- **Answer**: Students might mention properties such as hardness, texture, shape, and size.

For any objects students could not identify, show them the objects and ask them what other physical properties (observable with other senses) would have helped them identify the objects. Students might mention color, odor, or taste.

Differentiated Instruction

If you haven't started a physical science word wall yet, this is a good time to start one because this lesson introduces basic concepts that are relevant to several other FlexBook® chapters, including matter, density, and physical and chemical properties. Pair any students who need extra help with students who excel, and assign each pair a lesson vocabulary term to add to the word wall. They should include the definition and an example of the assigned term. Encourage them to include a drawing as well.

Enrichment

Ask a few students to demonstrate differences in chemical reactivity. In their demonstration, have students mix vinegar with baking soda and with another, similar-looking substances such as salt that will not react with vinegar. Have them point out the evidence that the baking soda—but not the other substance—reacts with the vinegar. (Only the baking soda froths up when combined with vinegar. This happens because a chemical change has occurred and formed a new substance—carbon dioxide gas.)

Science Inquiry

Use one or more of the inquiry activities at the URL below to introduce physical properties that can be used to identify different liquids. The activities begin on page 131 of the PDF document, which is a product of the American Chemical Society's Education Division. The comprehensive document provides a panoply of teaching resources, including background information, procedures, expected results, worksheets, and assessment rubrics.

- http://www.inquiryinaction.org/pdf/InquiryinAction.pdf

Common Misconceptions

Students commonly think that gases such as air are not matter because they are invisible. Demonstrate that gases consist of matter and take up space. Blow up a balloon and relate the increase in size of the balloon to the air that has been added to it. Explain that particles of air are constantly moving and bumping against the inner surface of the balloon, causing it to inflate.

Answers to You Try It!

Problem: If you have a mass of 50 kg on Earth, what is your weight in newtons?

Solution: Your weight is (50 kg $\times$ 9.8 N/kg) = 490 N.

Problem: An object has a mass of 180 kg and a volume of 90 m^3. What is its density?

Solution: The density of the object equals 180 kg/90 m^3 = 2 kg/m^3.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define matter.
   - [Matter is defined as anything that has mass and volume.]
2. How does mass differ from weight?
   - [Mass is the amount of matter in a substance or object. Weight is a measure of the force of gravity pulling on an object. The more matter an object contains, generally the more it weighs. That's because an object with more mass is pulled by gravity with greater force. However, the weight of an object will change if the force of gravity changes, even if its mass remains constant.]
3. Describe the displacement method for measuring the volume of an object.
   - [To find volume using the displacement method, the object is added to the water in a measuring container. The increase in volume of the water when the object is added represents the volume of the object.]
4. Identify two physical properties and two chemical properties of matter.
   - [Answers may vary. *Sample answer:* Two physical properties of matter are density and color. Two chemical properties of matter are the ability to burn and the ability to react with other substances.]
5. Create a table comparing and contrasting physical properties of tap water and table salt.
   - [Tables may vary but should show similarities and differences in the physical properties of tap water and table salt. For example, salt is a white solid, whereas water is a clear liquid. Neither salt nor water has an odor, but salt tastes salty, whereas water has no taste.]

6. Apply the concept of density to explain why oil floats on water.
   - [Density is the mass per unit volume of a substance. A liquid with lower density will float on a liquid with higher density. Oil has a lower density than water, so oil floats on water.]
7. Some kinds of matter are attracted to a magnet. Is this a physical or chemical property of matter? How do you know?
   - [The ability to be attracted by a magnet is a physical property of matter. You know it's a physical property because it can be detected without changing matter to a different substance. All you need to do is place the matter near a magnet to see if it is attracted to the magnet.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.1 Quiz in *CK–12 Physical Science Quizzes and Tests.*

Points to Consider

The physical and chemical properties of substances can be used to identify them. That's because different kinds of matter have different properties.

- What property could you use to tell the difference between iron and aluminum?

***Sample answer*: You could use the property of attraction to a magnet to tell the difference between iron and aluminum**

- How could you tell whether a liquid is honey or vinegar?

***Sample answer*: You could pour the two liquids from one container to another. The honey would be thicker and would**

3.3 Lesson 3.2 Types of Matter

Key Concept

Elements are pure substances with unique properties. The smallest particles of elements are atoms. Compounds are unique substances that form when two or more elements combine chemically. The smallest particles of compounds are molecules, but some compounds form crystals instead.

Standards

- SCI.CA.8.PS.3.b, c
- MCR.6-8.SCI.8.1, 2, 4, 7, 8
- NSES.5-8.B.1.1, 2, 3
- AAAS.6-8.1.A.4; AAAS.6-8.1.C.1; AAAS.6-8.4.D.1, 2, 3, 8, 17, 19; AAAS.6-8.10.F.1, 2

Lesson Objectives

- Describe elements and atoms.
- Describe compounds, molecules, and crystals.
- Define mixture, and identify types of mixtures.

Lesson Vocabulary

- **atom**: smallest particle of an element that still has the element's properties
- **colloid**: homogeneous mixture in which the particles are large enough to reflect light and be seen but too small to settle or filter out of the mixture
- **compound**: unique substance that forms when two or more elements combine chemically
- **crystal**: rigid, lattice-like framework of many atoms bonded together that is formed by some compounds such as table salt
- **element**: pure substance that cannot be separated into any other substances
- **mixture**: combination of two or more substances in any proportions
- **molecule**: smallest particle of a compound that still has the compound's properties
- **solution**: homogeneous mixture in which particles are too small to reflect light and be seen and also too small to settle or be filtered out of the mixture
- **suspension**: heterogeneous mixture in which particles are large enough to reflect light and be seen and also large enough to settle or be filtered out of the mixture

Teaching Strategies

Introducing the Lesson

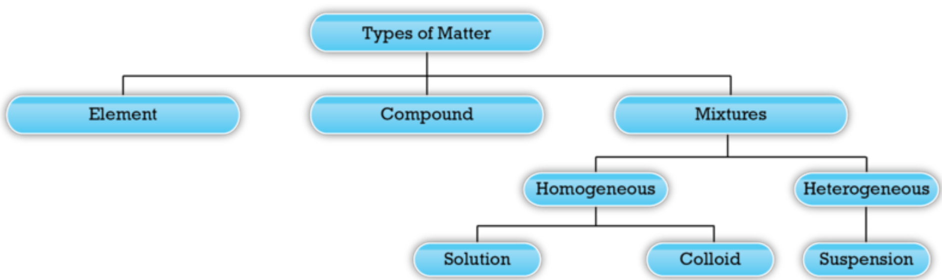
Students are likely to have learned about elements and atoms in previous science classes. Call on volunteers to share what they can recall about them. Tell the class they will learn about elements, atoms, and other types of matter in this lesson.

Demonstration

Reinforce the important idea that a compound is a unique substance that always has the same composition. Show students samples of two compounds that each contains only hydrogen and oxygen: water (H_2O) and hydrogen peroxide (H_2O_2). Explain how the proportions of hydrogen and water differ in the two compounds. Also discuss how their properties differ (e.g., hydrogen peroxide is so reactive that it kills germs and bleaches color from hair).

Differentiated Instruction

Work with any students who need extra help to make a concept map of types of matter. A sample concept map is shown below:



Enrichment

Encourage a few creative students to make three-dimensional models of a crystal of sodium chloride. For example, they might use Styrofoam balls of different colors to represent the sodium and chloride ions and "bond" them together with glue or toothpicks. Invite students to explain their models to the rest of the class. Afterward, put the models on display in the classroom.

Science Inquiry

Have groups of students devise procedures for separating the following mixtures into their components based on their different physical properties:

- pepper and iron filings
- sugar and sand

Give groups a chance to share their procedures and offer each other feedback. You can have groups carry out the procedures if time allows.

Common Misconceptions

A common student misconception is that atoms are "mini-versions" of the elements they represent. For example, students might think that atoms of copper are copper-colored and the atoms of gold are gold-colored. Correct this misconception by explaining that atoms consist of smaller particles—called protons, neutrons, and electrons—that are identical in all atoms, regardless of the element. Atoms of different elements have different numbers of these particles and this is what gives the atoms different properties.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is an element? Give three examples.
    - [An element is a pure substance that cannot be separated into any other substances. Examples may vary. *Sample answer:* Three examples of elements are hydrogen, oxygen, and carbon.]
2. Describe compounds.
    - [Compounds are unique substances that form when two or more elements combine chemically. Compounds always have the same components in the same proportions. They also have the same composition throughout.]
3. Identify molecules and crystals.
    - [Molecules are the smallest particles of a compound that still have the compound's properties. They consist of two or more atoms that are joined together. Crystals are rigid, lattice-like frameworks of many atoms joined together. Some compounds form crystals instead of molecules.]
4. What are mixtures?
    - [Mixtures are combinations of two or more substances in any proportions. The substances may be elements or compounds, and they retain their original properties when mixed together.]
5. How could you use water and a coffee filter to separate a mixture of salt and sand?
    - [You could mix the salt and sand with the water to dissolve the salt. Then you could pour the water through the coffee filter to filter out the sand. The sand would remain in the filter, and the water that passed through the filter would contain only the salt. The salt could be separated from the water by allowing the water to evaporate and leave the salt behind.]
6. Homogenized milk is a colloid. It has been treated to prevent its different components from separating when it stands. When nonhomogenized milk stands, the cream rises to the top because it is less dense than the rest of the milk. Which type of mixture is nonhomogenized milk? Explain your answer.
    - [Nonhomogenized milk is a suspension because its cream particles are large enough to separate when the milk stands.]
7. Create a table comparing and contrasting compounds and mixtures. Include an example of each.

- *Sample answer*: **Table below**

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Lesson Quiz

Check students' mastery of the lesson with Lesson 3.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The properties of matter are not fixed. In fact, matter is always changing.

- What are some ways you have seen matter change?

***Sample answer*: I have seen matter change from a solid to a liquid when ice melted to water.**

- What do you think caused the changes?

***Sample answer*: Ice changed to water when it became warmer.**

3.4 Lesson 3.3 Changes in Matter

Key Concept

Physical changes are changes in the physical properties of matter. Chemical changes are changes in the chemical properties of matter. Matter cannot be created or destroyed even when it changes. This is the law of conservation of mass.

Standards

- SCI.CA.8.PS.5.d
- MCR.6-8.SCI.8.6, 8; MCR.6-8.SCI.12.7
- NSES.5-8.A.1.4; NSES.5-8.B.1.2
- AAAS.6-8.4.D.12, 17

Lesson Objectives

- Define and give examples of physical changes in matter.
- Define and give examples of chemical changes in matter.
- State the law of conservation of mass.

Lesson Vocabulary

- **chemical change**: change in matter that occurs when matter changes chemically into an entirely different substance with different chemical properties
- **law of conservation of mass**: law stating that matter cannot be created or destroyed
- **physical change**: change in one or more of matter's physical properties

Teaching Strategies

Introducing the Lesson

Show students a small wooden toy and ask them to brainstorm ways they could change it (e.g., use a hammer to pound dents in it, cut it into smaller pieces with a saw, burn it in a fire, paint it to change its color, drill holes in it). Tell students they will learn about changes in matter in this lesson.

Demonstration

Demonstrate physical and chemical changes by cutting a sheet of paper and burning an identical sheet of paper. Discuss the products of each change and whether either change is reversible.

Differentiated Instruction

Guide students in making Frayer models for the terms physical change and chemical change. You can see a sample Frayer model below. Students should keep their completed models in their science notebook.

TABLE 3.2: **Sample Frayer model**

Term: physical change **Definition:** change in one or more of matter's physical properties.	**Drawing:** [Student sketch of a saw cutting a log]
Example: Cutting a log	**Non-example:** Burning a log

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a physical change in matter?
   - [A physical change in matter is a change in one or more of matter's physical properties.]
2. What happens during a chemical change in matter?
   - [During a chemical change in matter, matter changes chemically into an entirely different substance with different chemical properties.]
3. State the law of conservation of mass.
   - [The law of conservation of mass states that matter cannot be created or destroyed.]
4. When a plant grows, its mass increases over time. Does this mean that new matter is created? Why or why not?
   - [No new matter was created. Matter cannot be created or destroyed. The plant took in substances from the environment that allowed it to grow and increase in mass. For example, it took in water and nutrients through its roots from the soil and carbon dioxide through its leaves from the air.]
5. Butter melts when you heat it in a pan on the stove. Is this a chemical change or a physical change? How can you tell?
   - [Butter melting is a physical change. You can tell that it's a physical change because the melted butter can be changed back to solid butter by just allowing it to cool. The melted butter also tastes the same as solid butter, another sign that its chemical makeup doesn't change when it melts.]
6. Compare and contrast physical and chemical changes in matter. Give an example of each type of change.

- [A physical change results in different physical properties, but the chemical makeup of the substance does not change. An example of a physical change is glass breaking. A chemical change results in new substances with different chemical properties. An example of a chemical change is wood burning.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 3.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Some physical changes in matter are changes of state.

- What are the states of matter?

Students may know the three most common states of matter on Earth: solids, liquids, and gases.

- What might cause matter to change state?

***Sample answer*: A change in temperature might cause matter to change state.**

CHAPTER 4 TE States of Matter

Chapter Outline

4.1 Chapter 4: States of Matter

Chapter Overview

Matter can exist in four states: solid, liquid, gas, or plasma. The state of matter depends on the kinetic energy of its particles. For gases, the relationships among pressure, volume, and temperature are given by the gas laws. Changes of state are physical changes that occur when matter absorbs or loses energy.

Online Resources

See the following Web sites for appropriate laboratory activities:

The "States of Matter Simulation Lab" at the following URL includes a downloadable simulation, student worksheet, teacher's guide, and teaching ideas. It is suitable for Lessons 4.1 and 4.3.

- http://phet.colorado.edu/en/simulation/states-of-matter

When you teach Lesson 4.2, go to the URL below for links to many labs and other activities relating to gases and the gas laws.

- http://www.nclark.net/GasLaws

Students can investigate the properties of gases with the lab at this URL: http://galileo.phys.virginia.edu/outreach/8thgradesol/PropertiesGasFrm.htm .

This lab will help students understand how particle movement changes as matter changes state.

- http://sciencenetlinks.com/lessons/a-matter-of-state/

In this tasty ice cream lab, students can investigate the effects of temperature on changes of state.

- http://galileo.phys.virginia.edu/education/outreach/8thgradesol/TastyPhaseChangeFrm.htm

In the phase change lab at the URL below, students will observe that water stays at a constant temperature as it changes state.

- http://apps.caes.uga.edu/sbof/main/lessonPlan/PhaseChangesMatter.pdf

These Web sites may also be helpful:

The following URL provides links to a wealth of resources for teaching middle school students about states of matter, including activities, labs, slideshows, graphic organizers, online quizzes, and study and review games.

- http://www.science-class.net/Chemistry/states.htm

When you teach Lesson 4.2, you or your students can use the animation at the URL below to explore the behavior of gases in greater depth. The animation can be used to plot graphs of pairs of properties that represent the gas laws.

- http://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html

You can find background information and simple activities on changes of state at this URL: http://www.brainpopjr.com/science/matter/changingstatesofmatter/grownups.weml .

For more advanced activities on changes of state, go to this URL: http://www.inquiryinaction.org/classroomactivities/activities_by_chapter.php?chapter=6&chapter_title=States+of+Matter .

Pacing the Lessons

TABLE 4.1: **Pacing the Lessons**

Lesson	Class Period(s) (60 min)
4.1 Solids, Liquids, Gases, and Plasma	2.0
4.2 Behavior of Gases	2.0
4.3 Changes of State	2.0

4.2 Lesson 4.1 Solids, Liquids, Gases, and Plasmas

Key Concept

Matter can exist in four states: solid, liquid, gas, or plasma. Solids have a fixed volume and a fixed shape, liquids have a fixed volume but not a fixed shape, and gases have neither a fixed volume nor a fixed shape. Like gases, plasmas lack a fixed volume and shape, but unlike gases, plasmas can conduct electricity and respond to magnetism. The state of matter depends on the kinetic energy of the particles of matter.

Standards

- SCI.CA.8.PS.3.c, d, e
- MCR.6-8.SCI.8.3; MCR.6-8.SCI.9.1
- NSES.5-8.B.3.1
- AAAS.6-8.4.D.5, 6, 14; AAAS.6-8.4.E.4

Lesson Objectives

- Describe matter in the solid state.
- State properties of liquid matter
- Identify properties of gases.
- Describe plasma.
- Explain the relationship between energy and states of matter.

Lesson Vocabulary

- **energy**: ability to cause changes in matter
- **gas**: state of matter that has neither a fixed volume nor a fixed shape
- **kinetic energy**: energy of moving matter
- **kinetic theory of matter**: theory that all matter consists of constantly moving particles
- **liquid**: state of matter that has a fixed volume but not a fixed shape
- **plasma**: state of matter lacking a fixed volume and fixed shape that contains ions so it can conduct electricity and respond to magnetism
- **solid**: state of matter that has a fixed volume and fixed shape
- **states of matter**: different forms (solid, liquid, gas, and plasma) in which matter can exist without the chemical makeup of matter changing

Teaching Strategies

Introducing the Lesson

Introduce states of matter with this riddle:

If an optimist sees a glass as half full and a pessimist sees the glass as half empty, how does a chemist see the glass?

Call on students to answer the riddle. (The chemist sees the glass as completely full because it is half-full of liquid and half full of gas.) Tell the class they will learn about liquids, gases, and other states of matter in this lesson.

Activity

Use the classroom activity at the following URL to introduce states of matter at the molecular level. Students will construct models showing how water molecules are arranged in the three physical states. After the activity, they will be able to explain the molecular behavior of ice, water, and water vapor.

- http://www.ucar.edu/learn/1_1_2_3t.htm

Demonstration

Demonstrate to the class how a liquid's volume is fixed even though it takes the shape of its container. Pour a given volume of water from a measuring cup to a graduated cylinder. After students observe the volume and shape of the water in each container, ask them to describe how the shape changes.

Differentiated Instruction

Give less proficient readers the following open-ended cloze prompts to complete as they read the lesson.

1. The four states of matter are __________.
2. A solid is a state of matter that _________.
3. Two basic types of solids are __________.
4. A liquid is a state of matter that __________.
5. Two special properties of liquids are __________.
6. A gas is a state of matter that __________.
7. A plasma is a state of matter that __________.

Enrichment

Ask a small group of students to create a Web site on energy and matter, beginning with the kinetic theory of matter and the relationship between energy and states of matter. Have students update the Web site with additional relevant information from later chapters of the FlexBook® resource as the school year progresses. Their Web site might include definitions, background information, images, and links to videos, animations, quizzes, and games. Encourage the rest of the class to make use of the Web site as they study energy and matter in the FlexBook® resource.

Science Inquiry

Model the kinetic theory of matter with this edible popcorn activity. Ask students to write up their observations and relate them to the theory.

- http://teachers.net/lessons/posts/91.html

Real-World Connection

Discuss a real-world application of matter in the plasma state. Explain the role of plasma in a plasma-display TV. In these devices, a difference in voltage is applied to a gas that is sandwiched between layers of glass in the display panel. When electric current flows through the gas, it changes to a plasma that emits light. You or your students can learn more at this URL: http://electronics.howstuffworks.com/plasma-display1.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are states of matter?
   - [States of matter are the different forms in which matter can exist. They include solid, liquid, gas, and plasma states. State of matter is a physical property of matter.]
2. What are the properties of solids?
   - [Solids have a fixed volume and a fixed shape.]
3. State the properties of liquids.
   - [Liquids have a fixed volume but not a fixed shape. Instead, they take the shape of their container. Liquids also have a free surface.]
4. Describe properties of gases.
   - [Gases have neither a fixed volume nor a fixed shape. Instead, they take the volume and shape of their container. They expand to fill up all available space.]
5. How do plasmas compare with gases?
   - [Like gases, plasmas lack a fixed volume and fixed shape. Unlike gases, plasmas can conduct electricity and respond to magnetism because they consist of charged particles called ions.]
6. Apply the concept of surface tension to explain why the surface of water in the glass shown in **Figure** 4.1 is curved upward. Why doesn't the water overflow the glass?
   - [Surface tension is a force that pulls particles at the exposed surface of a liquid toward other liquid particles. This force keeps the water in the glass from overflowing even though there is a little more water than the glass holds. Instead of overflowing the top of the glass, the water particles pull together and create a curved top surface.]

FIGURE 4.1

The surface of water in the glass is curved upward. How does surface tension explain this phenomenon?

7. Explain the relationship between energy and states of matter.
   - [The particles of matter are constantly moving. They have kinetic energy. The particles of matter of the same kind are attracted to one another. The force of attraction tends to pull the particles closer together. They need a lot of kinetic energy to overcome the force of attraction and move apart. In solids, particles don't have enough kinetic energy to overcome the force of attraction between them. They stay in one place and can only vibrate. In liquids, particles have enough kinetic energy to partly overcome the force of attraction between them. They can slide over one another but not pull completely apart. In gases, particles have a lot of kinetic energy. They can completely overcome the force of attraction between them and move apart.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You read in this lesson that gases expand to fill their container.

- What if gas were forced into a smaller container? Would it shrink to fit?

***Sample answer*: The gas particles would move closer together to fit into the smaller container.**

- What other properties of the gas might change if its particles were crowded closer together?

Accept all reasonable responses. Some students might reason that the gas particles would push against the inside of th

4.3 Lesson 4.2 Behavior of Gases

Key Concept

Particles of a gas are constantly moving and colliding with other things, giving the gas pressure. The gas laws describe the relationships among pressure, volume, and temperature of a given amount of gas.

Standards

- SCI.CA.8.IE.9.g
- NSES.5-8.G.3.2
- AAAS.6-8.1.A.4; AAAS.6-8.1.C.1; AAAS.6-8.4.D.5; AAAS.6-8.9.B.3; AAAS.6-8.12.D.1, 4

Lesson Objectives

- Define pressure.
- State the gas laws.

Lesson Vocabulary

- **Amonton's law**: gas law stating that, if the volume of a gas is held constant, increasing the temperature of the gas increases its pressure
- **Boyle's law**: gas law stating that, if the temperature of a gas is held constant, increasing the volume of the gas decreases its pressure
- **Charles's law**: gas law stating that, if the pressure of a gas is held constant, increasing its temperature increases its volume
- **pressure**: gas law stating that, if the pressure of a gas is held constant, increasing its temperature increases its volume

Teaching Strategies

Introducing the Lesson

Ask students to recall from Lesson 4.1 the properties of matter in the gaseous state. (Gases have neither a fixed volume nor a fixed shape. Instead, they take both the volume and shape of their container.) Tell the class that the ability of gases to fill their containers gives them some interesting behaviors, which they will learn about in this lesson.

Discussion

Discuss the imaginative analogy at the URL below (of monkeys randomly throwing tennis balls in a room). The analogy may help students understand why gases have pressure and how variables such as temperature are related to gas pressure.

- http://www.geocities.com/CapeCanaveral/7639/atmosphere/heatnpressure.htm

Demonstration

Demonstrate the pressure that air exerts with the century-old "egg-in-a-bottle" experiment. Complete instructions, as well as an entertaining video demonstration, can be found at this URL: http://www.stevespanglerscience.com/experiment/egg-in-bottle .

Building Science Skills

At the start of class, while students watch, fully inflate and tie off a balloon. Then place the balloon in an ice chest or refrigerator. Ask students to predict how the balloon might be different after it cools. At the end of class, bring out the balloon, which should be noticeably smaller, and challenge students to explain why.

Differentiated Instruction

Tell students to make a main ideas/details chart for the lesson. Before they read, they should write the main headings from the lesson on the left side of a sheet of paper, leaving space between them for details. Then, as they read the lesson, students should fill in details on the right side of the chart

Enrichment

Ask a few interested students to research the three scientists who discovered the gas laws: Robert Boyle, Jacques Charles, and Guillaume Amontons. Tell them to a write a short, illustrated profile of each scientist that includes how he discovered the gas law that bears his name. Make the profiles available to the rest of the class, and encourage other students to read them.

Science Inquiry

Have pairs of students explore the gas properties of volume, temperature, and pressure with the simulation at the URL below. They should hold one of the three properties constant, vary one of the other two properties, and observe how the third property changes. For example, while holding volume constant, they can vary temperature and see how pressure changes. They should repeat this process until they have investigated each pair of properties. Tell students to create data tables to record several values for each pair of properties. Then have them graph the data and identify which gas law each graph represents.

- http://phet.colorado.edu/en/simulation/gas-properties

Real-World Connection

Relate the behavior of gases to students' daily lives. Explain how air pressure is needed to blow up balloons, inflate tires, flush toilets, drink through straws, play musical instruments, and even breathe.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define pressure.
   - [Pressure is the amount of force pushing against a given area.]
2. Why do gases exert pressure?
   - [Gases exert pressure because their particles are constantly moving and bumping into each other and other matter. The force of the particles against whatever they bump into creates pressure.]
3. What is Boyle's law?
   - [Boyle's law is the gas law that states, if the temperature of a gas is held constant, increasing the volume of the gas decreases its pressure.]
4. State Charles's law.
   - [According to Charles's law, if the pressure of a gas is held constant, increasing the temperature of the gas increases it volume.]
5. Assume you have a closed glass container that contains only air. If you heat the air in the closed container, it will gain energy. What other property of the air will also change?
   - [The pressure of the air will also change. Pressure will increase as the temperature of the air increases. This is an application of Ammonton's law.]
6. Draw a graph to show the relationship between the volume and pressure of a fixed amount of gas.
   - [Graphs should show an inverse relationship between volume and pressure.]
7. A weather balloon is released at Earth's surface. It rises high in the atmosphere. As the balloon rises, it expands and eventually bursts. Explain why.
   - [A weather balloon expands and eventually bursts as it rises higher into the atmosphere because the air pressure outside the balloon decreases with increasing altitude.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that heating a gas gives its particles more kinetic energy. As a result, its volume or pressure also increases. The opposite happens when a gas is cooled.

- What might happen if you cool a gas to an even lower temperature? Might it change state and become a liquid?

If a gas is cooled below its boiling point, it will condense and change to the liquid state.

- Can you predict the role of energy in changes of state?

Changes in energy are responsible for changes of state. For example, as the energy of matter decreases, matter may ch

4.4 Lesson 4.3 Changes of State

Key Concept

Changes of state are physical changes that occur when matter absorbs or loses energy. Processes in which matter changes state include freezing, melting, vaporization, evaporation, condensation, sublimation, and deposition.

Standards

- SCI.CA.8.PS.3.d; SCI.CA.8.PS.7.c
- NSES.5-8.B.1.1
- AAAS.6-8.4.D.5, 6, 14, 16

Lesson Objectives

- Explain the role of energy in changes of state.
- Outline the processes of freezing and melting.
- Describe vaporization and condensation.
- Define sublimation and deposition.

Lesson Vocabulary

- **condensation**: process in which a gas changes to a liquid
- **deposition**: process in which a gas changes directly to a solid without going through the liquid state
- **evaporation**: process in which a liquid changes to a gas without boiling
- **freezing**: process in which a liquid changes to a solid
- **melting**: process in which a solid changes to a liquid
- **sublimation**: process in which a solid changes directly to a gas without going through the liquid state
- **temperature**: average kinetic energy of particles of matter
- **vaporization**: process in which a liquid boils and changes to a gas

Teaching Strategies

Introducing the Lesson

Review states of matter and introduce changes of state with the resources at the following URL. As students enter the classroom, play the karaoke song while displaying the lyrics on a screen, and encourage students to sing along.

Then show the 3-minute video. After the video, ask students what they learned about changes of state from the video. Tell them they will learn more about changes of state in this lesson. If you want to extend this introduction, click on the "Teacher Guide" at the Web site for more ideas.

- http://teacher.scholastic.com/activities/studyjams/matter_states/

Using Visuals

Call students' attention to the picture of the pothole puddle in the FlexBook® lesson.

- **Question**: If the same amount of rainwater fell into a broader, shallower pothole, which puddle would evaporate more quickly?
- **Answer**: The water in the broader, shallower pothole would evaporate more quickly because it would have more surface area exposed to the air. This would allow more water molecules to escape into the air at the same time (assuming other conditions such as temperature are the same).

Activity

Have students play the game at the following URL to apply their knowledge of the processes involved in changes of state.

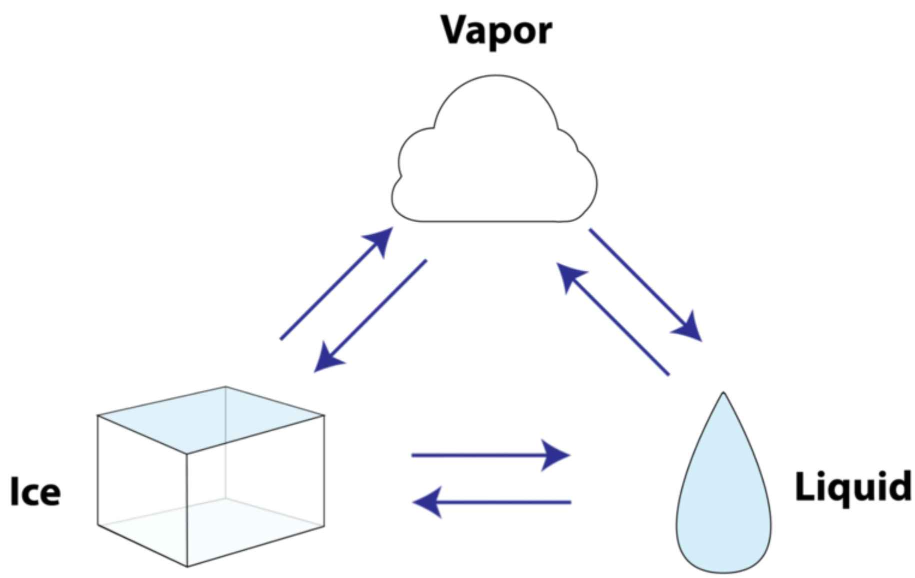
- http://www.bbc.co.uk/bitesize/ks2/science/materials/changing_states/play/

Demonstration

Students are likely to have first-hand experience with all of the changes of state described in the lesson with the possible exception of sublimation. Demonstrate sublimation by placing dry ice (solid carbon dioxide) in a clear glass container. Have students observe as the solid dry ice changes directly into carbon dioxide gas without passing through the liquid state.

Differentiated Instruction

Make changes of state more concrete by using a familiar example—water. Draw a cycle diagram like the one below, and have students label the arrows with the correct processes.



Enrichment

Ask a few students who need extra challenges to learn how matter changes to the plasma state. They can start with the URLs below. Have them share what they learn in an oral report.

- http://education.jlab.org/qa/plasma_02.html

Science Inquiry

With the activity at the following URL, students can design and conduct their own experiment to find out how heating water affects the rate of evaporation. In the activity, they will identify variables and controls and draw conclusions from their observations. The Web site provides complete teacher instructions, a student activity sheet, background reading, and extensions to the activity.

- http://www.inquiryinaction.org/classroomactivities/activity.php?id=32

Common Misconceptions

Researchers have identified several common misconceptions that students may hold about how matter changes state. Two are listed below. Read the misconceptions to the class and call on volunteers to restate them as true statements. Additional misconceptions are available at this URL: http://beyondpenguins.ehe.osu.edu/issue/water-ice-and-snow/common-misconceptions-about-states-and-changes-of-matter-and-the-water-cycle .

Misconception: Water in an open container disappears because it changes into air.

True statement: Water in an open container evaporates, or changes from liquid water to water vapor.

Misconception: Drops of water on the outside of a cold glass have seeped, or "sweated," through the glass.

True statement: The drops of water have condensed from water vapor in the air that came into contact with the cold glass.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Identify the processes involved in changes of state between liquids and solids.
    - [The processes involved in changes of state between liquids and solids are freezing and melting. Freezing is the process in which a liquid changes to a solid. Melting is the process in which a solid changes to a liquid.]
2. Define vaporization and evaporation. State how the two processes differ.
    - [Vaporization is the process in which a liquid boils and changes to a gas. Evaporation is the process in which particles at the exposed surface of a liquid absorb just enough energy to pull away from the liquid and escape into the air. Both processes involve a liquid changing to a gas, but unlike vaporization, evaporation does not involve the liquid boiling.]
3. What is sublimation? Give an example.
    - [Sublimation is the process in which a solid changes directly to a gas. An example is solid carbon dioxide changing directly to the gaseous form.]
4. Define deposition. When does it occur?
    - [Deposition is the process in which a gas changes directly to a solid. It occurs when gas particles become very cold.]
5. Cliff opened the oven door to check on the cake he was baking. As hot, moist air rushed out of the oven, his eyeglasses steamed up. Explain why.
    - [Cliff's eyeglasses steamed up when he opened the oven door because hot, moist air escaped from the oven and water vapor in the air condensed on the cooler surface of his glasses.]
6. Explain the role of energy in changes of state.
    - [Energy is always involved in changes of state. Matter either loses or absorbs energy when it changes from one state to another. For example, when matter changes from a liquid to a solid, it loses energy. When it changes from a solid to a liquid, it absorbs energy.]
7. Form a hypothesis to explain why the melting points of different solids vary.
    - [Answers may vary but should reflect a correct understanding of the role of energy and heating in changes of state from solids to liquids. *Sample answer*: Melting points of different solids vary because some solids have greater forces of attraction between their particles.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 4.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read that atoms and molecules of the same kind of matter have forces of attraction between them. Atoms consist of even smaller particles. These particles are held together by certain forces as well.

- What are the particles that make up atoms?

Students may be familiar with protons, neutrons, and electrons.

- What forces might hold them together?

Some students may remember that electrons are positively charged and protons are positively charged and that they a

4.5 References

1. Joy Sheng. . CC BY-NC 3.0

CHAPTER 5 TE Atoms

Chapter Outline

5.1 Chapter 5: Atoms

Chapter Overview

An atom consists of protons, neutrons, and electrons; and protons and neutrons consist of quarks. The strong force and electric force hold the atom together. An atom can be characterized by its atomic number and mass number. The history of the atom began with Democritus and included major contributions by Dalton, Thomson, Rutherford, and Bohr. Modern ideas about the atom include energy levels, orbitals, and electron clouds.

Online Resources

See the following Web sites for appropriate laboratory activities:

This active lab is an entertaining way for students to explore atomic structure and other concepts introduced in Lesson 5.1. It uses simple materials such as laundry baskets and colored balls and does not require a science lab. You can divide the class into two teams and have them compete to do the activity with the fewest mistakes in the least amount of time. The URL provides complete instructions, extensions, assessments, diagrams, and an answer key.

- http://www.middleschoolscience.com/atomicmusicalchairs.pdf

The lab "Electron Probability" at the URL below is a creative way to help students understand probability distributions of electrons in the electron cloud model of the atom (Lesson 5.3).

- [mrsj.exofire.net/chem/docs/eprob_lab.doc mrsj.exofire.net/chem/docs/eprob_lab.doc]

These Web sites may also be helpful:

The URL below has links to several sites that offer information, lesson plans, simulations, hands-on activities, and online quizzes about atoms.

- http://ethemes.missouri.edu/themes/574

When you teach Lesson 5.2, students may benefit from the overview of atomic history at the following URL. It includes review questions, a summary, and exercises so students can check their comprehension.

- http://www.absorblearning.com/chemistry/demo/units/LR301.html#Exercises

For background information on modern atomic theory in Lesson 5.3, these URLs may be useful:

- http://en.wikipedia.org/wiki/Atomic_orbital
- http://www.chemguide.co.uk/atoms/properties/atomorbs.html
- http://www.chem.purdue.edu/gchelp/aos/whatis.html
- http://www.chm.davidson.edu/vce/atomicorbitals/index.html

Pacing the Lessons

TABLE 5.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
5.1 Inside the Atom	2.0
5.2 History of the Atom	2.0
5.3 Modern Atomic Theory	2.0

5.2 Lesson 5.1 Inside the Atom

Key Concept

The nucleus of an atom contains positive protons and neutral neutrons, which are held together by the strong force. Protons and neutrons consist of even smaller particles called quarks, which are held together by gluons. Negative electrons constantly move around the nucleus because of the attraction of opposite electric charges. The number of protons in an atom is the atomic number, which is unique for each element. The number of protons plus neutrons is the mass number, which equals the atom's mass in atomic mass units.

Standards

- SCI.CA.8.PS.3.a; SCI.CA.8.PS.7.b; SCI.AC.8.IE.9.f
- MCR.6-8.SCI.8.1; MCR.6-8.SCI.9.1
- AAAS.6-8.4.D.1, 2; AAAS.6-8.4.G.5; AAAS.6-8.11.B.1, 3; AAAS.6-8.11.D.3

Lesson Objectives

- Compare and contrast protons, neutrons, and electrons.
- Describe the forces that hold the particles of atoms together.
- Define atomic number and mass number.
- Describe ions and isotopes
- Identify the particles called quarks.

Lesson Vocabulary

- **atomic mass unit (amu)**: SI unit for the mass of an atom, where 1 amu equals the mass of a proton (about 1.7 x 10-24 grams)
- **atomic number**: number of protons in an atom
- **electron**: negatively charged atomic particle that moves around the nucleus of the atom
- **ion**: positively or negatively charged particle that forms when an atom gains or loses electrons
- **isotope**: atom that differs in the number of its neutrons from other atoms of the same element
- **mass number**: number of protons plus neutrons in an atom; equal to the atom's mass in atomic mass units (amu)
- **neutron**: electrically neutral atomic particle inside the nucleus of an atom
- **nucleus**: tiny region at the center of an atom that contains protons and neutrons and makes up almost all of the atom's mass
- **proton**: positively charged atomic particle inside the nucleus of an atom
- **quark**: type of fundamental particle of matter that makes up protons and neutrons

Teaching Strategies

Introducing the Lesson

Play a word association game with the class to introduce the lesson. Tell students to say whatever word first comes to mind when they hear the word "atom." (Sample responses might include "matter," "tiny," "nucleus," "molecule," "electron," and "particle.") The activity will help students recall what they already know about atoms.

Activity

Help students learn the parts of the atom with the Atoms Family worksheet and song at the first URL below. Divide the class into small groups and have each group complete the worksheet. Encourage students to sing the Atoms Family song. Finally, have groups complete the Atoms Family math challenge at the second URL.

- http://sciencespot.net/Media/atomsfam.pdf
- http://sciencespot.net/Media/atomicmath.pdf

Building Science Skills

Stress the importance of using models to study atoms because they are so small. Then have students create models of the atom using one or more ideas suggested at the following URL.

- http://www.proteacher.org/c/457_Atoms_and_Molecules.html

Demonstration

Have students examine the periodic table .You can use the interactive periodic table at the following URL with a projector or TV screen. Focus on one element in the table, such as carbon. Point out its atomic number and atomic mass (atomic weight). Based on these two numbers, have students calculate the number of neutrons in the atom.

- http://www.ptable.com/

Differentiated Instruction

Pair English language learners and native English speakers, and have partners make a cluster diagram centered on the atom. They should add surrounding circles for parts of the atom, atomic forces, atomic number and mass number, ions and isotopes, and quarks. Tell them to add important details to each circle.

Enrichment

Ask students to make a word-search or criss-cross puzzle using lesson vocabulary terms. They can make the puzzle by hand or use the free puzzle maker at the URL below. Distribute copies of their puzzles for other students to solve.

- http://www.discoveryeducation.com/free-puzzlemaker/?CFID=3512110&CFTOKEN=69625103

Science Inquiry

Divide the class into pairs and have partners explore the interactive "Build an Atom" simulation at the URL below. Students will build an atom with subatomic particles and observe how the element, charge, and mass of the atom change as they add the different particles.

- http://phet.colorado.edu/en/simulation/build-an-atom

Common Misconceptions

The URL below lists several common misconceptions that middle schoolers may have about atoms. Use some or all of the misconceptions to create a true-or-false quiz. For any misconceptions that students think are true, explain why they are false.

- http://departments.weber.edu/sciencecenter/7th%20misconceptions.htm

Answer to You Try It!

Problem: An atom has an atomic number of 8 and a mass number of 16. How many neutrons does it have? What is the atom's mass in atomic mass units?

Solution: The atom has 8 neutrons (16 –8). Its mass is 16 amu (same as its mass number).

Reinforce and Review

Lesson Worksheets

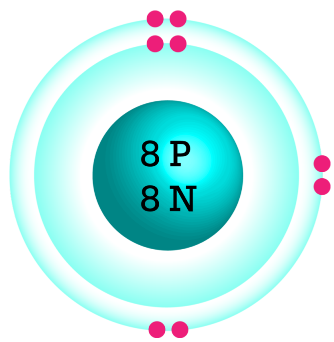
Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Describe the nucleus of an atom.
   - [The nucleus is a positively charged region at the center of an atom. It consists of protons and neutrons, and it contains most of the atom's mass. However, in size, it makes up just a tiny part of the atom.]
2. Outline the forces that hold particles together in an atom.
   - [Negative electrons are attracted to positive protons. This electrical force of attraction keeps the electrons moving about the nucleus instead of flying off. Another force, called the strong force, holds the nucleus together. The strong force is stronger than the electric force pushing protons apart, but it affects only nearby particles. It is not effective if the nucleus becomes too large.]
3. What does the atomic number of an atom represent?
   - [The atomic number of an atom represents the number of protons in the nucleus of the atom. This number is unique for atoms of each kind of element.]

4. Define isotope. Give an example.
    - [An isotope is an atom with a different number of neutrons than other atoms of the same element. An example of an isotope is deuterium. This is an isotope of hydrogen with one neutron (most hydrogen atoms have zero neutrons).]
5. What are quarks?
    - [Quarks are tiny particles of matter that make up protons and neutrons. Scientists have identified six different types of quarks.]
6. If an atom gains electrons, it becomes an ion. Is the ion positively or negatively charged? Explain your answer.
    - [If an atom gains electrons and becomes an ion, the ion is negatively charged. That's because electrons have a negative charge. When electrons are added to an atom, it upsets the balance between protons and electrons that makes atoms neutral. The overall charge of the ion is negative because there are more electrons than protons.]
7. What is the atomic mass (in atomic mass units) of the atom represented by the model below?



    - [The atomic mass of an atom is the number of protons plus the number of neutrons. The atomic mass of the atom represented by the model is 8 protons + 8 neutrons = 16 amu.]
8. Make a table comparing and contrasting protons, neutrons, and electrons. Include their location, mass, and electric charge.
    - [Sample **Table** below:]

{

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you saw several simple models of atoms. Models are useful for representing things that are very small. Scientists have used models to represent atoms for more than 200 years. In the next lesson, you'll read about some of the earlier models.

- How might scientists have modeled atoms before the particles inside atoms were discovered?

***Sample answer*: They might have modeled them with simple solid objects such as marbles.**

- How do you think earlier models might have differed from the models in this lesson?

***Sample answer*: Earlier models would not have included the particles inside the atom.**

5.3 Lesson 5.2 History of the Atom

Key Concept

The ancient Greek philosopher Democritus first introduced the idea of the atom. The idea was re-introduced by John Dalton in 1800. He provided evidence for atoms and developed atomic theory. J.J. Thomson discovered electrons and proposed the plum pudding model of the atom. Ernest Rutherford discovered the nucleus and protons and proposed the planetary model of the atom.

Standards

- MCR.6-8.SCI.11.1, 3, 4; MCR.6-8.SCI.13.5
- NSES.5-8.A.2.5, 7; NSES.5-8.G.2.1; NSES.5-8.G.3.3
- AAAS.6-8.1.A.3, 4; AAAS.6-8.1.B.2; AAAS.6-8.4.D.1, 2; AAAS.6-8.10.F.1, 2; AAAS.6-8.11.B.1, 3, 5; AAAS.6-8.12.D.9

Lesson Objectives

- State Democritus's ideas about the atom.
- Outline Dalton's atomic theory.
- Explain how Thomson discovered electrons.
- Describe how Rutherford found the nucleus.

Lesson Vocabulary

No new vocabulary terms are introduced in this lesson.

Teaching Strategies

Introducing the Lesson

Before you teach this lesson, demonstrate to students the thinking behind Democritus's idea of the atom. As students watch, cut an apple in half. Then cut one of the halves in half. Continue cutting the pieces in half until they are too small to cut into smaller pieces. Relate the demonstration to Democritus's idea of "uncuttable" pieces, or atomos. He proposed that matter is made up of tiny particles that cannot be reduced to smaller pieces. Tell students they will learn in this lesson more about Democritus's idea as well as other early ideas about the atom.

Demonstrate

You can demonstrate Dalton's, Thomson's, and Rutherford's atomic models using bowls of gelatin with and without fruit such as berries. Dalton's model can be represented by a bowl of plain gelatin, Thomson's by a bowl of gelatin with berries scattered throughout it, and Rutherford's by a bowl of gelatin with a single berry in the middle. Have students match the bowls of gelatin with the scientists' models of the atom.

Activity

Have students do the "Rutherford Roller" activity at the following URL. The activity simulates Rutherford's famous gold-foil experiments in which he deduced the existence of the atomic nucleus from indirect evidence. At the end of the activity, relate it to Rutherford's experiments.

- http://www.exo.net/~emuller/activities/Rutherford%20Roller.pdf#search=%22Rutherford%20experiment%20with%20marbles%22

Discussion

Discuss Dalton's atomic theory and how well it has withstood the test of time. List the parts of the theory on the board, and ask students which part or parts they think may no longer be accepted (atoms are the smallest particles of matter, which cannot be divided into small particles). Remind students that scientists now know there are particles smaller than the atom, including extremely small particles called quarks.

Differentiated Instruction

Assign the two questions below for students to think about. Then pair any English language learners or less proficient readers with other students, and have partners discuss the questions. Finally, have the students work together to write answers to the questions.

1. Atoms are too small to be seen without special microscopes that were invented in the 1980s, but scientists had already learned a lot about atoms before then. How could scientists learn about atoms without being able to see them?
2. What did early scientists think atoms were like? How did early ideas differ from today's ideas about atoms?

Enrichment

Students with an interest in history might enjoy researching and creating a timeline of the history of the atom. Tell them to include modern discoveries and ideas as well as the events described in this lesson. They can start with the URLs below. Display their timeline in the classroom and refer to it as you teach this lesson and the next.

- http://www.nobeliefs.com/atom.htm
- http://atomictimeline.net/index.php
- http://www.timetoast.com/timelines/28969
- http://www.visionlearning.com/library/module_viewer.php?mid=50

Science Inquiry

Have students do one or more of the hands-on simulation activities described at the URL below. The simulations will allow them to model how subatomic particles were discovered on the basis of indirect evidence.

- http://mypages.iit.edu/~smile/ch9211.html

History Connection

Place the achievements of Ernest Rutherford in historical context. Have students read about the life and discoveries of Ernest Rutherford at one or more of the URLs below. Based on their reading, ask them to identify what they think is Rutherford's most important scientific contribution. Also ask whether they agree or disagree with a Rutherford biographer's claim that "Rutherford was one of the most illustrious scientists of all time."

- http://www.bbc.co.uk/history/historic_figures/rutherford_ernest.shtml
- http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1908/rutherford-bio.html
- http://www.chemheritage.org/discover/online-resources/chemistry-in-history/themes/atomic-and-nuclear-structure/rutherford.aspx
- http://www.aboutnuclear.org/view.cgi?fC=History,Hall_of_Fame,Ernest_Rutherford
- http://www.blupete.com/Literature/Biographies/Science/Rutherford.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. State Democritus's ideas about the atom.
   - [Democritus thought that matter consists of tiny particles that cannot be cut into smaller pieces. He called these particles atomos, or "uncuttable." This is where the modern word atom comes from.]
2. What evidence did Dalton use to argue for the existence of atoms?
   - [Dalton used evidence from his research to argue for the existence of atoms. For example, from his research on the pressure of gases, he concluded that gases consist of tiny, individual particles of matter that are in constant motion.]
3. State Dalton's atomic theory.
   - [Dalton's atomic theory has three main ideas: (i) All substances are made of atoms. Atoms are the smallest particles of matter and cannot be divided into smaller particles. They also cannot be created or destroyed. (ii) All atoms of the same element are alike and have the same mass. Atoms of different elements are not alike and have different masses. (iii) Atoms join together to form compounds. A given compound always consists of the same kinds of atoms in the same ratio.]
4. Describe how Thompson discovered electrons.
   - [Thompson discovered electrons by passing electric current through a vacuum tube. When electric current flowed through the tube, it flowed from the negative plate at one end to the positive plate at the other end. This showed that the current consisted of flowing negative charges. Positive and negative plates along the sides of the vacuum tube caused the current to bend toward the side with the positive plate. This showed that the charge was carried by particles of matter rather than by rays, which some scientists had thought.]

5. Create sketches to compare and contrast Thompson's and Rutherford's models of the atom.
   - [Sketches may vary but should correctly represent Thompson's and Rutherford's models of the atom. The sketches might resemble FlexBook® Figures 5.11 and 5.13, respectively.]
6. Based on Rutherford's work, use evidence and reasoning to argue for the existence of the nucleus.
   - [Rutherford did experiments in which he aimed beams of positively charged alpha particles at a thin sheet of gold foil. Most of the alpha particles passed straight through the foil, but a few bounced back as though they had struck a wall. This evidence showed that all the positive charge is concentrated at the center of the atom, which he called the nucleus.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read how models of the atom changed as scientists discovered the particles that make up atoms. In the next lesson, you will read how Rutherford's model was revised as scientists learned even more about electrons. For example, they discovered that electrons do not travel around the nucleus in random orbits as Rutherford thought.

- Can you predict how electrons might move around the nucleus?

***Sample answer*: Electrons might move in more than one direction around the nucleus.**

- How might Rutherford's model be changed to show this?

Students should describe a different way to model how electrons move around the nucleus.

5.4 Lesson 5.3 Modern Atomic Theory

Key Concept

Bohr introduced the idea of energy levels, which confine electrons to certain fixed distances from the nucleus. Today, electrons are represented by an electron cloud model. Denser regions of the cloud, called orbitals, show where electrons are most likely to be.

Standards

- MCR.6-8.SCI.11.3, 4
- NSES.5-8.A.2.5; NSES.5-8.G.2.1
- AAAS.6-8.1.A.3; AAAS.6-8.1.B.2; AAAS.6-8.11.B.1, 3, 5; AAAS.6-8.12.D.9

Lesson Objectives

- Define energy levels.
- Describe the electron cloud and orbitals.

Lesson Vocabulary

- **electron cloud**: area surrounding the nucleus of an atom where electrons are likely to be
- **energy level**: area located at a fixed distance from the nucleus of an atom where electrons can orbit the nucleus
- **orbital**: dense region in the electron cloud around the nucleus of an atom where electrons are most likely to be

Teaching Strategies

Introducing the Lesson

Start a simple sketch of a hydrogen atom on the board by drawing a small circle labeled "nucleus." Add a smaller circle labeled "proton" inside the nucleus. Call on a student to come to the board and add the electron and its orbit to the sketch. (The student is likely to draw a circle around the nucleus and add a symbol such as a dot for the electron.) Point out that this is how electrons are usually represented but it's misleading. Explain that if the nucleus were the size of the nucleus in the sketch, then the electron orbit would actually be about half a mile away with nothing but empty space in between. Tell students they will learn more about electrons and where they are located in the atom when they read this lesson.

Using Visuals

Students may confuse energy levels and orbitals. Relate the energy levels in Figure 5.15 to the number of orbitals per energy level in Table 5.1.

Question: If an atom has electrons only in the first energy level, how many orbitals and electrons can it have?
Answer: It can have a maximum of one orbital and two electrons.
Question: If an atom has electrons in just the first two energy levels, how many orbitals and electrons can it have?
Answer: It can have a maximum of six orbitals (one in energy level 1 and four in energy level 2) and a maximum of 12 electrons (2 per orbital).

Discussion

Differentiated Instruction

Have students make a KWL chart for the position of electrons in atoms. Tell them to divide a sheet of paper into three columns and label them from left to right "Know," "Want to Know," and "Learned." Before they start reading, they should fill in the first column with what they already know (e.g., electrons are located outside the nucleus). They should also fill in the second column with questions they still have (e.g., How far from the nucleus are the electrons?). Tell students to try to find answers to their questions when they read the lesson. Respond to any questions that remain unanswered after they finish reading.

Enrichment

Interested students can dig deeper into orbitals and learn about s, f, p, and other specific orbitals. The URLs below are good sources of information and images. You might want to have them teach the topic to the class. If so, have them use visuals in their presentation.

- http://en.wikipedia.org/wiki/Atomic_orbital
- http://www.chemguide.co.uk/atoms/properties/atomorbs.html
- http://www.d.umn.edu/~pkiprof/ChemWebV2/AOs/index.html

Science Inquiry

Challenge the class to brainstorm how they might create a two- or three-dimensional representation of the electron cloud model. How could they represent the nucleus? The electron cloud? For ideas, students can see animated two-dimensional representations of the electron cloud model at these URLs:

- http://www.regentsprep.org/regents/physics/phys05/catomodel/cloud.htm
- http://www.lionden.com/chemistry_models.htm

Real-World Connection

Relate energy levels to the real world. Virtually all students will be familiar with fluorescent lights. Tell them that the light is energy emitted by electrons jumping from higher to lower energy levels. They can learn more at this URL: http://home.howstuffworks.com/fluorescent-lamp.htm .

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are energy levels?
   - [Energy levels are areas located at fixed distances from the nucleus of an atom where electrons can orbit the nucleus.]
2. Which energy level has the smallest amount of energy?
   - [Energy level 1, which is closest to the nucleus, has the smallest amount of energy.]
3. Define orbitals.
   - [Orbitals are dense regions in an electron cloud around the nucleus of an atom where electrons are most likely to be.]
4. How many electrons can be found in an orbital?
   - [An orbital has a maximum of two electrons.]
5. A change in energy caused an electron in an atom to jump from energy level 2 to energy level 3. Did the atom gain or lose energy?
   - [If an electron in an atom jumped from the second to third energy level, the atom must have gained energy. This is because energy is needed for electrons to move from an energy level with less energy (level 2) to an energy level with more energy (level 3).]
6. Create a sketch to model the concept of the electron cloud.
   - [Sketches may vary but should correctly model the electron cloud concept. The sketches might resemble **Figure** 5.17.]
7. Explain how orbitals are related to energy levels.
   - [The number of orbitals per energy level increases at energy levels farther from the nucleus.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 5.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you learned that atoms of each element have a unique number of protons. This is one way that each element differs from all other elements.

- How could the number of protons be used to organize elements?

Sample answer: **They could be organized in ascending order, from the element with the smallest number of protons to**

- If one element has more protons than another element, how do their numbers of electrons compare?

The element with more protons also has more electrons because an atom always has equal numbers of protons and ele

CHAPTER 6 TE Periodic Table

Chapter Outline

6.1 Chapter 6: Periodic Table

Chapter Overview

Mendeleev developed the first periodic table of the elements, which he based on atomic mass. The modern periodic table is based on atomic number. Elements can be grouped in three major classes: metals, nonmetals, and metalloids. They differ in their number of valence electrons, which explains many of their properties. Group 1 of the periodic table consists of hydrogen and the alkali metals, group 2 consists of the alkaline Earth metals, groups 3–12 contain transition metals, groups 13–16 each contain at least one metalloid as well as metals and/or nonmetals, and group 18 consists of noble gases. Reactivity of elements generally decreases from group 1 through group 18.

Online Resources

See the following Web sites for appropriate laboratory activities:

The following URL has links to several periodic table labs.

- http://www.nclark.net/PeriodicTable

The lab at the URL below is a high-school lab on the properties of metals and nonmetals, but it has adaptations for younger students.

- http://www.discoveryeducation.com/teachers/free-lesson-plans/pursuit-of-the-properties-of-metals-and-nonmetals.cfm

Try this online video lab when you teach classes of elements in Lesson 6.2.

- http://schoolwaxtv.com/learn-lab-files-neutralisation

With this lab, students can explore trends in reactivity in the periodic table: http://www.berenato.net/Labs/PeriodicTrendslab .

These Web sites may also be helpful:

These URLs have interactive periodic tables that provide in-depth information about each element.

- http://periodic.lanl.gov/index.shtml
- http://www.rsc.org/periodic-table

These Web sites offer a plethora of middle school resources about the periodic table.

- http://www.science-class.net/Chemistry/periodic_table.htm
- http://www.middleschoolscience.com/chemistry.htm

Pacing the Lessons

TABLE 6.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
6.1 How Elements Are Organized	1.5
6.2 Classes of Elements	2.0
6.3 Groups of Elements	2.0

6.2 Lesson 6.1 How Elements Are Organized

Key Concept

Mendeleev developed the first periodic table of the elements in 1869. He organized the elements by increasing atomic mass. The modern periodic table is based on atomic number. Elements in each period go from metals on the left to metalloids and then to nonmetals on the right. Within groups of the periodic table, elements have similar properties.

Standards

- SCI.CA.8.PS.3.a, f; SCI.CA.8.PS.7.a, b
- MCR.6-8.SCI.8.4
- NSES.5-8.A.2.1; NSES.5-8.B.1.3
- AAAS.6-8.4.D.2, 8; AAAS.6-8.11.B.5; AAAS.6-8.11.C.4; AAAS.6-8.12.D.2

Lesson Objectives

- Describe Mendeleev's periodic table of the elements.
- Give an overview of the modern periodic table of the elements.

Lesson Vocabulary

- **group**: column of the periodic table, which contains elements with similar properties
- **period**: row of the periodic table that contains elements ranging from metals on the left to metalloids and then to nonmetals on the right
- **periodic table**: table of elements arranged by increasing atomic number (modern periodic table) or by increasing atomic mass (Mendeleev's periodic table)

Teaching Strategies

Introducing the Lesson

Introduce the periodic table with a deck of cards. Lay out the cards by suit and number where students can see them. Create a 4-column by 13-row grid by placing the cards in each suit in a separate column, starting with the ace in the first row and ending with the king in the last row. Discuss how the cards in the rows and columns form regular patterns (e.g., all the cards in row 1 are aces, all the cards in column 1 are spades). Tell students they will learn in this lesson how elements are also arranged in rows and columns that form regular patterns.

Using Visuals

Have students look at the modern periodic table in the FlexBook® lesson. Point out how atomic number (number of protons) increases across each period and down each row. Make sure students understand the placement of the lanthanides and actinides. Then, review the information provided by the table and have students apply it by answering the following questions:

Question: Bromine is a nonmetal with the chemical symbol Br. How many protons does it have?
Answer: Bromine's atomic number is 35, so it has 35 protons.
Question: Nickel has the chemical symbol Ni and is in period 4. In which class of elements is nickel?
Answer: Nickel is a metal.
Question: Find hydrogen, represented by the chemical symbol H, in the upper left corner of the periodic table. What can you infer about hydrogen from the table?
Answer: Hydrogen is a nonmetal with an atomic number of 1, which means that it has 1 proton.

Activity

Using resources from the following URL, play "Element Bingo" with the class. It will help students learn the chemical names of the elements, which is very helpful for using the periodic table.

- http://education.jlab.org/beamsactivity/6thgrade/elementbingo/index.html

Differentiated Instruction

Help students distinguish between periods and rows of the periodic table. Work with them to make a compare/contrast table for period and group like the sample **Table** 6.2.

TABLE 6.2: Periodic Table

Period or Group?	What Is It?	How Many Are There?	How Does Atomic Number Change?
Period	row of the table	7	increases by 1 from left to right
Group	column of the table	18	increases by different amounts from top to bottom

Enrichment

Challenge a small group of creative students to invent a board game using the periodic table as the game board. For example, players might roll dice to determine which element to land on with their game piece, and the winner might be the first player to land on a certain number of elements in each class. Encourage other students to play the game to help familiarize them with the periodic table.

Science Inquiry

Have groups of students solve the "Alien Periodic Challenge" describe at the URL below (under "Labs"). You can find links to all the materials you need at the Web site.

- http://www.nclark.net/PeriodicTable

Common Misconceptions

Avoid the following misconceptions about the periodic table. The History Connection that follows is one way to help avoid them.

- The periodic table in its present form is the way the elements have always been organized.
- There is only one way to organize the elements.

History Connection

Give students a more detailed history of the periodic table. The URLs below are good sources of information. Students will better appreciate how many different scientists have contributed to the development of this fundamental tool of chemistry.

- http://en.wikipedia.org/wiki/History_of_the_periodic_table
- http://www.wou.edu/las/physci/ch412/perhist.htm
- http://www.bpc.edu/mathscience/chemistry/history_of_the_periodic_table.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How did Mendeleev organize the elements?
   - [Mendeleev organized the elements by atomic mass. He put them in rows of increasing atomic mass until there were eight elements in a row. Then he started on the next row and completed it the same way, and so on throughout the rest of the table.]
2. How does the modern periodic table differ from Mendeleev's table?
   - [The modern periodic table organizes the elements by atomic number rather than by atomic mass. The modern table also includes many more elements. It has more groups as well.]
3. What is a period in the periodic table?
   - [A period in the periodic table is one of the rows of the table. From left to right across each period, elements keep increasing in atomic number by one. The elements also change from metals on the left side of the table, to metalloids, and then to nonmetals on the right.]

4. What is a group in the periodic table?
   - [A group in the periodic table is one of the columns of the table. From top to bottom within a group, elements increase in atomic number but have similar properties.]
5. An unknown element has an atomic number of 44. Identify the element's symbol and the symbols of two other elements that have similar properties.
   - [The element with the atomic number 44 has the chemical symbol Ru, which is in group 8 of the periodic table. Other elements in the same group have similar properties, so students should write symbols for two of the other elements in group 8 (Fe, Os, Hs).]
6. Mendeleev's table and the modern periodic table organize the elements based on different information, yet most elements are in the same order in both tables. Explain why.
   - [The modern periodic table is based on atomic number, which is the number of protons in the atoms of an element. Mendeleev's table is based on atomic mass, which is the sum of protons and neutrons in the atoms of an element. Atomic number and atomic mass usually change in the same way from one element to the next. Therefore, most elements are in the same order in both tables.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Elements are classified as metals, metalloids, or nonmetals.

- Do you know some examples of metals?

***Sample answer*: iron, silver, copper, and gold**

- How do you think metals might differ from the other two classes of elements?

Unlike the other two classes of elements, metals are good conductors of electricity.

6.3 Lesson 6.2 Classes of Elements

Key Concept

Metals are the largest class of elements. They are good conductors of electricity and heat, and many are shiny, ductile, and malleable. Most metals are solids at room temperature. Nonmetals are the second largest class of elements. They do not conduct electricity, are poor conductors of heat, and the majority are gases. Metalloids are elements that have properties of both metals and nonmetals, and all are solids at room temperature. Atoms of elements in different classes vary in their number of valence electrons, and this explains many of their properties.

Standards

- SCI.CA.8.PS.3.a, f; SCI.CA.8.PS.7.a, c
- MCR.6-8.SCI.8.5, 9
- NSES.5-8.A.1.5; NSES.5-8.B.1.1, 2
- AAAS.6-8.4.D.8, 9, 15, 16

Lesson Objectives

- Identify properties of metals.
- List properties of nonmetals.
- Describe metalloids.
- Relate valence electrons to reactivity of elements by class.

Lesson Vocabulary

- **metal**: class of elements that are good conductors of electricity
- **metalloid**: class of elements that have some properties of metals and some properties of nonmetals
- **nonmetal**: class of elements that do not conduct electricity
- **valence electron**: electron in the outer energy level of an atom that is potentially involved in chemical reactions

Teaching Strategies

Introducing the Lesson

Focus students' attention on elements in the periodic table with one of the "Periodic Table Teaser" PowerPoint presentations at the following URL.

- http://sciencespot.net/Pages/startersphysci.html

Activity

Have students complete the interactive activity at the URL below. They will be presented with the main classes of elements and their properties, followed by quiz questions to check their understanding.

- http://www.wisc-online.com/Objects/ViewObject.aspx?ID=GCH6004

Discussion

Discuss with the class the general differences between metals and nonmetals. The URL below provides a good summary of their differences. Include a discussion of the chemical property of electronegativity and relate it to the number of valence electrons in metals and nonmetals. This information will be important when they learn about chemical bonds in subsequent chapters of the FlexBook® resource.

- http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/metal.html

Differentiated Instruction

Discuss with the class the general differences between metals and nonmetals. The URL below provides a good summary of their differences. Include a discussion of the chemical property of electronegativity and relate it to the number of valence electrons in metals and nonmetals. This information will be important when they learn about chemical bonds in subsequent chapters of the FlexBook® resource.

- http://hyperphysics.phy-astr.gsu.edu/hbase/pertab/metal.html

Enrichment

Ask a few students to create a display of some common objects that consist of metals (e.g., aluminum can, copper wire) and other objects that consist of nonmetals (e.g., charcoal, match). Then have them use the objects to demonstrate some of the properties of each class of elements.

Science Inquiry

Have groups of students do Science Inquiry Activity 2, "Elemental Classification," at the URL below. They will compare some of the chemical properties of metals and nonmetals.

- http://dev.nsta.org/ssc/pdf/v4-0961s.pdf

Health Connection

Describe the role of metals in good health. You can learn which metals are vital to human health and the roles they play at these URLs:

- http://www.livescience.com/18247-metals-human-body-health-nigms.html
- http://www.eurometaux.eu/MetalsToday/MetalsFAQs/Metalsessentialforhumanhealth.aspx

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are metals? Name one example.
    - [Metals are elements that are good conductors of electricity. They are the largest of the three classes of elements. Students may give any example of a metal.]
2. Define nonmetal, and give an example.
    - [Nonmetals are elements that do not conduct electricity. They are the second largest class of elements. Students may give any example of a nonmetal.]
3. State one way that metalloids may be like metals and one way they may be like nonmetals.
    - [Answers may vary. *Sample answer*: Many metalloids can conduct electricity like metals but only at certain temperatures. They may also be shiny like metals, but they are usually brittle like solid nonmetals.]
4. What are valence electrons?
    - [Valence electrons are electrons in the outer energy level of an atom. They are potentially involved in chemical reactions.]
5. A mystery element is a dull, gray solid. It is very reactive with other elements. Classify the mystery element as a metal, nonmetal, or metalloid. Explain your answer.
    - [The mystery element is very reactive, so it could be a metal or nonmetal. It is dull instead of shiny, so it is likely to be a nonmetal.]
6. Create a Venn diagram for metals, metalloids, and nonmetals. The diagram should show which properties are different and which, if any, are shared among the three groups of elements.
    - [Venn diagrams may vary but should correctly identify properties that are different and properties that are shared among the three classes of elements.]
7. Relate number of valence electrons to reactivity of classes of elements.
    - [The number of valence electrons determines how likely an element is to react with other elements. For example, metals have just one or a few valence electrons, so they are very reactive. They readily give up their few valence electrons and combine with other elements. Metalloids have more valence electrons, so

they are less reactive than metals. Nonmetals have the greatest number of valance electrons. If gaining one or two electrons will give them a full outer energy level, they may be very reactive. Those that already have a completely full outer energy level are unreactive.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The number of valence electrons increases from left to right across each period of the periodic table. By the end of the period, the outer energy level is full. Moving on to the next period of the table, electrons are added to the next higher energy level. This happens in each row of the periodic table.

- How do you think the number of valence electrons compares in elements within the same column (group) of the periodic table?

Elements within each group have the same number of valence electrons.

- How might this be reflected in the properties of elements within a group?

With the same number of valence electrons, elements within a group have similar properties, especially in terms of rea

6.4 Lesson 6.3 Groups of Elements

Key Concept

Group 1 of the periodic table consists of hydrogen and the alkali metals. All of them are very reactive. Group 2 consists of the alkaline Earth metals. They are very reactive but less so than Group 1 elements. Groups 3–12 contain transition metals, which are less reactive than metals in groups 1 and 2. Groups 13–16 each contain at least one metalloid as well as metals and/or nonmetals, and they vary in reactivity and other properties. Group 17 contains halogens, which are highly reactive nonmetals. Group 18 consists of noble gases, which are unreactive.

Standards

- SCI.CA.8. PS.3.a, f; SCI.CA.8.PS.7.a, c
- MCR.6-8.SCI.8.5, 9, 10
- NSES.5-8.A.1.5; NSES.5-8.B.1.1, 2
- AAAS.6-8.4.D.8, 9, 10, 15, 16, 17

Lesson Objectives

- Identify hydrogen and alkali metals.
- Describe alkaline Earth metals.
- List properties of transition metals.
- Identify groups containing metalloids.
- Give properties of halogens.
- Describe noble gases.

Lesson Vocabulary

- **alkali metal:** metal in group 1 of the periodic table that has one valence electron and is highly reactive
- **alkaline Earth metal:** metal in group 2 of the periodic table that has two valence electrons and is very reactive but less so than an alkali metal
- **halogen:** nonmetal in group 17 of the periodic table that has seven valence electrons and is highly reactive
- **noble gas:** nonmetal in group 18 of the periodic table that has eight valence electrons (or two in the case of helium) and is unreactive
- **transition metal:** metal in groups 3 to 12 of the periodic table that is hard and shiny and less reactive than metals in groups 1 and 2

Teaching Strategies

Introducing the Lesson

At the start of class, demonstrate the reactivity of alkali metals with the excellent video at the URL below. Alternatively (or in addition), you can do a live demonstration of one or more alkali metals reacting with water. The vigorous reaction will be sure to get students' attention and pique their interest in alkali metals. Explain that a vigorous reaction with water is a characteristic property of all metals in group 1 of the periodic table. Tell students they will learn in this lesson the properties of all the groups in the periodic table.

- http://www.open.edu/openlearn/science-maths-technology/science/chemistry/alkali-metals

Building Science Skills

Ask students to predict the properties of a few specific elements in different groups, based on their general knowledge of each group. They can check their predictions by finding the properties of the specific elements in this interactive periodic table:

- http://www.rsc.org/periodic-table

Activity

Have students try to match each element to the class or group to which it belongs by doing the activity at the following URL. They can check their answers at the Web site.

- http://www.sciencegeek.net/Chemistry/taters/Unit2ElementClasses.htm

Differentiated Instruction

Assign each student one of the vocabulary terms in the lesson so all the terms are covered. Then ask students to make a Frayer model for their term. They should draw a large box, divide it into four parts labeled "Definition," "Drawing," "Example," and "Non-example," and then fill in the box for their term.

Enrichment

Challenge a few students to role-play elements in different groups by acting out their properties. Ask the rest of the students to guess which groups they are role-playing.

Science Inquiry

Describe a few "mystery elements" from different groups, and challenge students to identify in which group each element belongs. You can find detailed information about specific elements at this URL:

- http://periodic.lanl.gov/index.shtml

Common Misconceptions

The activity at the URL below will reveal and correct misconceptions about the periodic table. It uses concept mapping to explore and revise students' ideas. It is also a good way to review Chapter 6 concepts.

- http://media.rsc.org/Misconceptions/Miscon%20periodic%20table.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are alkali metals? What is one example?
   - [Alkali metals are all the elements—except for hydrogen—in group 1 of the periodic table. Students can name any alkali metal in group 1 as an example.]
2. Identify an alkaline Earth metal. How reactive is it?
   - [Students should name one of the alkaline Earth metals in group 2. Alkaline Earth metals are very reactive but less so than alkali metals.]
3. Which element is the only transition metal that is a liquid at room temperature?
   - [The only transition metal that is a liquid at room temperature is mercury.]
4. In which groups of the periodic table would you find metalloids?
   - [You would find metalloids in groups 13–16 of the periodic table.]
5. State why halogens are highly reactive.
   - [Halogens are highly reactive because they contain seven valence electrons. They need to gain just one more valence electron to fill their outer energy level.]
6. Describe noble gases.
   - [Noble gases are the elements in group 18. They are all colorless, odorless gases. They are unreactive because they have eight valence electrons filling their outer energy level.]
7. Assume you have a sample of an unknown element. At room temperature, it is a soft solid. You cut a small piece from the sample with a knife and drop the piece into a container of water. It bursts into flames. Which group of the periodic table does the unknown element belong in?
   - [The unknown element belongs in group 1 of the periodic table, the alkali metals.]
8. Both hydrogen (H) and helium (He) are gaseous nonmetals. Why are they placed on opposite sides of the periodic table?
   - [Hydrogen and helium are placed on opposite sides of the periodic table because of their valence electrons and reactivity. Hydrogen has just one electron, making it highly reactive like the alkali metals in group 1, which have one electron in their outer energy level. Helium has two electrons, so its sole energy level is full. This makes it unreactive like the other noble gases in group 18, which have their outer energy level filled.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 6.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Reactive elements combine easily with other elements. This explains why they usually exist in nature in compounds rather than in pure form.

- How do you think elements join together to form compounds?

Elements join together in chemical reactions to form compounds.

- Do you think this might vary from one group of elements to another?

With different numbers of valence electrons and differing reactivity, elements vary from one group to another in how t

CHAPTER 7 TE Chemical Bonding

Chapter Outline

7.1 Chapter 7: Chemical Bonding

Chapter Overview

A chemical bond is a force of attraction between atoms that share or transfer electrons. When atoms of different elements bond together, they form a chemical compound, which is a new substance with a fixed ratio of elements. Types of bonds include ionic, covalent, and metallic bonds. The different types of bonds form compounds that have different properties.

Online Resources

See the following Web sites for appropriate laboratory activities:

When you teach Lesson 7.2, use the guided inquiry lab "Introducing Ionic bonds: How Does the String Hold Together" at the following URL. It reveals the crystal structure of ionic compounds.

- http://serc.carleton.edu/sp/mnstep/activities/20131.html

Students can explore ionic and covalent bonding with the lab at the URL below. It uses an online simulation. The Web site provides all needed materials, including a link to the simulation.

- http://www.ltftraining.org/Portals/ltftraining/docs/science/Open_Lessons/MG_Sugar%20and%20Salt%20Solutions_web_Open%20Lesson.pdf

After students finish the chapter, have them do the inquiry lab "Ionic, Covalent, Metallic" at the following URL. They will devise tests to identify whether unknown materials contain ionic, covalent, or metallic bonds. Both student and teacher pages are included.

- http://misterguch.brinkster.net/middleschoolworksheets.html

These Web sites may also be helpful:

Take advantage of the excellent resources from the American Chemical Society's Middle School Chemistry Project (see URL below). The site offers detailed lesson plans and a large collection of multimedia resources. See Chapter 4, Lessons 4–6 for chemical bonding.

- http://www.middleschoolchemistry.com/lessonplans/chapter4/

The link below has several worksheets and other materials relating to chemical bonding.

- http://misterguch.brinkster.net/middleschoolworksheets.html

This concise, well-written video uses animation to explain ionic and covalent bonding.

- http://www.schooltube.com/video/7870b1153b034ec08d7a/

Pacing the Lessons

TABLE 7.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
7.1 Introduction to Chemical Bonds	1.5
7.2 Ionic Bonds	2.0
7.3 Covalent Bonds	2.0
7.4 Metallic Bonds	1.5

7.2 7.1 Introduction to Chemical Bonds

Key Concept

A chemical bond is a force of attraction between atoms that occurs when atoms share or transfer electrons. A chemical compound is a new substance that forms when atoms of different elements form chemical bonds. A compound always consists of a fixed ratio of elements.

Standards

- SCI.CA.8.PS.3.b
- MCR.6-8.SCI.8.2, 8
- NSES.5-8.B.1.1, 2, 3
- AAAS.6-8.4.D.3

Lesson Objectives

- Define chemical bond.
- List general properties of compounds.

Lesson Vocabulary

- **chemical bond:** force of attraction between atoms or ions that occurs when atoms share or transfer valence electrons
- **chemical formula:** symbol of a chemical compound using chemical symbols and subscripts to represent the ratio of atoms in the compound

Teaching Strategies

Introducing the Lesson

Introduce chemical bonding and the formation of chemical compounds by help students recall what they already know about compounds from Chapter 3 in CK–12 Physical Science for Middle School FlexBook® resource. Ask the following questions.

Question: What is a compound?

Answer: A compound is unique substance that forms when two or more elements combine chemically.

Question: How does a compound differ from a mixture?

Answer: A compound always contains the same elements in the same ratio, whereas a mixture is any combination of substances in any proportions.

Tell students they will learn in this lesson how compounds form.

Using Visuals

Use the models of hydrogen, oxygen, and water in the FlexBook® lesson to teach the basics of chemical bonding. Explain the electron dot diagrams, which are used here for the first time in the FlexBook®. Make sure students understand that each hydrogen atom shares a pair of electrons with the oxygen atom.

Building Science Skills

Chemical formulas may be difficult for some students. Define the prefixes that are used to name covalent compounds, and explain how subscripts are used in chemical formulas to indicate the number of each type of atom. Give students extra practice by having them complete the following table.

TABLE 7.2: Extra Practice

Name of Compound	Number of Atoms of Each Type	Chemical Formula
carbon monoxide	carbon: 1 oxygen: 1	CO
nitrogen trifluoride	nitrogen: fluorine: 3	
sulfur dioxide	sulfur: oxygen:	
carbon tetrachloride		

Differentiated Instruction

Have students complete a main ideas/details chart as they read the lesson. Tell them to list the main ideas on the left side of a sheet of paper and fill in details for each main idea on the right side of the paper. Students should identify at least one main idea for each of the main headings in the lesson.

Enrichment

Ask one or more advanced students to lead a class discussion of the properties of compounds and how they differ from the properties of the elements that combine to form them. Tell students to prepare for the discussion by learning the properties of several compounds and their constituent elements.

Science Inquiry

This guided inquiry activity will allow students to develop their own concepts about chemical bonding. They will also learn how to draw electron dot diagrams, which are introduced in this lesson of the FlexBook® resource. In addition, the activity introduces ionic and covalent bonds, which are covered in the next two lessons of this chapter.

- http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=20&ved=0CGUQFjAJOAo&url=http%3A%2F%2Fwww.nslc.ucla.edu%2Fstep%2Fgk12%2Flessons%2520(word)%2FMath%2FChemistry%2520lessons%2FBondingSGould.doc&ei=gUb_T6K0IKb30gHc57SuBA&usg=AFQjCNFHmcpAgrIr8nIh080y6ic8ruiRLg&sig2=ld6gzpfPuoM3qcbU460wrQ

Common Misconceptions

Students commonly hold the misconception that that a chemical bond is a material connection between atoms or ions. Ball-and-stick models of molecules may contribute to this misconception. Make sure students know that chemical bonds are forces and do not consist of matter.

Answer To Try It!

Problem: A molecule of nitrogen dioxide consists of one atom of nitrogen (N) and two atoms of oxygen (O). What is its chemical formula?

Solution: The chemical formula of nitrogen dioxide is NO_2.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a chemical bond?
   - [A chemical bond is a force of attraction between atoms or ions. It occurs when atoms share or transfer valence electrons.]
2. Define chemical compound.
   - [A chemical compound is a substance that consists of two or more elements that have combined chemically in a fixed ratio.]
3. Which atoms and how many of each make up a molecule of sulfur dioxide? Write the chemical formula for this compound.
   - [Sulfur dioxide has one sulfur atom and two oxygen atoms. Its chemical formula is SO_2.]
4. Why does a molecule of water have a more stable arrangement of electrons than do individual hydrogen and oxygen atoms?
   - [In a molecule of water, an oxygen atom shares a pair of electrons with each of two hydrogen atoms. This gives the oxygen atom eight electrons in its outer energy level, and it gives each hydrogen atom two electrons in its only energy level. As a result, all three atoms have a more stable arrangement of electrons than they had as individual atoms.]

5. Explain how the ratio of elements in a compound is related to the compound's properties.
    - [The ratio of elements in a compound is fixed and determines the compound's properties. If a substance has a different ratio of the same elements, it is a different compound with different properties.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you learned about chemical bonds in a water molecule. The bonds form between atoms of hydrogen and oxygen when they share electrons. This type of bond is an example of a covalent bond.

- What might be other ways that atoms can bond together?

Atoms can form double or triple covalent bonds, in which they share two or three pairs of valence electrons.

- How might ions form bonds?

Ions transfer electrons and form large structures called crystals, in which many ions are bonded together in a repeatin

7.3 Lesson 7.2 Ionic Bonds

Key Concept

An ionic bond is the force of attraction that holds together oppositely charged metal and nonmetal ions. Ionic bonds are strong, and they form rigid crystals rather than molecules. Ionic compounds are brittle solids with high melting and boiling points. They are also good conductors of electricity but only as liquids or when dissolved in water.

Standards

- SCI.CA.8.PS.3.b, c, f; SCI.CA.8.PS.7.a, c
- MCR.6-8.SCI.8.2, 5, 8
- AAAS.6-8.4.D.3, 16, 17

Lesson Objectives

- Describe how ionic bonds form.
- List properties of ionic compounds.

Lesson Vocabulary

- **ionic bond:** force of attraction that holds together positive and negative ions; forms when atoms of a metal give up valence electrons to atoms of a nonmetal
- **ionic compound:** compound that forms when oppositely charged metal and nonmetal ions are held together in a crystal by ionic bonds

Teaching Strategies

Introducing the Lesson

Call on students to define the word ion and explain how ions form. (These concepts were introduced in Chapter 5 of the CK-12 Physical Science for Middle School FlexBook® resource.) Go around the room calling on one student after another until the correct definition and explanation have been given. Tell students they will learn in this lesson how ions form bonds with other ions.

Discussion

Discuss the role of oxidation number in the formation of ionic bonds. State that the oxidation number of an element reflects the number of electrons it gains or loses when it forms ionic bonds. For example, in the ionic compound sodium chloride (NaCl), the oxidation number of sodium is +1 (it loses one electron), and the oxidation number of chloride is -1 (it gains one electron). Explain how knowing oxidation numbers allows you to predict which ions may form bonds together.

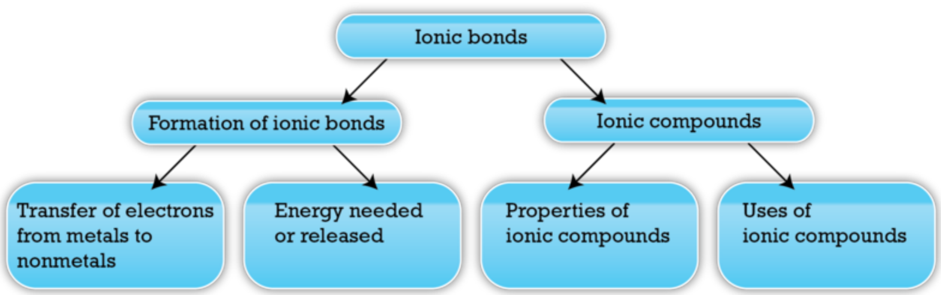
Activity

Students can role-play ionic bonding with the activity "Bond with a Classmate," which is described at the following URL. Each student will represent a specific ion and try to find other "ions" with which they can form ionic bonds. Complete instructions and materials are provided at the Web site. Before students do the activity, you will need to explain oxidation number to the class if you haven't already done so (see Discussion strategy just above).

- http://sciencespot.net/Pages/classchem.html#Anchorbond

Differentiated Instruction

Work with the class to make a concept map for the lesson. A sample concept map is shown below. You can copy the framework of the concept map on the board or an overhead transparency and then help students fill it in.



Enrichment

Some students may want to investigate why ionic compounds become good conductors of electricity when dissolved in water. Suggest they learn more online, starting with the URL below. Ask them to share what they learn with the class.

- http://misterguch.brinkster.net/ionic.html

Science Inquiry

Tell students that an important property of ionic compounds is their ability to conduct electricity when dissolved in water. Knowing whether an unknown substance can conduct electricity in a water solution is one way of identifying whether it is ionic. Divide the class into small groups, and challenge each group to design a plan to test whether an aqueous solution of an unknown compound can conduct electricity. (They might describe making a circuit that passes through the solution and includes a device such as a buzzer or light bulb to indicate whether or not current is flowing through the circuit.)

Common Misconceptions

Students commonly think that all compounds form molecules. Stress that ionic compounds form crystals instead of molecules. Call students' attention to the sodium chloride crystal diagram and photo in their FlexBook® lesson. Make sure they understand that the crystal consists of a repeating pattern of many sodium and chloride ions. You may also want to have students watch salt crystals forming with time-lapse photography at one of the following URLs.

- http://www.youtube.com/watch?v=QwiPplYoH7Q
- http://www.youtube.com/watch?v=uoexANHeWoU
- http://www.youtube.com/watch?v=2KTrt38SYlc

Answer to You Try It!

Problem: What is the name of the ionic compound composed of positive barium ions and negative iodide ions?

Solution: The compound is named barium iodide.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is an ionic bond?
   - [An ionic bond is the force of attraction that holds together positive and negative ions. It forms when atoms of a metal element give up electrons to atoms of a nonmetal element.]
2. Outline the role of energy in the formation of an ionic bond.
   - [Energy is involved in the formation of an ionic bond. It takes energy to remove valence electrons from metal atoms. When nonmetal atoms gain the electrons, energy is released. The amount of energy needed or released depends on the atoms involved. Generally, the least amount of energy is needed to remove the one valence electron from alkali metals, and the greatest amount of energy is released by halogen elements when they gain one valence electron.]
3. List properties of ionic compounds.
   - [Ionic compounds are solids with high melting and boiling points. Their crystals are rigid and brittle, so they are likely to break rather than bend when struck. Solid ionic compounds are poor conductors of electricity. However, in the liquid state or when dissolved in water, ionic compounds are good conductors of electricity.]
4. Create a model to represent the ionic bonds in a crystal of the salt lithium iodide (LiI).

- [Students should sketch a model of the ionic bonds in a crystal of lithium iodide (LiI). It should show a lattice of alternating positive lithium ions and negative iodide ions, like the ions of sodium and chloride in the diagram in the FlexBook® lesson.]

5. A mystery compound is a liquid with a boiling point of 50 °C. Is it likely to be an ionic compound? Why or why not?
   - [Ionic compounds are solids with high boiling points. The mystery compound is a liquid with a relatively low boiling point. Its boiling point is even lower than the boiling point of water, which is not an ionic compound. Therefore, the mystery compound is unlikely to be an ionic compound.]
6. Explain why ionic bonds form only between atoms of metals and nonmetals.
   - [Ionic bonds form when one atom gives up one or more valence electrons to another atom. Ionic bonds form only between atoms of metals and nonmetals because metals "want" to give up valence electrons and nonmetals "want" to gain valence electrons.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Bonds form not only between atoms of metals and nonmetals. Nonmetals may also bond with nonmetals.

- How do you think bonds form between atoms of nonmetals?

Atoms of nonmetals form covalent bonds in which they share, rather than transfer, electrons.

- Can you think of examples of compounds that consist only of nonmetals?

***Sample answer*: Examples include water and carbon dioxide.**

7.4 Lesson 7.3 Covalent Bonds

Key Concept

A covalent bond is the force of attraction that holds together two atoms of the same or different nonmetals that share a pair of electrons. In polar covalent bonds, one atom attracts the shared electrons more strongly and becomes slightly negative while the other atom becomes slightly positive. Covalent compounds form individual molecules rather than crystals. They have low melting and boiling points and are poor conductors of electricity. Molecules of polar covalent compounds are attracted to each other.

Standards

- SCI.CA.8.PS.3.b; SCI.CA.PS.6.c; SCI.CA.PS.7.c
- MCR.6-8.SCI.8.2, 8
- AAAS.6-8.4.D.3, 16, 17

Lesson Objectives

- Describe how covalent bonds form.
- Compare properties of polar and nonpolar covalent compounds.

Lesson Vocabulary

- **covalent bond:** force of attraction that holds together two atoms that share a pair of electrons
- **covalent compound:** compound that forms when atoms of nonmetals form molecules that are held together by covalent bonds
- **hydrogen bond:** weak bond that forms between a slightly positive hydrogen atom in one molecule and a slightly negative atom in another molecule
- **nonpolar:** not having oppositely charged ends, as in nonpolar covalent bond or nonpolar covalent compound
- **polar:** having oppositely charged ends, as in polar covalent bond or polar covalent compound

Teaching Strategies

Introducing the Lesson

Water is used as an example of covalent bonding throughout this lesson. Introduce the lesson by helping students recall what they already know about water. Call on several students at random to complete this sentence in one or a few words:

Water is __________.

Ask a volunteer to record the answers on the board. Conclude by telling the class that water is an example of a covalent compound and they will learn about covalent compounds in this lesson.

Activity

Have students do the "Bonding Basics" activity at the following URL. The Web site provides instructions, worksheets, and other helpful materials for the activity. Students will use simple headbands and ping-pong balls to form covalent and ionic bonds with each other. They will be able to visualize clearly how the two types of bonds differ.

- http://sciencespot.net/Pages/classchem.html#Anchor-49575

Discussion

Discuss how covalent and ionic bonds are not completely discrete types of bonds but more like two ends of a continuum. Virtually all bonds involve some differences in attraction for electrons unless the bonds form between two atoms of the same element. Only these bonds are completely neutral in charge. The greater the polarity of a covalent bond, the closer it is to an ionic bond.

Differentiated Instruction

Have less proficient readers find the topic sentence of each paragraph in the lesson. Explain that the topic sentence is often, though not always, the first sentence in the paragraph, and that it typically states the main idea of the paragraph. The rest of the sentences in the paragraph usually support or provide details about the main idea. Demonstrate by identifying the topic sentences of the first couple of paragraphs in the lesson.

Enrichment

Ask interested students to delve deeper into the polarity of water. They should research how water's polarity affects its properties and makes it an unusual compound. They can start with the URLs below. Have them create a display, video, or other visual presentation to share what they learn with the rest of the class.

- http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html
- http://www.mrswiltrout.com/Ch3-1-EffectsOfWaterPolarity.pdf

Science Inquiry

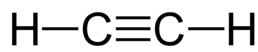
Students can model covalent and ionic bonding with the activity "Candy Compounds" at the following URL. The PDF includes everything you need except the candy. The activity can be done by individual students, pairs, or small groups.

- http://sciencespot.net/Media/candycompounds.pdf

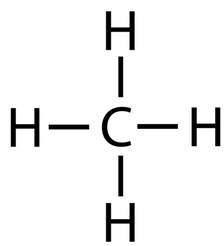
Common Misconceptions

Students may think erroneously that any molecule with polar bonds must be a polar molecule. Give students additional examples (besides carbon dioxide, which is the example given in the FlexBook®) of nonpolar molecules that contain polar bonds. You might use the two examples below. Challenge students to explain why these two molecules are nonpolar despite having polar bonds.

1. Acetylene (C_2H_2):



2. Methane (CH_4):



Answer to You Try It!

Problem: What is the name of the compound that contains three oxygen atoms and two nitrogen atoms? What is its chemical formula?

Solution: The name is of the compound dinitrogen trioxide, and its chemical formula is N_2O_3.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

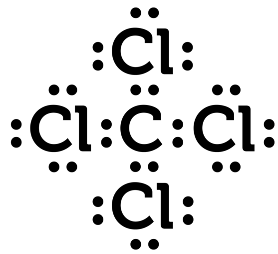
Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a covalent bond?
   - [A covalent bond is the force of attraction that holds together two atoms that share a pair of electrons.]
2. What is the difference between a polar and nonpolar covalent bond?
   - [In a polar covalent bond, one atom attracts the shared electrons more strongly and becomes slightly negative in charge, while the other atom attracts the shared electrons less strongly and becomes slightly positive in charge. In a nonpolar covalent bond, both atoms attract the shared electrons equally and remain neutral in charge.]
3. List general properties of covalent compounds.

- [Covalent compounds have relatively low melting and boiling points so they often exist as gases or liquids at room temperature. They are also poor conductors of electricity, and many do not dissolve in water.]

4. The electron dot diagram below represents a covalent compound. Do you think it is a polar or nonpolar compound? Explain.



- [The compound is nonpolar because all sides of the molecule have the same element. Therefore, no side will have a different charge than any other side.]

5. Explain why covalent bonds form.
   - [Covalent bonds form because they give atoms a more stable arrangement of electrons. By sharing electrons, the atoms fill their outer energy levels.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You read in this lesson that covalent bonds may form between atoms of the same nonmetal element. For example, hydrogen atoms (H) commonly form covalent bonds to form hydrogen molecules (H_2).

- Do you think bonds may also form between atoms of the same metallic element?

Yes; bonds also form between atoms of the same metallic element.

- Predict what these metallic bonds might be like.

Metallic bonds form between positive metal ions and the "sea" of valence electrons surrounding them—their own and

7.5 Lesson 7.4 Metallic Bonds

Key Concept

A metallic bond is the force of attraction between a positively charged metal ion and the valence electrons it shares with other ions of the metal, forming a lattice-like structure. With freely moving electrons, metals are good conductors of electricity and can change shape without breaking. Pure metals may be less useful than mixtures of metals, called alloys, which include steel, bronze, and brass.

Standards

- SCI.CA.8.PS.7.C
- AAAS.6-8.4.D.3, 16; AAAS.6-8.8.B.1, 2, 5

Lesson Objectives

- Describe how metallic bonds form.
- Relate the nature of metallic bonds to the properties of metals.
- Identify alloys and their uses.

Lesson Vocabulary

- **alloy:** mixture of a metal with one or more other elements
- **metallic bond:** force of attraction between a positive metal ion and the valence electrons it shares with other ions of the metal

Teaching Strategies

Introducing the Lesson

Help students recall what they learned in Chapter 6 about metals and their properties by asking them these questions:

Question: What are metals?
  Answer: Metals are elements that are good conductors of electricity.
Question: Why are almost all metals solids are room temperature?
  Answer: Metals are solids at room temperature because they have high melting points.

Question: What are some other properties of metals?

Answer: Metals are generally shiny, ductile, and malleable. They are also good conductors of heat, and many metals are very reactive with other elements.

Tell students that the properties of metals are due to the nature of metallic bonds, which they will read about in this lesson.

Activity

Have students use the animated activity at the following URL to better understand why metals behave as they do. They will be able to apply different physical forces and heat to a model metal and observe how the metallic bonds respond.

- http://www.teachersdomain.org/asset/phy03_int_metal-fla/

Differentiated Instruction

Now that students have read about ionic, covalent, and metallic bonds, have them make a compare-contrast table of the three bond types. You may want to make the table as a class activity. You can start a table like **Table** 7.3 on the board or an overhead, and then call on students to fill in the cells.

TABLE 7.3: **Compare-Contrast of the Three Bond Types**

Type of Bond	Element Class(es)	Description	Structure	Example
Ionic	metal-nonmetal	ions transfer electrons	crystal	sodium chloride (NaCl)
Covalent	nonmetal-nonmetal	atoms share electrons	molecule	water (H_2O)
Metallic	metal-metal	positive ions share a sea of free electrons	lattice	almost all metals

Enrichment

Ask students to choose a specific alloy that is not described in the FlexBook® lesson, learn more about it, and then create a poster showing its composition, properties, and uses. If more than one student does the activity, make sure each student chooses a different alloy. Students can start with general Web sites about alloys, such as those listed below, to help them decide which alloy to investigate. Display their posters in the classroom, and encourage other students to learn from them.

- http://www.chemistrydaily.com/chemistry/Alloy
- http://www.gcsescience.com/ex29.htm
- http://www.eurometaux.eu/MetalsToday/MetalsFAQs/Whatarealloys.aspx

Science Inquiry

Divide the class into small groups and tell each group to explore metallic bonding and the properties of metals with the interactive lesson at the URL below. As they work through the lesson, they will be challenged to apply what they learn to make predictions and develop explanations. The lesson provides many links to additional information, animations, and other helpful materials. Answers with detailed explanations are also provided.

- http://www.saskschools.ca/curr_content/chem20/metals/metintro.html

Real-World Connection

Discuss uses of alloys in students' daily lives. Point out that just about all the metal objects they use are actually made of alloys. Explain that alloys are developed to have certain properties that make them useful for specific applications. Here are two examples not included in the FlexBook® lesson:

1. Solder is an alloy of tin and lead that has a low melting point. This makes it useful for fusing metal parts.
2. Nichrome is an alloy of nickel and chromium with a high melting point and high resistance to electric current. These properties make it useful for heating elements in toasters and other appliances.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a metallic bond?
    - [A metallic bond is the force of attraction between a positive metal ion and the valence electrons it shares with other ions of the metal.]
2. Define alloy and give three examples.
    - [An alloy is a mixture of a metal and one or more other elements. Examples may vary. Sample answer: Three examples of alloys are steel, bronze, and brass.]
3. Create a model to represent the metallic bonds in solid iron (Fe).
    - [Students should sketch a model representing the metallic bonds in iron (Fe). It should show a lattice of positive iron ions surrounded by negative electrons. The sketch should resemble the diagram in the FlexBook® lesson.]
4. Relate metallic bonds to the properties of metals.
    - [Metallic bonds explain some of the unique properties of metals. Because of their freely moving electrons, metals are good conductors of electricity. The ions of a metal can move within the "sea" of electrons without breaking the metallic bonds that hold them together. Because the ions can move, metals can change shape without breaking. This allows them to be ductile and malleable.]
5. Compare and contrast metallic and ionic bonds.
    - [*Sample answer*: Metallic bonds form between ions and electrons of the same metal. Ionic bonds form between oppositely charged ions of a metal and a nonmetal. Metallic bonds are strong but flexible. Ionic bonds are strong but rigid.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 7.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Compounds form when atoms of different elements combine. This process is a chemical reaction.

- How would you define chemical reaction?

A chemical reaction is a process in which some substances change into others.

- How do you think chemical reactions are related to chemical changes in matter, such as wood burning and iron rusting?

Chemical changes occur because of chemical reactions.

CHAPTER 8 TE Chemical Reactions

Chapter Outline

8.1 Chapter 8: Chemical Reactions

Chapter Overview

A chemical reaction is a process in which some substances change into different substances. Evidence such as a change in color shows that a chemical reaction has occurred. Chemical reactions are represented by chemical equations, which must balance because mass is always conserved in chemical reactions. Types of chemical reactions include synthesis, decomposition, single and double replacement, and combustion reactions. In terms of energy, reactions can be classified as endothermic or exothermic.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this lab, students will determine what observable factors are changed in a chemical reaction and what factors remain constant. The lab uses a closed system and introduces students to the conservation of matter in chemical reactions.

- http://serendip.brynmawr.edu/sci_edu/farber/pdf/balloon.pdf

The inquiry-based chemical reactions lab at the following URL uses the 5 E approach of Engage, Explore, Explain, Extend, and Evaluate. The lab allows students to investigate chemical reactions, conservation of mass, and balancing chemical equations using materials available in a supermarket.

- http://www.csupomona.edu/~cemast/supermarket_chemical_reactions-1.pdf

For lesson 8.2, students can do Experiment 3 (Reactions 1: Types of Reactions) beginning on page 30 of the PDF document below. In the lab, students carry out and observe chemical reactions and identify the types of reactions they represent. The lab will take less time if you divide the class into groups and have each group carry out one of the reactions. Then groups can share and discuss their results.

- http://dwb4.unl.edu/ChemSource/SourceBook/151ILAB.pdf

At the following URL, you can link with several labs, each focusing on a different type of chemical reaction (synthesis, decomposition, single replacement, double replacement).

- http://www.cdrucker.com/files/pagesgen/ScientificInquiry.html

Students can make ice cream while investigating endothermic and exothermic reactions with the activity at the following URL.

- http://www.create.cett.msstate.edu/create/classroom/lplan_view.asp?articleID=50

The guided inquiry lab at this URL also investigates endothermic and exothermic reactions.

- http://serc.carleton.edu/sp/mnstep/activities/19869.html

This Web site may also be helpful:

The following URL from the American Chemical Society provides excellent materials for teaching middle school chemistry. Chapter 6 on chemical reactions has several lessons relevant to this FlexBook® chapter. It includes lesson plans that offer numerous downloadable materials and multimedia. The lesson plans include teacher demonstrations, scripted questions, student activities, and extension ideas, among other useful resources.

- http://www.middleschoolchemistry.com/lessonplans/chapter6/

Pacing the Lessons

TABLE 8.1: **Pacing the Lessons**

Lesson	Class Period(s) (60 min)
8.1 What Is Science?	1.0
8.2 Chemical Equations	1.0
8.3 Types of Chemical Reactions	2.0
8.4 Chemical Reactions and Energy	2.0

8.2 Lesson 8.1 Introduction to Chemical Reactions

Key Concept

A chemical reaction is a process in which some substances change into different substances. In a chemical reaction, bonds break in reactants and new bonds form in products. Evidence that a chemical reaction has occurred include a change in color, a change in temperature, the production of a gas, or the formation of a solid precipitate.

Standards

- SCI.CA.8.PS.5.a
- MCR.6-8.SCI.8.8
- NSES.5-8.B.1.2
- AAAS.6-8.4.D.3, 17, 18, 19; AAAS.6-8.11.C.9

Lesson Objectives

- Describe how chemical reactions occur.
- List signs that a chemical reaction has occurred.

Lesson Vocabulary

- **chemical reaction:** process in which some substances, called reactants, change chemically into different substances, called products
- **equilibrium:** balance between opposing changes, such as the forward and reverse directions of a chemical reaction
- **product :** substance produced in a chemical reaction
- **reactant:** substance that starts a chemical reaction

Teaching Strategies

Introducing the Lesson

Introduce chemical reactions by describing several different changes in matter and asking students whether they are chemical or physical changes. Be sure to include examples of each type of change (e.g., ice melting and salt dissolving for physical changes; leaves changing color and wood burning for chemical changes). Discuss with the class how chemical changes differ from physical changes. Tell students they will learn in this lesson how chemical changes occur.

Activity

Teach the basics of chemical reactions by using the lesson "What Is a Chemical Reaction" at the URL below. In the lesson, you will first demonstrate a chemical reaction between candle wax and oxygen and then show students an animation of a similar reaction. Students will also use atom model cutouts to model the reaction and see that all the atoms in the reactants show up in the products. The Web site provides detailed instructions, scripted questions, multimedia, a student worksheet with answers, and other helpful resources.

- http://www.middleschoolchemistry.com/lessonplans/chapter6/lesson1

Using Visuals

Point out the photos showing evidence of chemical reactions in the FlexBook® lesson. Challenge students to think of other examples showing similar evidence of chemical reactions. Examples might include silver tarnishing (change in color), fireworks exploding (change in temperature), plants making food by photosynthesis (production of a gas), and eggs cooking (production of a solid).

Differentiated Instruction

Pair any English language learners and less proficient readers with native speakers and more proficient readers. Ask partners to make a Frayer model for the term chemical reaction. They should draw a large box divided into four parts (labeled "Definition," "Drawing," "Example," and "Nonexample") and then fill in each part of the box.

Enrichment

Ask a few students to collaborate on producing a PowerPoint presentation of lesson content. Their presentation should summarize and illustrate the main lesson concepts. Set aside class time for the students to present their PowerPoint to the class.

Science Inquiry

Have small groups of students do the Explore activity (No. 2) at the following URL. They will investigate the question: "How do you know when a precipitate is formed in a chemical reaction?" Students will combine two clear colorless solutions and observe the formation of a solid and a gas. They will also analyze the chemical equation for the reaction and connect the equation to the actual reactants and products. The Web site provides a complete suite of materials relating to the activity.

- http://www.middleschoolchemistry.com/lessonplans/chapter6/lesson3

Common Misconceptions

A very common misconception is that changes of state are chemical changes. Explain that changes of state change only the physical and not the chemical properties of matter because matter that changes state remains the same kind of matter. For example, if liquid water freezes, the ice is still composed of water. All you need to do is melt the ice to get liquid water again.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define chemical reaction.
   - [A chemical reaction is a process in which some substances change into different substances.]
2. What are the reactants and products in a chemical reaction?
   - [The reactants are the substances that start the chemical reaction. The products are the substances that are produced in the chemical reaction.]
3. Describe what happens to the atoms involved in a chemical reaction.
   - [The atoms involved in a chemical reaction are rearranged during the reaction. As a result, the atoms are in different combinations in the products than they were in the reactants.]
4. List four common signs that a chemical reaction has occurred.
   - [Four common signs that a chemical reaction has occurred are a change in color, a change in temperature, the production of a gas, and the formation of a precipitate.]
5. Tina made a "volcano" by pouring vinegar over a "mountain" of baking soda. The wet baking soda bubbled and foamed. Did a chemical reaction occur? How do you know?
   - [Yes; a chemical reaction occurred. You know because bubbles of gas were produced and the production of a gas is a sign that a chemical reaction has occurred.]
6. Explain the meaning of the term "equilibrium" as it applies to a chemical reaction. How can you tell when a chemical reaction has reached equilibrium?
   - [Equilibrium is a balance between opposing changes. In a chemical reaction, equilibrium is the point at which the forward and reverse reactions occur at the same rate. You can tell when a chemical reaction has reached equilibrium because there is no further change in the amounts of reactants and products.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In a figure above, you saw how hydrogen and oxygen combine chemically to form water.

- How could you use chemical symbols and formulas to represent this reaction?

$2H_2 + O_2 \rightarrow 2H_2O$

- How many molecules of hydrogen and oxygen are involved in this reaction? How many molecules of water are produced? How could you include these numbers in your representation of the reaction?

Two molecules of hydrogen and one molecule of oxygen are involved in this reaction, and two molecules of water are p

8.3 Lesson 8.2 Chemical Equations

Key Concept

A chemical equation is a symbolic representation of a chemical reaction. Coefficients are used to balance chemical equations so there are the same numbers of each type of atom in the products as there are in the reactants. Chemical equations must be balanced because of the law of conservation of mass, which was first demonstrated by Antoine Lavoisier.

Standards

- SCI.CA.8.PS.5.b
- MCR.6-8.SCI.8.6
- NSES.5-8.B.1.2
- AAAS.6-8.1.A.4; AAAS.6-8.4.D.12, 13; AAAS.6-8.10.F.3; AAAS.6-8.11.C.3; AAAS.6-8.12.D.11

Lesson Objectives

- Describe how to write chemical equations.
- Demonstrate how to balance chemical equations.
- Relate the law of conservation of mass to balancing chemical equations.

Lesson Vocabulary

- **chemical equation:** symbolic representation of a chemical reaction

Teaching Strategies

Introducing the Lesson

Call on a volunteer to go to the board and write the general equation for a chemical reaction (Reactants $\rightarrow$ Products), which was introduced in the previous lesson. Call on other students to explain what each part of the equation represents. Then tell the class that they will learn in this lesson how to write chemical equations for specific chemical reactions.

Building Science Skills

Using the board or an overhead projector, demonstrate how to write and balance chemical equations. Describe in words a simple reaction (such as the formation of water from hydrogen and oxygen), and then represent it with a chemical equation. Explain what each part of the equation represents. Be sure to distinguish the uses of coefficients and subscripts. Also, explain how and why the equation must be balanced. Work with the class to balance two or three of the equations (with answers) at the URL below (click on HM003 and HM004). Then ask students to try to balance some of the other equations. This could a homework assignment.

- http://misterguch.brinkster.net/middleschoolworksheets.html

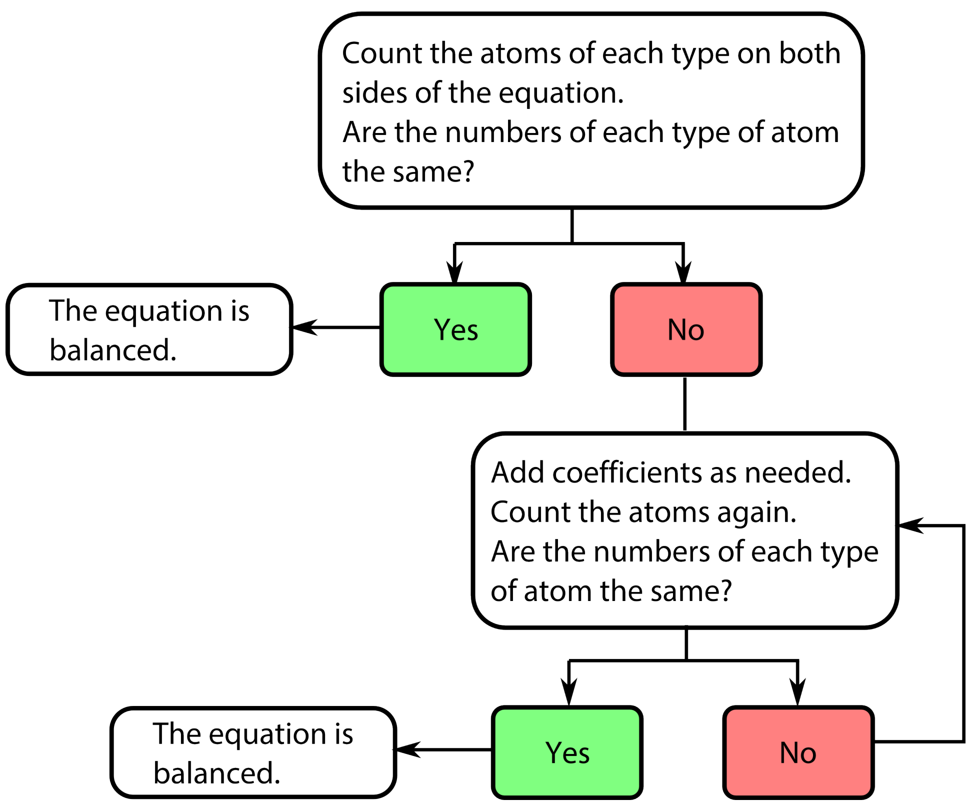
Demonstration

Using the board or an overhead projector, demonstrate how to write and balance chemical equations. Describe in words a simple reaction (such as the formation of water from hydrogen and oxygen), and then represent it with a chemical equation. Explain what each part of the equation represents. Be sure to distinguish the uses of coefficients and subscripts. Also, explain how and why the equation must be balanced. Work with the class to balance two or three of the equations (with answers) at the URL below (click on HM003 and HM004). Then ask students to try to balance some of the other equations. This could a homework assignment.

- http://misterguch.brinkster.net/middleschoolworksheets.html

Differentiated Instruction

Work with students to create a flow chart for the steps in balancing a chemical equation. A sample flow chart is shown below. Then have students apply the completed flow chart to a simple equation to make sure they understand the process.



Enrichment

Have interested students learn more about Lavoisier's research and why he is called the "Father of Modern Chemistry." They should investigate how Lavoisier discovered the role of oxygen in combustion, respiration, and rusting, and how he disproved the phlogiston theory. Ask the students to create a poster, Web page, or other visual presentation to share what they learn with the rest of the class.

Science Inquiry

Use the guided-inquiry activity "What Is that Stuff?" as a fun way for students to investigate the conservation of mass in chemical reactions. The activity also reinforces basic science skills (measuring, observing) and introduces the role of energy in chemical reactions.

- http://blog.teachersource.com/tag/conservation-of-mass/

Math Connection

Compare and contrast math equations and chemical equations. It may give students a deeper understanding of both types of equations. Here are some points you might make:

- Both types of equations use letters as symbols. In a math equation, the letters represent variables, such as mass, time, or price. In a chemical equation, the letters represent elements and compounds.
- Both types of equations must balance. In a math equation, the two sides must be numerically equal. In a chemical equation, the two sides must have the same number of each type of atom.
- Both types of equations are governed by "rules." A math equation is governed by mathematical operations. A chemical equation is governed by the nature of chemical reactions and the law of conservation of mass.

Answer to You Try It!

Problem: Balance these chemical equations:

$$\mathrm{Zn} + \mathrm{HCl} \rightarrow \mathrm{ZnCl_2} + \mathrm{H_2}$$
$$\mathrm{Cu} + \mathrm{O_2} \rightarrow \mathrm{CuO}$$

Solution:

$$\mathrm{Zn} + 2\mathrm{HCl} \rightarrow \mathrm{ZnCl_2} + \mathrm{H_2}$$
$$2\mathrm{Cu} + \mathrm{O_2} \rightarrow 2\mathrm{CuO}$$

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a chemical equation? Give an example.
   - [A chemical equation is a symbolic representation of a chemical reaction. Examples may vary. *Sample answer*: $C + O_2 \rightarrow CO_2$.]
2. What is a coefficient? How are coefficients used in chemistry?
   - [A coefficient is a number placed in front of a chemical symbol or chemical formula. It shows how many atoms or molecules of the substance are involved in a reaction. Coefficients are used in chemistry to balance chemical equations.]
3. Describe how Antoine Lavoisier showed that matter is conserved in chemical reactions.
   - [Antoine Lavoisier carefully measured the mass of reactants and products in many different chemical reactions. He carried out the reactions inside a sealed jar. As a result, any gases involved in the reactions were captured and measured. In every case, the total mass of the jar and its contents was the same after the reaction as it was before the reaction took place. This showed that matter was neither created nor destroyed in the reactions.]
4. Draw a sketch that shows how atoms are rearranged in the chemical reaction represented by equation 2.
   - [Sketches may vary but should reflect an understanding how atoms are rearranged in the reaction $2H_2 + O_2 \rightarrow 2H_2O$. Sketches should show that bonds break between hydrogen atoms and between oxygen atoms in the reactants, and that bonds form between hydrogen and oxygen atoms in the products.]
5. Balance this chemical equation: $Hg + O_2 \rightarrow HgO$.
   - [The balanced equation is $2Hg + O_2 \rightarrow 2HgO$.]
6. Explain why it is necessary to balance chemical equations.
   - [It is necessary to balance chemical equations because matter cannot be created or destroyed in a chemical reaction. Therefore, in every chemical reaction, the same number of each type of atom must appear in the products as started in the reactants.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you saw examples of chemical reactions in which two reactants combine to yield a single product. This is called a synthesis reaction. It is just one type of chemical reaction.

- What might be other types of chemical reactions

An obvious type is the opposite of a synthesis reaction: a decomposition reaction. Other types are replacement and cor

- How might one reactant produce more than one product?

This occurs in a decomposition reaction when a single reactant breaks down to form two or more products.

8.4 Lesson 8.3 Types of Chemical Reactions

Key Concept

A synthesis reaction occurs when two or more reactants combine to form a single product. In a decomposition reaction, the opposite occurs: one reactant breaks down into two or more products. A replacement reaction (single or double) occurs when ions switch places in compounds. In a combustion reaction, a substance reacts quickly with oxygen.

Standards

- MCR.6-8.SCI.8.8, 10
- NSES.5-8.B.1.2
- AAAS.6-8.4.D.10, 17; AAAS.6-8.5.E.7

Lesson Objectives

- Explain how synthesis reactions occur.
- Describe how decomposition reactions occur.
- Describe single and double replacement reactions.
- Explain how combustion reactions occur.

Lesson Vocabulary

- **combustion reaction:** chemical reaction in which a substance reacts quickly with oxygen, producing carbon dioxide, water, and energy; commonly called burning
- **decomposition reaction chemical:** reaction in which one reactant breaks down into two or more products
- **replacement reaction:** chemical reaction in which ions switch places in one compound (single replacement) or in two compounds (double replacement)
- **synthesis reaction:** chemical reaction in which two or more reactants combine to form a single product

Teaching Strategies

Introducing the Lesson

Use cartoons to pique students' interest in different types of chemical reactions. Have them describe the chemical reactions depicted by cartoons at the following URL. Then identify the type of reaction represented by each cartoon, and tell the class they will learn about the different types in this lesson.

- http://www.nclark.net/CartoonChemistry.doc

Activity

Show students animations of the different types of chemical reactions with the short video at the first URL below. Then use the PowerPoint presentation, student worksheet, and other materials at the second URL to let students explore the different types of reactions and apply what they learn.

- http://watchknowlearn.org/Video.aspx?VideoID=11933&CategoryID=2497
- http://sciencespot.net/Pages/classchem.html#chemreactions

Differentiated Instruction

Pair students who need extra help with students who are excelling, and have partners create a cluster diagram for types of chemical reactions. They should label a central circle "Types of Chemical Reactions" and surround it with five large circles, each labeled with a different type of reaction. Then they should add important details about each type of reaction, such as definition, general equation, and example.

Enrichment

Suggest to a few creative students that they write a rap about the five types of chemical reactions. The rap should describe and give examples of each type of reaction. Ask the students teach their rap to the rest of the class.

Science Inquiry

Have pairs of students apply their knowledge of types of reactions by classifying previously unseen chemical reactions. Ask partners to work together to complete the multiple choice activity at the following URL. If they disagree about a classification, they should discuss the evidence they are using to make the judgment. They can resolve disputes by checking the correct answers.

- http://www.sciencegeek.net/Chemistry/taters/EquationIdentification.htm

Common Misconceptions

Combustion is one of the most commonly misconceived ideas in chemistry. Students' familiarity with burning in their everyday lives means that they are likely to have preconceived notions about it, many of which may be incorrect. The research-based article at the URL below identifies many common combustion misconceptions that may help you anticipate erroneous thinking in your students.

- http://repository.nie.edu.sg/jspui/bitstream/10497/458/1/TL-15-2-52.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Write an equation for the chemical reaction in which hydrogen reacts with oxygen to form water. What type of reaction is this?
   - [The equation for the reaction in which hydrogen reacts with oxygen to form water is $2H_2 + O_2 \rightarrow 2H_2O$. This is a synthesis reaction.]
2. Write an equation for the reverse of the reaction in question 1. What type of reaction is this?
   - [The reverse of the reaction in question 1 is $2H_2O \rightarrow 2H_2 + O_2$. This is a decomposition reaction.]
3. Name the type of reaction represented by this general equation: $AB + CD \rightarrow AD + CB$
   - [The type of reaction represented by equation is a double replacement reaction.]
4. In the general equation in question 3, what do the individual letters represent?
   - [The individual letters represent ions.]
5. What are the reactants and products in a combustion reaction?
   - [In a combustion reaction, the products are some type of fuel, such as methane or glucose, and oxygen. The products are carbon dioxide and water. Energy is also released.]
6. Apply lesson concepts to classify the following chemical reactions:
   (a) $Zn + 2HCl \rightarrow H_2 + ZnCl_2$
   - [single replacement reaction]

   (b) $2KClO_3 \rightarrow 2KCl + 3O_2$
   - [decomposition reaction]

   (c) $2KI + Cl_2 \rightarrow 2KCl + I_2$
   - [single replacement reaction]

   (d) $AgNO_3 + KCl \rightarrow AgCl + KNO_3$
   - [double replacement reaction]
7. Compare and contrast the four types of reactions described in this lesson. Include an example of each type of reaction.
   - [A synthesis reaction is one in which two or more reactants combine to form a single product. It can be represented by $A + B \rightarrow C$. An example of a synthesis reaction is the combination of sodium and chlorine to produce sodium chloride. A decomposition reaction is one in which one reactant breaks down into two or more products. This is the reverse of a synthesis reaction. It can be represented by $AB \rightarrow A + B$. An example of a decomposition reaction is the breakdown of water to hydrogen and oxygen. A replacement reaction is one in which ions change places in one compound (single replacement) or two compounds (double replacement). A single replacement reaction can be represented by $A + BC \rightarrow B + AC$. A double replacement reaction can be represented by $AB + CD \rightarrow AD + CB$. An example of a (single) replacement reaction is potassium reacting with water to form potassium hydroxide and hydrogen. A

combustion reaction is one in which a substance, usually referred to as a fuel, reacts quickly with oxygen to form carbon dioxide and water. Energy is also released. A combustion reaction is commonly called burning. It can be represented by fuel + $O_2 \rightarrow CO_2 + H_2O$. An example is the burning of methane.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Combustion reactions release energy. Some other types of reactions absorb energy. They need a continuous supply of energy to occur.

- Can you think of any chemical changes that might absorb energy?

One possible answer is the chemical reaction that activates a chemical cold pack.

- What might be different about reactions that need energy to keep going?

In these reactions, it takes more energy to break bonds in reactants than is released when bonds form in products.

8.5 Lesson 8.4 Chemical Reactions and Energy

Key Concept

Endothermic reactions absorb energy, and exothermic reactions release energy. The total amount of energy remains constant because energy is conserved in chemical reactions. All chemical reactions need activation energy to get started. The rate of a chemical reaction is determined by factors such as temperature, concentration, and catalysts.

Standards

- SCI.CA.8.PS.5.C
- MCR.6-8.SCI.8.9; MCR.6-8.SCI.9.1, 2, 6; MCR.6-8.SCI.12.3
- NSES.5-8.B.3.1, 5
- AAAS.6-8.4.D.7; AAAS.6-8.4.E.1, 4; AAAS.6-8.5.E.2; AAAS.6-8.9.B.3; AAAS.6-8.12.D.1, 4

Lesson Objectives

- Describe endothermic reactions.
- Describe exothermic reactions.
- Relate the law of conservation of energy to chemical reactions.
- Define activation energy.
- Identify factors that affect the rates of chemical reactions.

Lesson Vocabulary

- **activation energy:** energy needed to start a chemical reaction
- **catalyst:** substance that increases the rate of a chemical reaction but is not changed or used up in the reaction
- **concentration:** number of particles of a substance in a given volume
- **endothermic reaction:** chemical reaction that needs a constant input of energy to continue because it takes more energy to break bonds in the reactants than is released when new bonds form in the products
- **exothermic reaction:** chemical reaction that releases energy because it takes less energy to break bonds in the reactants than is released when new bonds form in the products
- **law of conservation of energy:** law stating that matter cannot be created or destroyed in chemical reactions
- **reaction rate:** speed at which a chemical reaction occurs

Teaching Strategies

Introducing the Lesson

Generate student interest by showing them the 10-second activation energy analogy at the following URL. Tell them the video is an analogy for an aspect of chemical reactions they will learn about in this lesson. Ask them to guess what it represents. (Answer: Pushing the boulder uphill represents the energy needed to get a reaction started.)

- http://www.youtube.com/watch?v=1A2_0NNejnA

Discussion

Discuss the meaning of energy (ability to cause changes in matter) and how it relates to chemical reactions (in chemical reactions, matter changes into an entirely different kind of matter, so energy is always involved). Explain how chemical reactions can by classified on the basis of energy as endothermic or exothermic.

Using Visuals

Call students' attention to the activation energy graphs in the FlexBook® lesson. Have them relate the graphs to pushing a boulder to the top of a hill (the analogy presented above in Introducing the Lesson).

Question: How is activation energy like pushing a boulder to the top of a hill?
Answer: Activation energy must be added until a certain level is reached before the reaction can proceed, just as the boulder must be pushed up to the top of the hill before it can roll down the other side.

Activity

Students can compare endothermic and exothermic reactions by doing the hot pack/cold pack activity at this URL: http://www.education.com/reference/article/exothermic-endothermic-reactions/ .

Differentiated Instruction

Using the board or a projector, work with students to create a compare/contrast table for endothermic and exothermic reactions. Headings in the table might include "Type of Reaction," "Energy (Released or Absorbed)" and "Example."

Enrichment

Ask a small group of original thinkers to create and present a role-play of endothermic and exothermic reactions. They must include the role of energy when they act out each reaction. Engage the other students in the class by asking them to write a review of the performance.

Science Inquiry

Have groups of students do the inquiry activity at the following URL. They will carry out a chemical reaction and measure the temperature of reactants and products to determine whether the reaction is endothermic or exothermic.

- http://www.inquiryinaction.org/classroomactivities/activity.php?id=26

Life Science Connection

Discuss catabolic and anabolic reactions in living things as examples of exothermic and endothermic reactions. You might make the following points:

- Catabolic reactions are exothermic reactions. They break down more complex substances to simpler ones and release energy. This occurs during digestion. For example, large protein molecules in food are broken down to smaller amino acid molecules.
- Anabolic reactions are endothermic reactions. They build up more complex substances from simpler ones and absorb energy. For example, cells make large protein molecules by combining many small amino acid molecules.
- All the anabolic and catabolic reactions combined make up the metabolism of a living organism.

Real World Connection

Ask the class to brainstorm examples of endothermic and exothermic processes that occur around them in the real world. Examples might include plants making food (photosynthesis) for an endothermic process and logs burning (combustion) for an exothermic process.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What form of energy is needed for the endothermic reaction called photosynthesis?
   - [Energy in the form of light is needed for photosynthesis.]
2. What evidence shows that combustion reactions are exothermic?
   - [Evidence that combustion reactions are exothermic is the heat and light energy they produce.]
3. What happens to the energy that is absorbed in an endothermic reaction?
   - [The energy that is absorbed in an endothermic reaction is stored as chemical energy in the bonds of the products.]
4. In an exothermic reaction, which has more stored chemical energy: the reactants or the products?
   - [In an exothermic reaction, the reactants have more stored chemical energy than the products.]
5. Define activation energy.
   - [Activation energy is the energy needed to start a chemical reaction.]
6. List four factors that affect the rates of chemical reactions.
   - [Four factors that affect the rates of chemical reactions are temperature, concentration, and surface area of reactants; and presence of catalysts.]

7. Suppose you put a whole antacid tablet in one glass of water and a crushed antacid tablet in another glass containing the same amount of water at the same temperature. Both tablets would start reacting and producing bubbles of gas. Use lesson concepts to predict which tablet would stop producing bubbles first. Explain your prediction. Then, with the permission of an adult, do the activity. Do your results agree with your prediction?
    - [*Sample answer*: I predict that the crushed tablet would stop producing bubbles first. The crushed tablet has more surface area, so it should react more quickly. If students do the activity, they should get this result.]
8. Sketch a simple graph to show how energy changes in an exothermic reaction. Include activation energy in your graph.
    - [Students' graphs may vary but should reflect an understanding of how energy changes in an exothermic reaction. They should include an initial burst of energy labeled "activation energy." They should also show that there is a net release of energy, with products having less energy than reactants. The graphs should resemble the exothermic reaction graph in the FlexBook® lesson.]
9. Compare and contrast endothermic and exothermic chemical reactions.
    - [An endothermic reaction is one that absorbs energy. In an endothermic reaction, it takes more energy to break bonds in the reactants than is released when new bonds form in the products. As a result, the reaction needs a constant input of energy to keep going. The general equation for an endothermic reaction is Reactants + Energy → Products. An exothermic reaction is one that releases energy. In an exothermic reaction, it takes less energy to break bonds in the reactants than is released when new bonds form in the products. As a result, the reaction releases enough energy for the reaction to keep going without a constant input of energy. The general equation for an exothermic reaction is Reactants → Products + Energy.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 8.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You read in this chapter that most fuels contain carbon. In the next chapter, you will learn much more about carbon.

- What do you already know about carbon?

***Sample answer*: Carbon is a nonmetal element that occurs in hydrocarbons and many other compounds.**

- Based on carbon's position in the periodic table, predict how it reacts and the type of bonds it forms.

***Sample answer*: Based on carbon's position in the periodic table, you know it has four valence electrons, so you can pre**

Chapter 9 TE Chemistry of Carbon

Chapter Outline

9.1 Chapter 9: Chemistry of Carbon

Chapter Overview

Carbon is a nonmetal with four valence electrons. It forms four covalent bonds and often forms polymers. Hydrocarbons, which contain only carbon and hydrogen, are the simplest carbon compounds. They may be saturated or unsaturated hydrocarbons. They come from fossil fuels and are used as fuels and to make many products. Carbon compounds in living things include carbohydrates, proteins, lipids, and nucleic acids. These biochemical compounds are responsible for most functions in living things. Photosynthesis and cellular respiration are two of the most important biochemical processes.

Online Resources

See the following Web sites for appropriate laboratory activities:

Use this lab to introduce students to carbon bonding with a focus on hydrocarbons. Students will be able to explain and illustrate how hydrocarbons form.

- http://teachers.net/lessons/posts/3339.html

In this pencil-and-paper activity, students name and draw structural formulas for hydrocarbons. Analysis questions extend the content and require students to apply what they know about hydrocarbons. Teacher notes and student pages are included in the document.

- http://www.esrl.noaa.gov/gmd/education/lesson_plans/Naming%20and%20Creating%20Hydrocarbons.pdf

This lab uses food as a way for students to explore monomers, polymers, and macromolecules.

- http://www.yale.edu/ynhti/curriculum/units/2009/3/09.03.01.x.html

This URL provides links to several photosynthesis and cellular respiration labs.

- http://www.nclark.net/PhotoRespiration

These Web sites may also be helpful:

The "Chemistry of Petroleum" lessons, which can be accessed at the following URL, allow students to investigate hydrocarbons in depth. Each lesson includes scripted questions, activities, videos, worksheets, and other useful materials.

- http://sciencenetlinks.com/lessons/chemistry-of-petroleum-1/

This resource provides a summary of the reactivity of different classes of hydrocarbons. You can use it to extend the content of Lesson 8.2.

- http://www.elmhurst.edu/~chm/vchembook/500hydrocarbons.html

The following URL offers many quizzes, worksheets, and activities about biochemical molecules. Most are aimed at high school students but could be adapted for middle school students or used for enrichment.

- http://www.lessonplansinc.com/biology/grade_level/High/

You can find several minds-on activities dealing with biological molecules, photosynthesis, and cellular respiration at this URL: http://serendip.brynmawr.edu/exchange/bioactivities/proteins

The URL below provides many teacher-tested games, puzzles, videos, and other classroom resources dealing with photosynthesis.

- http://www.neok12.com/Photosynthesis.htm

Go to this URL for more activities relating to photosynthesis as well as some activities on cellular respiration: http://www.nclark.net/PhotoRespiration

Pacing the Lessons

TABLE 9.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
9.1 Properties of Carbon	1.0
9.2 Hydrocarbons	2.0
9.3 Carbon and Living Things	2.0
9.3 Biochemical Reactions	1.0

9.2 Lesson 9.1 Properties of Carbon

Key Concept

Carbon is a nonmetal with four valence electrons. Each carbon atom forms four covalent bonds with other carbon atoms or with atoms of other elements. The bonds may be single, double, or triple bonds. Because of carbon's ability to form so many covalent bonds, it is found in most compounds and often forms polymers. Crystalline forms of pure carbon include diamond, graphite, and fullerenes.

Standards

- SCI.CA.8.PS.3.c
- AAAS.6-8.4.D.3; AAAS.6-8.8.B.6; AAAS.6-8.11.B.1

Lesson Objectives

- Explain how carbon forms bonds.
- Define monomer and polymer.
- Describe forms of carbon.

Lesson Vocabulary

- **monomer:** small molecule that forms covalent bonds with other such molecules to produce a large molecule called a polymer
- **polymer:** large molecule that consists of many smaller molecules, called monomers, joined together by covalent bonds

Teaching Strategies

Introducing the Lesson

Point out that this lesson begins a whole chapter devoted to the chemistry of a single element: carbon. Challenge students to predict why carbon is such an important element. (Possible answers: Carbon is found in most known compounds. Carbon compounds are the basis of life on Earth. Carbon in the form of carbon dioxide is a major cause of global climate change.)

Activity

Do the slime activity at the following URL. It's sure to be a hit with students, and it will allow them to explore polymers. The Web site provides teacher notes, a PowerPoint presentation, slime recipes, a complete student packet, and other useful materials so students can make the most of the activity.

- http://sciencespot.net/Pages/classchem.html#Anchor-poly

Differentiated Instruction

Provide students with an assortment of plastic pop beads, and tell them that each bead represents a small monomer molecule. Then have them join together individual beads to create a "polymer molecule." This activity may help kinesthetic learners develop a better understanding of polymer structure.

Enrichment

Suggest that interested students research fullerenes, including how they were discovered and the origin of their name. Students might start with the URLs below. Ask them to report back to the class on what they learn.

- http://www.sciencedaily.com/articles/f/fullerene.htm
- http://www2.fkf.mpg.de/andersen/fullerene/intro.html
- http://www.wisegeek.com/what-are-fullerenes.htm

Science Inquiry

Have students do the inquiry activity, "Exploring the Physical and Chemical Properties of Polymers," at the URL below.

- http://agpa.uakron.edu/p16/lesson.php?id=exploring_polymers&pg=abstract

Real World Connections

Ask the class to brainstorm all they ways they use the synthetic carbon polymers called plastics in their daily lives. Examples might include food and drink containers, dishes, shopping and trash bags, and a diversity of other plastic objects such as buckles and pens. Alternatively, students can take a "plastics inventory" of the classroom and see how many plastic items they can identify.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Describe the type of bonds that carbon forms.
   - [Carbon forms covalent bonds. In a covalent bond, atoms share a pair of electrons.]
2. How many bonds does a single carbon atom form?
   - [A single carbon atom forms four bonds.]
3. What are polymers and monomers?
   - [Polymers are large molecules that consist of many smaller molecules joined together by covalent bonds. Monomers are the smaller molecules that make up polymers. Polymers may consist of just one type of monomer or of more than one type.]
4. Name three forms of pure carbon. How do they differ?
   - [Three forms of pure carbon are diamond, graphite, and fullerenes. They differ in the arrangement of their carbon atoms.]
5. A certain compound consists of two carbon atoms and two hydrogen atoms. Each carbon atom is bonded with one hydrogen atom and also with the other carbon atom. How many bonds do the two carbon atoms share? Draw the structural formula for this compound.
   - [The two carbon atoms share three bonds. The structural formula for this compound should look like ethyne in the figure in the FlexBook® lesson.]
6. Explain why carbon is a component of most compounds.
   - [Carbon is a component of most compounds because of its ability to form bonds with itself and many other elements. It can also form compounds that range in size from very small to extremely large molecules.]
7. Relate the properties of graphite and diamond to the arrangement of their atoms.
   - [In diamond, each carbon atom is bonded to four other carbon atoms in a strong, rigid, three-dimensional structure. This makes diamond very hard. In fact, it is the hardest natural substance. In graphite, carbon atoms are arranged in layers. Bonds are strong between carbon atoms within each layer but relatively weak between atoms in different layers. The weak bonds between layers allow the layers to slide over one another. This makes graphite relatively soft and slippery.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The carbon compounds represented in the figures in the FlexBook® lesson contain only carbon and hydrogen. You will read more about this type of carbon compound in the next lesson, "Hydrocarbons."

- What might be some general properties of compounds that consist only of carbon and hydrogen? (*Hint:* What is methane used for?)

These compounds can be used as fuels in combustion reactions to produce heat.

- Do you know other examples of this type of compound?

Other examples include ethane and propane.

9.3 Lesson 9.2 Hydrocarbons

Key Concept

Hydrocarbons contain only carbon and hydrogen and are the simplest type of carbon-based compounds. Saturated hydrocarbons (alkanes) contain only single bonds between carbon atoms. Unsaturated hydrocarbons contain at least one double bond (alkenes) or triple bond (alkynes) between carbon atoms. Hydrocarbons are used as fuels and to manufacture many products. The main source of hydrocarbons is fossil fuels.

Standards

- SCI.CA.8.PS.3.c
- MCR.6-8.SCI.9.11
- NSES.5-8.B.1.1
- AAAS.6-8.11.B.1; AAAS.6-8.12.D.4

Lesson Objectives

- Define hydrocarbon.
- Describe and give examples of saturated hydrocarbons.
- Describe and give examples of unsaturated hydrocarbons.
- Identify uses and sources of hydrocarbons.

Lesson Vocabulary

- **alkane:** saturated hydrocarbon that contains only single bonds between carbon atoms
- **alkene:** unsaturated hydrocarbon that contains at least one double bond between carbon atoms
- **alkyne:** unsaturated hydrocarbon that contains at least one triple bond between carbon atoms
- **aromatic hydrocarbon:** unsaturated cyclic hydrocarbon that has a strong aroma and alternating single and double bonds between carbon atoms
- **hydrocarbon:** carbon-based compound that contains only carbon and hydrogen
- **isomer:** compound that has the same chemical formula as another compound but has molecules with a different shape and may have somewhat different properties
- **saturated hydrocarbon:** hydrocarbon that contains only single bonds between carbon atoms
- **unsaturated hydrocarbon:** hydrocarbon that contains at least one double or triple bond between carbon atoms

Teaching Strategies

Introducing the Lesson

Impress students with the diversity of hydrocarbons by showing them several very different examples of items made from hydrocarbons. Examples might include plastic wrap, plastic objects such as toys and containers, polyester fabric, wax candles, floor wax, lubricating oil, petroleum jelly, charcoal, and athletic shoes (soles). After students have had a chance to examine the items, say that they all consist entirely or mainly of hydrocarbons and that hydrocarbons contain only two elements, carbon and hydrogen. As they read this lesson, tell students to think about how so many products can be made from just two elements.

Activity

Provide students with materials such as Styrofoam balls (in two different colors to represent carbon and hydrogen atoms) and craft sticks (to represent bonds), and have them make models of butane and its isomer iso-butane. After students make their models, discuss whether changing the shape of the molecule changes its chemical formula. (The numbers of carbon and hydrogen atoms do not change so the chemical formula remains the same.)

Using Visuals

Have students compare the structural formulas shown in the FlexBook® lesson for ethane, ethene, and ethyne. Tell them to count the total number of bonds each carbon atom forms (carbon always forms four bonds).

Question: How do double or triple bonds between carbon atoms affect the number of hydrogen atoms in a hydrocarbon molecule?

Answer: Each double bond reduces the number of hydrogen atoms by two, and each triple bond reduces the number of hydrogen atoms by four.

Question: What are the chemical formulas for ethane, ethene, and ethyne?

Answer: Ethane is C_2H_6, ethene is C_2H_4, and ethyne is C_2H_2.

Differentiated Instruction

For students who need extra help with reading, including any English language learners, assign the following cloze prompts for them to complete as they read the lesson. Each prompt requires at least a few words to complete correctly and fully. (Sample responses are enclosed in brackets.) The activity will help the students focus their reading on the most important points.

1. Hydrocarbons are [compounds that contain only carbon and hydrogen].
2. Hydrocarbons are classified in two basic classes, called [saturated hydrocarbons and unsaturated hydrocarbons].
3. Saturated hydrocarbons contain only [single bonds between carbon atoms].
4. Unsaturated hydrocarbons contain at least one [double or triple bond between carbon atoms].
5. Hydrocarbon molecules can have different shapes, including [straight-chain, branched-chain, and cyclic shapes].
6. Hydrocarbons may have isomers, which are [compounds with the same atoms but different shapes].
7. Hydrocarbons are used for [fuels and to make products such as plastics and polyester fabric].
8. Most hydrocarbons come from fossil fuels, which include [oil, natural gas, and coal].

Enrichment

Ask one or more students to create a PowerPoint presentation or poster that compares and contrasts the three isomers of pentane (n-pentane, iso-pentane, and neo-pentane). They should include structural formulas, properties, and uses of each isomer.

Science Inquiry

Challenge students to predict the relationship between the number of carbon atoms in a hydrocarbon and the number of possible isomers that can form. (As the number of carbon atoms increases, the number of possible isomers goes up dramatically.) Share the **Table** 9.2 with students after they have made their predictions.

TABLE 9.2: **Number of Carbon Atoms vs Number of Possible Isomers**

Number of Carbon Atoms in Alkane Compound	Number of Possible Isomers
1-3	0
4	2
5	3
6	5
8	18
10	75
12	355
20	366,319
40	6.25×10^{13}

Math Connection

This is an extension of the Using Visuals strategy (above). Help the class develop general formulas for hydrocarbons with any number of carbon atoms. They can start by looking at the table of alkanes in their FlexBook® lesson. Ask them to compare the numbers of carbon and hydrogen atoms in each chemical formula and observe how the numbers change as more carbons are added. They should see a pattern that leads to the general alkane formula of C_nH_{2n+2}. Following the same process, they should determine that the general formula for alkenes is C_nH_{2n} and the general formula for alkynes is C_nH_{2n-2}. Discuss how the number of bonds between carbon atoms explains the different formulas.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

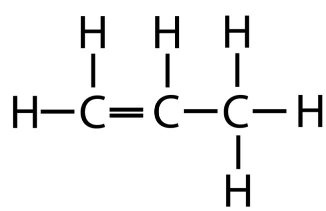
Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What are hydrocarbons?

- [Hydrocarbons are compounds that contain only carbon and hydrogen. They are the simplest type of carbon-based compounds.]

2. Describe how the boiling points of alkanes change as the number of carbon atoms per molecule increases.
   - [As the number of carbon atoms per molecule increases, the boiling points of alkanes increase.]
3. Identify and describe the three basic shapes of alkane molecules.
   - [The three basic shapes of alkane molecules are straight chains, branched chains, and rings. In straight-chain molecules, all the carbon atoms are lined up in a row. In branched-chain molecules, at least one of the carbon atoms branches off to the side. In ring-shaped, or cyclic, molecules, the chain of carbon atoms is joined at the two ends to form a ring.]
4. What are isomers?
   - [Isomers are compounds with the same number of each atom but with different shapes. This gives isomers somewhat different properties, such as different boiling and melting points.]
5. Define alkene and alkyne
   - [An alkene is an unsaturated hydrocarbon that contains at least one double bond. An alkyne is an unsaturated hydrocarbon that contains at least one triple bond.]
6. Describe aromatic hydrocarbons.
   - [Aromatic hydrocarbons are unsaturated cyclic hydrocarbons with a strong aroma. Their molecules have six carbon atoms in a ring, connected by alternating single and double bonds. They may consist of a single ring or multiple rings.]
7. Which type of hydrocarbon is represented by this structural formula? What is the compound's chemical formula? What shape does it have?



   - [The type of hydrocarbon represented by the structural formula is an alkene because it has a double bond between two of the carbon atoms. Its chemical formula is C_3H_6. It has a straight-chain shape.]
8. Compare and contrast saturated and unsaturated hydrocarbons. Give an example of each.
   - [Saturated and unsaturated hydrocarbons are two basic classes of hydrocarbons. They differ in the number of bonds between their carbon atoms, but both types may have straight-chain, branched-chain, or cyclic shapes. Saturated hydrocarbons, also called alkanes, have only single bonds between carbon atoms. An example is ethane. Unsaturated hydrocarbons have at least one double or triple bond between carbon atoms. Those with double bonds are called alkenes. An example is ethene. Those with triple bonds are called alkynes. An example is ethyne. Unsaturated hydrocarbons with double bonds and ring shapes are called aromatic hydrocarbons. An example is benzene.]
9. Explain the relationship between plastics and fossil fuels.
   - [Plastics are synthetic polymers. They are made of hydrocarbon monomers. The hydrocarbons used to make plastics come from petroleum, which is a fossil fuel.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that fossil fuels form from the remains of dead organisms. As you will read in the next lesson, "Carbon and Living Things," organisms are made of carbon-based compounds.

- Do you know the names of any of the carbon compounds in living things? (*Hint*: Many of them are found in food.)

Carbon compounds in living things include carbohydrates, proteins, lipids, and nucleic acids.

- How might these carbon compounds be different from hydrocarbons?

These carbon compounds contain other elements such as oxygen in addition to carbon and hydrogen.

9.4 Lesson 9.3 Carbon and Living Things

Key Concept

Biochemical compounds, or carbon compounds found in living things, include carbohydrates, proteins, lipids, and nucleic acids. Most of them are polymers that contain oxygen, nitrogen, or other elements in addition to carbon and hydrogen. Functions of biochemical compounds include providing or storing energy, regulating body functions, making up cells and body structures, and storing genetic material.

Standards

- SCI.CA.8.PS.3.c; SCI.CA.8.PS.6.a, b, c
- AAAS.6-8.4.D.11; AAAS.6-8.11.B.1

Lesson Objectives

- Give an overview of biochemical compounds.
- Identify the structure and functions of carbohydrates.
- Describe protein structure, and list functions of proteins.
- Outline the structure and functions of lipids.
- Identify the structure of nucleic acids and their functions.

Lesson Vocabulary

- **biochemical compound:** any carbon-based compound found in living things (carbohydrate, protein, lipid, or nucleic acid)
- **carbohydrate:** biochemical compound such as sugar, starch, or cellulose that contains oxygen in addition to carbon and hydrogen
- **lipid:** biochemical compound such as fat or oil that contains oxygen in addition to carbon and hydrogen and is made up of long carbon chains called fatty acids
- **nucleic acid:** biochemical compound (either DNA or RNA) that contains oxygen, nitrogen, and phosphorus in addition to carbon and hydrogen; consists of one or two long chains of smaller molecules called nucleotides
- **protein:** biochemical compound that contains oxygen, nitrogen, and sulfur in addition to carbon and hydrogen; consists of one or more chains of smaller molecules called amino acids

Teaching Strategies

Introducing the Lesson

A fascinating way to introduce biochemical compounds is by playing excerpts of "molecular music" from the following URL. The music is computer generated from the three-dimensional structure of proteins. You can read the FAQ page of the Web site to learn more about how the musical compositions were created. Tell students they will learn about the biochemical compounds that are the basis for the music when they read this lesson.

- http://www.molecularmusic.com/

Using Visuals

As you teach lesson content, use the FlexBook® table "Classes of Biochemical Compounds" as an outline of lesson content. Refer students to the table as you introduce each class of compounds.

Activity

Have students do the simulation activity "The Tree of Life's Molecules" at the following URL. In the activity, which comes from the National Science Foundation, students will zoom down from living things to the macromolecules and the smaller molecules from which they are made. In the process, they will learn about the molecular structure of macromolecules and where examples of the molecules are located in cells.

- http://mw.concord.org/modeler/showcase/simulation.html?s=http://mw.concord.org/modeler/showcase/biology/treeoflife.html

Differentiated Instruction

Assign each of four students or pairs of students a different class of biochemical compounds, and have them make a Frayer model for that class. Make sure all four classes of compounds are covered. Post the completed Frayer models in the classroom so students can compare the four classes. A Frayer model should have the components shown in the reduced model below.

TABLE 9.3: Frayer model

Definition	**Drawing**
Example	**Non-example**

Enrichment

Arrange for one or more students to interview a professional with expert knowledge of food and nutrition about the roles of the four classes of biochemical compounds in a healthy diet. Possible professionals might include a nutritionist, dietician, or family and consumer sciences teacher. Ask students to make a video or transcript of the interview to share with the class.

Science Inquiry

Introduce protein synthesis with the protein synthesis activity "Building Sentences" at the following URL. Students will simulate protein synthesis by joining words (amino acids) to make a sentence (polypeptide). All necessary materials are provided at the Web site.

- http://www.lessonplansinc.com/science.php/biology/lessonplans/C107/

Real-World Connection

Students are likely to be familiar with the biochemical compounds that are in foods, but they may have erroneous ideas about them from the media. For example, they might think that all "carbs" and "fats" are bad and should be excluded as much as possible from the diet. Ask students to volunteer what they know about the four classes of compounds in relation to diet. Discuss and correct any misconceptions.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Name the four classes of biochemical compounds.
   - [The four classes of biochemical compounds are carbohydrates, proteins, lipids, and nucleic acids.]
2. What are sugars and starches? How are they used?
   - [Sugars are simple carbohydrates such as glucose. They are broken down to provide cells with energy. Starches are complex carbohydrates. They are polymers of sugars. They are used to store energy in plants. Other organisms get starches from plants and break them down to get sugars.]
3. Describe the structure of proteins. List three functions of proteins.
   - [Proteins consist of one or more chains of smaller molecules called amino acids. They contain oxygen, nitrogen, and sulfur in addition to carbon and hydrogen. Three functions of proteins are (any three): making up tissues, speeding up biochemical reactions, regulating life processes, helping defend against infections, and transporting materials.]
4. Describe the structure of nucleic acids. What components are found in each nucleotide?

- [Nucleic acids contain oxygen, nitrogen, and phosphorus in addition to carbon and hydrogen. They consist of chains of small molecules called nucleotides. Each nucleotide contains a phosphate group, a sugar, and a nitrogen-containing base. DNA consists of two long chains of nucleotides held together in a double helix shape by hydrogen bonds between base pairs. RNA consists of a single chain of nucleotides.]

5. A mystery biochemical compound contains only carbon, hydrogen, and oxygen. It is made by both plants and animals? In which class of biochemical compounds should it be placed?
   - [The mystery biochemical should be placed in the lipids class of biochemical compounds.]
6. Use structural formulas to illustrate the difference between fatty acids in oils and fatty acids in fats.
   - [The structural formula for fatty acids in oils should contain at least one double bond between carbon atoms. The structural formula for fatty acids in fats should contain only single bonds between carbon atoms. The structural formulas should resemble those in the figure in the Flexbook lesson showing saturated and unsaturated fatty acids.]
7. Explain the relationship between DNA and RNA.
   - [DNA stores genetic information in the cells of all living things. It contains the genetic code, which instructs cells how to make proteins. RNA "reads" the genetic code in DNA and is involved in the synthesis of proteins based on the code.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Biochemical compounds are involved in almost all life processes. One of the most important life processes is photosynthesis.

- What is photosynthesis?

Photosynthesis is the process in which plants and certain other organisms make glucose using light energy.

- Why is photosynthesis so important to living things?

Photosynthesis is ultimately responsible for virtually all the food used by living things.

9.5 Lesson 9.4 Biochemical Reactions

Key Concept

Photosynthesis is the process in which plants and certain other organisms synthesize glucose from carbon dioxide and water using light energy. Cellular respiration is the process in which the cells of living things break down glucose with oxygen to produce carbon dioxide and water and release energy. Enzymes are needed to speed up most biochemical reactions.

Standards

- SCI.CA.8.PS.5.a, c
- AAAS.6-8.5.A.1; AAAS.6-8.5.E.1, 2, 3, 4, 6, 7, 8; AAAS.6-8.6.C.3; AAAS.6-8.12.D.4

Lesson Objectives

- Describe photosynthesis.
- Outline cellular respiration.
- Explain the role of enzymes in biochemical reactions.

Lesson Vocabulary

- **cellular respiration:** process in which the cells of living things break down glucose with oxygen to produce carbon dioxide, water, and energy
- **enzyme:** biochemical catalyst that speeds up chemical reactions in living things
- **photosynthesis:** process in which plants and certain other organisms use light energy to synthesize glucose and release oxygen from carbon dioxide and water

Teaching Strategies

Introducing the Lesson

Use one of the photosynthesis songs at the following URLs to engage student interest in photosynthesis and introduce this lesson on biochemical processes.

- http://www.youtube.com/watch?v=wj8TGhcCnxs
- http://watchknowlearn.org/Video.aspx?VideoID=28355&CategoryID=6172

Building Science Skills

Have students do the *Elodea* activity at the following URL. They will use color changes of chemical indicators to draw conclusions about what happens chemically during photosynthesis. This is also a good activity to reinforce students' understanding of independent and dependent variables.

- http://www.ehow.com/way_5267691_photosynthesis-activities-middle-school.html

Activity

At the following URL, download the activity "Toothpicks and Enzymatic Reactions." It is a simple group activity that demonstrates how reaction rates depend on the concentration of enzymes.

- http://newyorkscienceteacher.com/sci/files/download.php?id=1213&file=Toothpicks_and_Enzymatic_Reactions_-2009.doc

Discussion

Discuss an analogy to help students understand enzymes. Compare an enzyme to a matchmaker (or match-making Web site). While it's possible that two people might have met and started dating on their own, a matchmaker makes the process faster and more likely. Like an enzyme, a matchmaker is not changed by making a match and can go on to make additional matches.

Differentiated Instruction

Suggest that students make a KWL chart for this lesson. First they should divide a sheet of paper into three columns, labeled from left to right Know, Want to Know, and Learned. Before students start reading the lesson, they should fill in the Know and Want to Know columns for photosynthesis and cellular respiration. After they read the lesson, they should add what they learned to the Learned column. Be sure to discuss any of the students' Want-to-Know questions that remain unanswered.

Enrichment

Ask a small group of students to role-play the processes of photosynthesis and cellular respiration, including how the two processes are related. They should show the molecules and energy changes involved in the two processes.

Science Inquiry

This inquiry activity allows students to explore the importance of light in photosynthesis. The activity takes several days to complete, but students need to spend just a few minutes each day on the activity.

- http://www.reachoutmichigan.org/funexperiments/agesubject/lessons/newton/phytosy.html

Common Misconceptions

Students may confuse the term cellular respiration with physiological respiration, or breathing. Explain how the two processes differ and also how they are related. The video at the URL below is an excellent, grade-appropriate explanation that will help overcome the misconception as well as review the process of cellular respiration.

- http://www.youtube.com/watch?v=4YSgo5ennAI

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is photosynthesis? Write the overall chemical equation for this process.
    - [Photosynthesis is the process in which plants and certain other organisms use light energy to synthesize glucose from carbon dioxide and water. Oxygen is also produced in the process. The overall chemical equation for photosynthesis is: $6CO_2 + 6H_2O$ + Light Energy $\rightarrow C_6H_{12}O_6 + 6O_2$]
2. What types of organisms undergo photosynthesis?
    - [Types of organisms that undergo photosynthesis include cyanobacteria, algae, and plants.]
3. What is cellular respiration? Write the overall chemical equation for this process.
    - [Cellular respiration is the process in which the cells of living things break down glucose with oxygen to produce carbon dioxide, water, and energy. The overall chemical equation for cellular respiration is:
4. C
5. $_6$
6. H
7. $_{12}$
8. O
9. $_6$
10. + 6O
11. $_2$
12. $\rightarrow$ 6CO
13. $_2$
14. + 6H
15. $_2$
16. O + Heat and Chemical Energy]
17. Define enzyme, and give an example.
    - [An enzyme is a biochemical catalyst. Examples may vary. *Sample answer*: An example of an enzyme is pepsin, which is an enzyme in the stomach that catalyzes the breakdown of proteins in amino acids.]
18. Create a cycle diagram to show how photosynthesis and cellular respiration are related.
    - [Cycle diagrams may vary but should show that the products of photosynthesis (glucose and oxygen) are the reactants of cellular respiration and that the products of cellular respiration (carbon dioxide and water) are the reactants of photosynthesis. The diagrams should also include the addition of light energy in photosynthesis and the release of heat and chemical energy in cellular respiration. Diagrams might resemble the first diagram in the FlexBook® lesson.]
19. Classify photosynthesis and cellular respiration as endothermic or exothermic reactions.
    - [Photosynthesis is an endothermic process. An endothermic process absorbs energy, and photosynthesis absorbs light energy. Cellular respiration is an exothermic process. An exothermic process releases energy, and cellular respiration releases heat and chemical energy.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 9.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The enzyme pepsin works only in the presence of acid. A strong acid is secreted into the stomach. It provides the acid that pepsin needs. You will learn about acids in the next chapter. Vinegar and lemon juice are two common acids.

- What do you think are properties of acids?

Acids taste sour and can conduct electricity.

- What other foods might contain acids?

Other citrus fruits besides lemons also contain acids.

CHAPTER 10 TE Chemistry of Solutions

Chapter Outline

10.1 Chapter 10: Chemistry of Solutions

Chapter Overview

A solution forms when a solute dissolves in a solvent. Many solutes are soluble in water because water is polar. Solubility is the amount of solute that can dissolve in a given amount of solvent at a given temperature. Concentration is the amount of solute in a given amount of solution. An acid is an ionic compound that produces positive hydrogen ions when dissolved in water. A base is an ionic compound that produces negative hydroxide ions when dissolved in water. The strength of acids and bases is measured by pH. The reaction of an acid and a base produces a salt and water.

Online Resources

See the following Web sites for appropriate laboratory activities:

The following URL provides links to many lab activities relating to the chemistry of solutions.

- http://www.nclark.net/Solutions

At the URL below, you can find an inquiry lab in which students investigate solubility and identify an unknown crystal based on its solubility.

- http://www.inquiryinaction.org/classroomactivities/activity.php?id=9

In this lab, students can test different substances with red cabbage juice to determine whether they are acids or bases.

- http://www.inquiryinaction.org/classroomactivities/activity.php?id=27

This is a follow-up lab to the acid/base lab above. Students will use their knowledge of color changes with red cabbage indicator to neutralize an acidic solution with a base and then neutralize a basic solution with an acid.

- http://www.inquiryinaction.org/classroomactivities/activity.php?id=28

This URL has a sequence of several excellent lab activities relating to acids, bases, pH, and neutralization reactions.

- http://www.middleschoolchemistry.com/lessonplans/chapter6/lesson9

These Web sites may also be helpful:

Many activities, worksheets, quizzes, and other resources for teaching solutions are available at this URL: http://www.nclark.net/Solutions .

Numerous activities and other resources on solution chemistry, dissolving, and related concepts are provided at the following URL.

- http://www.inquiryinaction.org/classroomactivities/topic.php?topic=Solubility

This URL has links to several videos on acids, bases, and the pH scale:

- http://www.neok12.com/Acids-and-Bases.htm

This URL has links to several articles, activities, and other resources on acids, bases, and pH.

- http://sciencespot.net/Pages/kdzchem3.html

These two URLs provide a selection of simple activities (e.g., matching and word-search games) that will help students learn or review the main points about acids, bases, and pH.

- http://www.quia.com/rd/1975.html?AP_rand=839976060
- http://www.quia.com/jg/347025.html

Another great Web site for teaching acids and bases comes from the Miami Museum of Science. It provides middle school teachers with many interesting resources for this content area.

- http://www.miamisci.org/ph/index.html

Pacing the Lessons

TABLE 10.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
10.1 Introduction to Solutions	1.5
10.2 Solubility and Concentration	1.0
10.3 Acids and Bases	2.5

10.2 Lesson 10.1 Chemistry of Solutions

Key Concept

A solution forms when a solute dissolves in a solvent. The rate of dissolving is faster with stirring, a higher temperature, or greater surface area. Many solutes are soluble in water because water is polar. Solutes generally lower the freezing point and raise the boiling point of solvents.

Standards

- NSES.5-8.D.1.7, 8
- AAAS.6-8.4.D.7; AAAS.6-8.12.D.8

Lesson Objectives

- Explain how solutions form.
- Identify properties of solutions.

Lesson Vocabulary

- **insoluble:** unable to dissolve in a given solvent
- **soluble:** able to dissolve in a given solvent
- **solute:** substance that dissolves in a solvent to form a solution
- **solvent:** substance that dissolves a solute to form a solution

Teaching Strategies

Introducing the Lesson

Help students recall what they already know about solutions from the FlexBook® chapter "Introduction to Matter." Ask the class questions such as these:

Question: What is a mixture?
Answer: A mixture is a combination of two or more substances in any proportions.
Question: A solution is a type of mixture. How does it differ from other types of mixtures?
Answer: Unlike other types of mixtures, a solution has particles that are too small to reflect light and too small to settle or be filtered out of the mixture.

Question: What are some examples of solutions?
Answer: Examples include salt water, sweet tea, and vinegar.

Tell students that they will learn much more about solutions when they read this chapter.

Activity

Do a kinesthetic activity in which students role-play how a solution forms. Have a small group of students play the role of solute particles and the rest of the students play the role of solvent particles. Give students balloons in two different colors or other visible markers to distinguish between those who represent the two different types of particles. At the start, the solute students should be clumped together and separate from the solvent students. Then have the two groups start moving and mixing together to form a solution. After the two groups of students are thoroughly "mixed," challenge students to relate dissolving to the kinetic theory of matter.

Differentiated Instruction

Partner English language learners and less proficient readers with other students, and ask partners to make a cluster diagram for solutions. In the center circle, they should write the term *Solutions*. Then they should add large surrounding circles for the main topics in the lesson (solutes, solvents, dissolving, properties of solutions). Finally, they should add definitions and important details to the main-topic circles.

Enrichment

Ask one or more students to create a flipbook to illustrate the process of dissolving. The flipbook should show particles of solvent gradually pulling apart particles of solute until solute particles are spread evenly throughout the resulting solution. Pass the completed flipbook around the class so other students can observe the process.

Science Inquiry

Before you discuss the process of dissolving, give students an opportunity to discover what happens when a solute dissolves in a solvent. Have pairs of students dissolve colored sugar crystals in warm water and observe the separation of the sugar particles under a microscope. Ask students to explain what they think is happening to the sugar at the particle level and to develop an operational definition of the term *dissolving* based on their observations.

Common Misconceptions

Because particles of solute seem to disappear in a solution, students may erroneously think that a solute does not add any mass to a solution, especially if the volume does not change or changes in a negative direction as it does, for example, in an ethanol-water solution. Using a balance, table salt, and water, demonstrate that the mass of the solution equals the sum of the masses of the solute and solvent.

Real-World Connection

As a homework assignment, have students make a list of several solutions they find at home and try to identify the solute and solvent of each solution. The next day, ask students to share and discuss their examples. Help them identify any of the examples that are not solutions and explain why. If they incorrectly identify the solute and solvent of any of the solutions, review the criteria for determining which substance in a solution is the solute and which is the solvent.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a solute? What is a solvent?
   - [A solute is the substance that dissolves in a solution. A solvent is the substance that dissolves the solute.]
2. Describe how an ionic compound such as salt dissolves in water.
   - [When an ionic compound such as salt dissolves in water, the negative oxygen ends of water molecules attract the positive ions of the ionic compound. The positive hydrogen ends of water molecules attract the negative ions of the ionic compound. These forces of attraction pull apart the ions. The ions spread out and are surrounded by water molecules.]
3. List three factors that affect the rate at which a solute dissolves.
   - [Three factors that affect the rate at which a solute dissolves include stirring, temperature, and surface area.]
4. How do solutes affect the properties of solvents?
   - [Solutes change physical properties of solvents. For example, they generally lower the freezing points and raise the boiling points of solvents.]
5. Create a lesson that explains to younger students how solutions form. With your teacher's approval, request permission to present your lesson to students in a lower grade.
   - [Lessons will vary but should demonstrate an understanding of how solutions form. The explanation should be couched in terms that are understandable to students in a lower grade. For example, they might include a demonstration of a solute such as salt dissolving in water and a diagram of particles of solute and solvent in the resulting solution.]
6. Do you think paint thinner is soluble in water? Why or why not?
   - [Paint thinner is not soluble in water because paint thinner is nonpolar, whereas water is a polar solvent.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Assume that you will stir salt into a cup of hot water to make a saltwater solution.

- How much salt do you think you could dissolve in the cup of hot water?

The correct answer depends on the temperature of the water. Students can read about the solubility of table salt and s

- Do you think you could dissolve more of some solutes than others?

Yes; solutes may differ greatly in their solubility. For example, you can dissolve much more sugar than table salt in the

10.3 Lesson 10.2 Solubility and Concentration

Key Concept

Solubility is the amount of solute that can dissolve in a given amount of solvent at a given temperature. The concentration of a solution is the amount of solute in a given amount of solution.

Standards

- SCI.CA.8.IE.9.f
- AAAS.6-8.9.B.3; AAAS.6-8.11.C.3; AAAS.6-8.12.B.1; AAAS.6-8.12.D.2, 4

Lesson Objectives

- Define solubility, and list factors that affect it.
- Define concentration, and explain how to calculate it.

Lesson Vocabulary

- **saturated solution:** solution that contains as much solute as can dissolve at a given temperature
- **solubility:** amount of solute that can dissolve in a given amount of solvent at a given temperature
- **unsaturated solution:** solution that contains less solute than can dissolve at a given temperature

Teaching Strategies

Introducing the Lesson

Call on two student volunteers to assist you in demonstrating the procedure described in the first paragraph of the Flexbook lesson. Give both students 500 mL of room-temperature water, and provide one student with 500 g of baking soda and the other student with 500 g of sugar. Then have students "race" to see which one can make his or her solute dissolve in the water more quickly by stirring the solute into the water. (All of the sugar will dissolve quickly but some of the baking soda will remain undissolved regardless of how long a time or how vigorously it is stirred.) Tell students they will learn why they got these results when the read this lesson.

Building Science Skills

Divide the class into groups and provide each group with the following materials: 100 mL of room-temperature water in a beaker, a $\frac{1}{4}$-teaspoon measure, a stirrer, and small amounts of sodium chloride, sucrose, calcium hydroxide, and copper(II) sulphate. Have groups design and carry out an investigation to test the solubility of the different substances in the water. (They should add each solute to the water $\frac{1}{4}$ teaspoonful at a time, stirring well after each addition, until the saturation point is reached and no more solute will dissolve after several minutes of stirring.) Make sure students record the number of $\frac{1}{4}$ teaspoonsful required for each solution to reach its saturation point. Have them create a bar graph comparing the results for the different solutes.

Activity

Prepare a series of saltwater solutions, starting with a very dilute solution and gradually increasing the concentration. Place one drop of each solution on each student's tongue until they can taste the solute in the water. Record how many students can taste the solution at each concentration, and then have students make a bar graph showing the frequency distribution by concentration.

Differentiated Instruction

Give visual and English language learners a visual demonstration of concentration. Make solutions of different concentrations with drops of food coloring and water. Students will be able to see the differences in concentration by the color of the solutions.

Enrichment

Ask gifted students to investigate another way that concentration of solutions can be measured, by molarity. They will need to learn the meaning of the mole as well as the definition of molarity. You might have them teach the topic to the rest of the class.

Science Inquiry

Challenge small groups of students to develop a procedure to determine how temperature affects solubility. Their procedures should investigate what mass of solute will dissolve in a solvent at different temperatures. Tell groups to identify their independent and dependent variables as well as factors they need to control. They should also describe how the variables will be measured and the expected outcome of the procedure.

Common Misconceptions

Students may confuse the concepts of saturation and concentration. Discuss how a solution can be saturated but not concentrated (or unsaturated but not dilute) and vice-versa. Provide them with specific examples (e.g., a saturated baking soda-water solution is much less concentrated than a saturated sugar-water solution).

Real-World Connection

Lead the class in brainstorming concentrated and dilute solutions in their day-to-day lives. Examples might include juice made from frozen juice concentrate and soda diluted by melting ice cubes.

Answers to You Try It!

Problem: A solution contains 249 grams of Epsom salt in 1 L of water at 20 °C. Is the solution saturated or unsaturated?

Solution: The solubility of Epsom salt is 250 grams per 1 L of 20 °C, so the solution is unsaturated.

Problem: Give an example of an unsaturated solution of table salt in 1 L of 20 °C water.

Solution: The solubility of table salt is 359 grams per 1 L of 20 °C water, so an unsaturated solution of table salt in this volume and temperature of water would be any amount less than 359 grams.

Problem: A 1 L container of juice drink, called brand A, contains 250 mL of juice. The rest of the drink is water. How concentrated is brand A juice drink?

Solution: The concentration of brand A is 250 mL/1000 L $\times$ 100% = 25%.

Problem: A 600 mL container of another juice drink, called brand B, contains 200 mL of juice. Which brand of juice drink is more concentrated, brand A or brand B?

Solution: The concentration of brand B is 200 mL/600 mL $\times$ 100% = 33%, so brand B is more concentrated.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define solubility.
    - [Solubility is the amount of solute that can dissolve in a given amount of solvent at a given temperature.]
2. Describe how temperature affects the solubility of gases, liquids, and solids.
    - [The solubility of liquids and solids increases with increasing temperature. The solubility of gases decreases with increasing temperature.]
3. State the effect of pressure on the solubility of gases.
    - [Gases are more soluble at higher pressures.]
4. What is the concentration of a solution?
    - [The concentration of a solution is the amount of solute in a given amount of solution.]
5. Regina made a solution with 50 mL of lemon juice and 200 mL of water. How much solution did she make? Which is the solute and which is the solvent? What is the concentration of the solution?
    - [Regina made 250 mL of solution. The solute is lemon juice and the solvent is water. The concentration of the solution is 50 mL/250 mL $\times$ 100% = 20%.]
6. A glass of warm soda goes flat more quickly than a glass of cold soda. Explain why.

- [A glass of warm soda goes flat more quickly than a glass of cold soda because the carbon dioxide gas dissolved in the soda is less soluble at warmer temperatures. Therefore, more gas comes out of solution when soda is warm than when it is cold.]

7. Use data in the bar graph in the lesson to describe a saturated solution of baking soda and water.
   - [The maximum amount of baking soda that can dissolve in 1 L of 20 °C water is 96 grams. A saturated solution contains as much solute as can dissolve at a given temperature. Therefore, a saturated solution of baking soda in water would contain 96 grams of baking soda in 1 L of 20 °C water.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Some solutions have special properties because they are acids. Orange juice is an example. It contains an acid called citric acid. It makes orange juice taste sour. Some solutions are bases rather than acids.

- Do you know examples of bases?

Examples of bases include sodium hydroxide, which is found in many cleaning products, and calcium hydroxide, whic

- How might bases differ from acids?

One way bases differ from acids is their taste. Bases are bitter rather than sour.

10.4 Lesson 10.3 Acids and Bases

Key Concept

An acid is an ionic compound that produces positive hydrogen ions when dissolved in water. A base is an ionic compound that produces negative hydroxide ions when dissolved in water. The strength of acids and bases is measured by pH. The reaction of an acid and a base produces a salt and water.

Standards

- SCI.CA.8.PS.3.b; SCI.CA.8.PS.5.a, e
- MCR.6-8.SCI.8.8
- NSES.5-8.B.1.2

Lesson Objectives

- Describe acids and how to detect them.
- Describe bases and how to detect them.
- Explain what determines the strength of acids and bases.
- Outline neutralization reactions and the formation of salts.

Lesson Vocabulary

- **acid:** ionic compound that produces positive hydrogen ions (H^+) when dissolved in water
- **acidity:** concentration of hydrogen ions in a solution
- **base:** ionic compound that produces negative hydroxide ions (OH^-) when dissolved in water
- **neutralization reaction:** reaction of an acid and a base that produces water and a salt, both of which are neutral in acidity
- **pH:** measure of the acidity, or hydrogen ion (H^+) concentration, of a substance
- **salt:** ionic compound formed when an acid and a base react

Teaching Strategies

Introducing the Lesson

Pique student interest in acids and bases by writing—and then revealing—a mystery message using "invisible ink." With a cotton swab dipped in lemon juice, write a brief message on white paper. The message will not be visible until you spray it lightly with red cabbage juice. The cabbage juice is an acid/base indicator, and it will turn pink when it contacts the acidic lemon juice. (If you had written your message with a base, the cabbage juice would turn green instead). Tell students they will understand the secret of the "invisible ink" when they learn about acids and bases in this lesson.

Activity

Have students do the online activity "Alien Juice Bar" to virtually test different substances with red cabbage juice in order to determine whether they are acids, bases, or neutral substances.

- http://sciencespot.net/Pages/kdzchem3.html

Demonstration

Use the activity at the following URL to demonstrate neutralization reactions using Erlenmeyer-flask "stomachs," stomach acid (HCl), and a variety of over-the-counter antacid tablets.

- http://mypages.iit.edu/~smile/ch8708.html

Differentiated Instruction

This well-done visual presentation on acids, bases, and pH may help visual learners and less proficient readers better understand lesson content. It includes a quiz and test so students can self-check their comprehension.

- http://www.bbc.co.uk/schools/ks3bitesize/science/chemical_material_behaviour/acids_bases_metals/activity.shtml

Enrichment

Have a small group of students who need extra challenges do the acid rain research activity at the URL below. Students will use the Internet to research the causes and effects of acid rain and the pH levels of rainwater for their state. Then they will collect data from the community and investigate solutions for acid rain.

- http://www.microsoft.com/education/en-us/teachers/plans/Pages/acid_rain.aspx

Science Inquiry

Assign the online challenge game at the URL below. In the game, students will find clues to learn how to test liquids for acidity, and then they will test several common liquids to determine whether they are acidic, basic, or neutral. They will also use the liquids to try to launch a cork rocket. Finally, they will use their results to identify a pattern (acids mixed with a metal carbonate, i.e., baking soda, produce carbon dioxide gas).

- http://pbskids.org/zoom/games/kitchenchemistry/virtual-start.html

Common Misconceptions

Ask students whether the following statements are true or false. (Both are false, as explained in brackets following the statements.)

All substances containing H are acidic, and all substances containing OH are basic.

- [Although all acids contain H and all bases contain OH, not all substances containing H or OH are acids or bases. They are acids or bases only if they form H^+ or OH^- ions when dissolved in water. Glucose is a good example. It contains both H and OH but forms a neutral solution when dissolved in water because it does not form ions.]

Strength and concentration mean the same thing.

- [Concentration refers to the amount of solute (acid or base) per volume of solution. Strength refers to the percent of solute particles that form ions in solution. Hydrochloric acid is a strong acid because almost all of it ionizes in solution. Acetic acid is a weak acid because only about 1% of it ionizes in solution.]

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is an acid? Give one use of acids.
   - [An acid is an ionic compound that produces positive hydrogen ions when dissolved in water. Uses may vary. *Sample answer*: One use of acids is to make fertilizer.]
2. What is a base? Name a common product that contains a base.
   - [A base is an ionic compound that produces negative hydroxide ions when dissolved in water. Products may vary. *Sample answer*: A common product that contains a base is soap.]
3. Outline how litmus paper can be used to detect acids and bases.
   - [A few drops of a solution can be placed on strips of red litmus paper and blue litmus paper. If the solution is an acid, it will turn blue litmus paper red. If it is a base, it will turn red litmus paper blue.]
4. Define acidity. How is it measured?
   - [Acidity is the concentration of hydrogen ions in a solution. It is measured with pH. A solution with greater acidity has a lower pH.]
5. An unknown substance has a pH of 7.2. Is it an acid or a base? Explain your answer.
   - [The unknown substance is a base. Bases have a pH greater than 7.]
6. If hydrochloric acid (HCl) reacts with the base lithium hydroxide (LiOH), what are the products of the reaction? Write a chemical equation for the reaction.

- [The products of the reaction are water and the salt lithium chloride. The equation for this reaction is: $HCl + LiOH \rightarrow H_2O + LiCl$.]

7. Battery acid is a stronger acid than lemon juice. Explain why.
   - [Battery acid has a pH of 0. Lemon juice has a pH of 2. A lower pH value means a solution is more acidic. An acid with greater acidity is stronger. Therefore battery acid is stronger than lemon juice.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 10.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Neutralization reactions, like the other chemical reactions you have read about so far, involve electrons. Electrons are outside the nucleus of an atom. Certain other reactions involve the nucleus of an atom instead. These reactions are called nuclear reactions. You will read about them in the next chapter.

- How do you think nuclear reactions might differ from chemical reactions?

Nuclear reactions involve the protons and neutrons inside the nucleus rather than the electrons outside the nucleus.

- Elements involved in nuclear reactions are radioactive. How do you think radioactive elements differ from other elements?

Unlike other elements, radioactive elements have nuclei that are unstable and constantly decay, or break down. As the

CHAPTER 11 TE Nuclear Chemistry

Chapter Outline

11.1 Chapter 11: Nuclear Chemistry

Chapter Overview

Radioactivity is an atom's ability to emit radiation from the nucleus. Many elements have radioactive isotopes and some elements have only radioactive isotopes. Nuclei of radioactive isotopes are unstable and undergo radioactive decay, in which they emit particles and/or energy and change to different elements. The rate of decay varies by element and is measured by the half-life. Nuclear reactions include nuclear fission and nuclear fusion. Both release huge amounts of energy. Einstein's equation, E = mc2, explains why.

Online Resources

See the following Web sites for appropriate laboratory activities:

Have pairs of students do the radioactive decay and half-life lab at the following URL. It is based on a hands-on simulation of radioactive decay using pennies in a shoebox. From the class data, students will be able to make several important inferences about the rate of decay of radioactive elements.

- http://www.middleschoolscience.com/halflife.pdf

The nuclear fission simulation lab at the URL below is an award-winning inquiry lab. It is based on the nuclear fission simulation at the same URL.

- http://phet.colorado.edu/en/contributions/view/3273

This lab activity explains nuclear fusion and how radiation is generated by stars, using marshmallows as a model. Students will explore cosmic radiation and where it comes from, and how the elements in the universe are generated. The PDF contains step-by-step instructions, photos, presentation tips, links to background information, and a printable periodic table of the elements.

- http://nightsky.jpl.nasa.gov/docs/SNNuclearFusion.pdf

These Web sites may also be helpful:

This document from NASA provides a detailed introduction to radiation and several related activities for middle school students. The focus is on the impact of radiation on living things.

- http://www.nasa.gov/pdf/284277main_Radiation_MS.pdf

At the following URL, you can find background readings and several activities on nuclear reactions and nuclear energy that were developed specifically for middle school students.

- http://www.uraweb.org/reports/skoog.pdf

The U.S. Department of Energy's Booklet "The Harnessed Atom" is a comprehensive middle school teacher's kit on nuclear energy. It includes many readings and review exercises that are germane to this chapter in the FlexBook® resource. The PDF document can be found at this URL: http://www.osti.gov/speeches/doene0072.pdf .

Pacing the Lessons

TABLE 11.1: Pacing the Lessons

Lesson	**Class Period(s) (60 min)**
11.1 Radioactivity	1.5
11.2 Radioactive Decay	2.0
11.3 Nuclear Energy	2.0

11.2 Lesson 11.1 Radioactivity

Key Concept

Radioactivity is the ability of an atom to emit radiation from the nucleus. Many elements have one or more radioactive isotopes, and elements with more than 83 protons have only radioactive isotopes. Harmless background radiation comes from many sources such as cosmic rays. Radon and some other natural sources of radiation are harmful. Radiation has several uses, including uses in medicine.

Standards

- SCI.CA.8.PS.7.b
- NSES.5-8.F.1.7
- AAAS.6-8.1.A.2; AAAS.6-8.6.E.6

Lesson Objectives

- Explain radioactivity and how it was discovered.
- Describe sources, dangers, and uses of radiation.

Lesson Vocabulary

- **radiation:** particles and/or energy emitted by the nucleus of a radioisotope or an accelerating particle
- **radioactivity:** ability of an atom to emit charged particles and energy from the nucleus
- **radioisotope:** radioactive isotope, or isotope that emits radiation from its nucleus

Teaching Strategies

Introducing the Lesson

Before students delve into nuclear reactions in this chapter, help refresh their knowledge of subatomic particles and isotopes. Play the well-done music video "Parts of an Atom Song" at the URL below. It was created by a sixth-grade science teacher for his students, using catchy music by the popular band Maroon 5.

- http://www.youtube.com/watch?v=O5iaw5WNuB0

Using Visuals

Have students use the periodic table in the FlexBook® lesson to identify all of the radioactive elements (atomic numbers 84–118) as well as the naturally occurring radioactive elements (atomic numbers 84–92). Point out that many elements with lower atomic numbers also have radioactive isotopes. Ask each student to select a number from 1 to 83 and find the element with that atomic number in the periodic table. Then have them suggest a possible radioactive isotope for that element. They can see if they are correct with an interactive elements site such as this one: http://www.webelements.com/ .

Differentiated Instruction

After students read the opening paragraph of the FlexBook® chapter, ask them to make a KWL chart to guide their reading of the first lesson. A sample chart has been started below (see **Table** 11.2). They should fill in the Know and Want to Know columns before they read the lesson and the Learned column as they read or complete the lesson.

TABLE 11.2: **KWL Chart**

Know	Want to Know	Learned
Example: Elements cannot change to other elements in chemical reactions.	*Example*: How can some elements change to other elements?	*Example*: Some elements can change to other elements when their nuclei give off particles and energy.

Enrichment

Suggest to students that they learn more about the research on radioactivity of Antoine Henri Becquerel and the Curies. They can start with the URLs below. Ask them to create a PowerPoint presentation to share what they learn with the rest of the class.

- http://www.nobelprize.org/nobel_prizes/physics/laureates/1903/becquerel-bio.html
- http://www.aboutnuclear.org/view.cgi?fC=History,Hall_of_Fame,Henri_Becquerel
- http://www.physics.isu.edu/radinf/cuire.htm
- http://www.nobelprize.org/nobel_prizes/physics/articles/curie/
- http://www.pbs.org/wnet/hawking/cosmostar/html/cstars_curies.html

Science Inquiry

Have students do the "Personal Radiation" activity (pages 36–39) at the following URL. In the activity, students can calculate the amount of natural radiation to which they are exposed and then formulate a hypothesis as to whether they need to modify their environment or behavior.

- http://www.uraweb.org/reports/skoog.pdf

Common Misconceptions

Misconceptions about radioactivity and radiation are common. The following URL identifies several of them and explains why they are incorrect. For each misconception, the Web site also offers detailed tutorials, simulations, or other interactive media that you and your students can access.

- http://www.furryelephant.com/content/radioactivity/teaching-learning/radioactivity-misconceptions/

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define radioactivity.
   - [Radioactivity is the ability of an atom to emit charged particles and energy from the nucleus.]
2. What is radiation?
   - [Radiation is a general term for the charged particles and energy emitted by radioactive nuclei.]
3. Describe how radioactivity was discovered.
   - [Radioactivity was discovered in 1896 by a French physicist named Antoine Henri Becquerel. He was experimenting with uranium and wanted to see if uranium gives off rays of energy after being exposed to sunlight. He placed a bit of uranium on a photographic plate and exposed it to sunlight. The uranium left an image on the plate, showing that it had given off rays. Becquerel wanted to confirm his results and placed more uranium on another plate. However, the day was cloudy, so he put the plate in a drawer. The next day, he found that the uranium had left an image on the plate. Becquerel had determined that uranium gives off rays even without getting energy from light. He had discovered radioactivity.]
4. What is background radiation? Where does it come from?
   - [Background radiation is a low level of radiation that occurs naturally in the environment. It comes from various sources, including small amounts of radioactive elements in rocks and cosmic rays that arrive on Earth from outer space.]
5. Why is radiation harmful to both living and nonliving things?
   - [Radiation is harmful to both living and nonliving things because it knocks electrons out of atoms and changes them to ions. It also breaks bonds in DNA and other biochemical compounds.]
6. Identify three uses of radiation.
   - [Three uses of radiation are to determine the ages of ancient rocks and fossils; to provide energy for the generation of electricity; and to diagnose and treat diseases such as cancer.]
7. Assume that an isotope has 83 protons and 83 neutrons. Is it radioactive? Why or why not?

- [If an isotope has 83 protons and 83 neutrons, it is likely to be radioactive. Its nucleus is unstable because it contains too few neutrons for the number of protons. For a large nucleus with many protons to be stable, the ratio of neutrons to protons should be closer to 2:1, not 1:1 as in this isotope.]

8. Explain why elements with more than 83 protons have only radioactive isotopes.
   - [Elements with more than 83 protons have only radioactive isotopes because the force of repulsion among all those protons overcomes the strong force holding them together. This makes their nuclei unstable and radioactive.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that unstable nuclei emit particles and energy.

- What type of particles do you think unstable nuclei emit?

Particles include alpha particles, which consist of two protons and two neutrons, and beta particles, which are electron

- What form of energy do you think these nuclei give off?

They give off energy in the form of gamma rays.

11.3 Lesson 11.2 Radioactive Decay

Key Concept

Radioactive decay is the process in which unstable nuclei emit particles and energy and change to different elements. Types of decay include alpha, beta, and gamma decay. They differ in what is emitted, how far it can travel, and what it can penetrate. The rate of radioactive decay, measured by the half-life, varies from one radioisotope to another.

Standards

- AAAS.6-8.4.D.2; AAAS.6-8.4.F.9

Lesson Objectives

- Identify three types of radioactive decay.
- Define the half-life of a radioisotope.
- Explain radioactive dating.

Lesson Vocabulary

- **half-life:** length of time it takes for half of a given amount of a radioisotope to decay
- **radioactive dating:** method of determining the age of fossils or rocks that is based on the rate of decay of radioisotopes
- **radioactive decay:** process in which the unstable nucleus of a radioisotope becomes stable by emitting charged particles and energy and changing to another element

Teaching Strategies

Introducing the Lesson

Introduce radioactive decay by probing students' understandings of the term *decay*. Play a word association game, using *decay* as the prompt. Call on each student in turn to say the first word that comes to mind when they hear the word *decay*. (Possible responses might include rot, break down, spoil, fall apart.) When no new responses are forthcoming, explain to the class that they will learn how unstable nuclei decay when they read this lesson. Challenge them to predict what decay means in this context.

Activity

Use the activity at the URL below to introduce the three types of radioactive decay. With the activity, students can explore how decay leads to the transmutation of elements. It requires them to use mathematical reasoning and graphing skills and will give them an understanding of radioactive decay at the conceptual level. The URL provides all necessary worksheets and other materials for students as well as teacher notes and sample answers.

- http://www.nuclearscienceweek.org/images/uploads/Alphas-Betas-Gammas-Oh-My.pdf

Differentiated Instruction

Work with students to make a compare/contrast table for alpha, beta, and gamma decay. A sample is shown in the **Table** 11.3.

TABLE 11.3: Compare/Contrast Table for Decay

Type of Decay	What Is Emitted?	Is a New Element Produced?
Alpha	alpha particle (2 protons + 2 neutrons) & energy	yes
Beta	beta particle (1 electron) & energy	yes
Gamma	energy (only)	no

Enrichment

Ask one or more students to make a Jeopardy quiz game on lesson content. First, they should prepare a list of at least 20 answers that require contestants to generate the correct questions. Here are two possible examples:

Answer: Tiny particle emitted by uranium-238 when it changes to thorium-234
Question: What is an alpha particle?
Answer: Rays of energy that can be stopped only be several meters of concrete
Question: What are gamma rays?

After the students have created the list of answers (including the number of points for each one based on difficulty), have them lead the class in playing the game. Contestants can be individual students, partners, or small groups. If you wish, you can have the students use the Flash Jeopardy game generator at this URL below to create an online version of the game: http://www.superteachertools.com/jeopardy/ .

Science Inquiry

Assign the half-life and radioactive dating game lab at the first URL below. The lab worksheet guides students in using the simulation at the second URL below. In the lab, students investigate the half-lives of carbon-14 and uranium-238 and use radioactive dating to estimate the ages of virtual fossils and rocks. In the analysis section, students apply the concepts of half-life and radioactive dating to solve additional problems.

- http://phet.colorado.edu/en/contributions/view/3534
- http://phet.colorado.edu/en/simulation/radioactive-dating-game

Common Misconceptions

The URL below provides an alternative radioactive dating activity to the one described just above. In this "Date a Rock!" activity, students use simulated rock samples, each one containing a different proportion of a parent radioisotope and its daughter product. By counting atoms and using knowledge of the half-life of the parent radioisotope, students estimate the ages of the rock samples. The Web site includes a materials list, overhead transparencies, teaching strategy, pre- and post-lab assessments, extensions, and other resources.

- http://www.indiana.edu/~ensiweb/lessons/date.les.html

Life Science Connection

Discuss the importance of radioactive dating to our understanding of how living things have evolved. The URL below provides additional information that you may want to share with students.

- http://www.c14dating.com/int.html

Answers to You Try It!

Problem: Fill in the missing subscript and superscript to balance this nuclear equation: $^{222}_{?}\text{Ra} \rightarrow ^{?}_{86}\text{Rn} + ^{4}_{2}\text{He} + \text{Energy}$

Solution: The missing subscript of Ra is 88, and the missing superscript of Rn is 218.

Problem: Fill in the missing subscript and superscript in this nuclear equation: $^{14}_{?}\text{C} \rightarrow ^{?}_{7}\text{N} + ^{0}_{-1}e + \text{Energy}$

Solution: The missing subscript of C is 6, and the missing superscript of N is 14.

Problem: What fraction of a given amount of hydrogen-3 would be left after 36.9 years of decay?

Solution: The half-life of hydrogen-3 is 12.3 years, so 36.9 years is 3 half-lives. Therefore, after 36.9 years, $\frac{1}{2}$ x $\frac{1}{2}$ x $\frac{1}{2}$ = [U+215B] of the given amount of hydrogen-3 would be left.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is radioactive decay?
   - [Radioactive decay is the process in which unstable nuclei become stable by emitting charged particles and energy and changing from one element to another.]
2. Define half-life.

- [Half-life is the unit used to measure the rate of decay of a radioactive isotope. A radioisotope's half-life is the length of time it takes for half of a given amount of the isotope to decay.]

3. Which type of radioactive decay is represented by each of the following nuclear equations?
   (a) $^{60}_{27}\text{Co} \rightarrow ^{60}_{28}\text{Ni} + ^{0}_{-1}e + \text{Energy}$
      - [beta decay]
   (b) $^{263}_{106}\text{Sg} \rightarrow ^{259}_{104}\text{Rf} + ^{4}_{2}\text{He} + \text{Energy}$
      - [alpha decay]
4. Complete the following nuclear equation. First add the missing subscript. Then use the periodic table to identify the unknown element (X). $^{211}_{85}\text{At} \rightarrow ^{207}_{?}X + ^{4}_{2}\text{He} + \text{Energy}$
   - [The missing subscript is 83. The unknown element is bismuth (Bi).]
5. Create a model to demonstrate the concept of the half-life of a radioisotope.
   - [Models may vary but should show that students understand the concept of half-life. The model should demonstrate how a given amount of a radioisotope decreases by half during each half-life.]
6. Assume that a fossil contains one-eighth of the carbon-14 that was present in the organism when it was alive. How long has it been since the organism died?
   - [A fossil that contains one eighth of the original amount of carbon-14 has gone through three half-lives of radioactive decay ($\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2}$ = [U+215B]). One half-life of carbon-14 is 5,730 years, so three half-lives are 3 × 5,730 years = 17,190 years. Therefore, it has been 17,190 years since the organism died.]
7. Compare and contrast alpha, beta, and gamma decay.
   - [Alpha, beta, and gamma decay are three types of radioactive decay. In alpha decay, an unstable nucleus emits two protons and two neutrons plus energy. In beta decay, an unstable nucleus emits an electron plus energy. The electron comes from a neutron, which breaks down to a proton and an electron (the proton stays in the nucleus). In gamma decay, an unstable nucleus emits gamma rays, which are waves of energy. Both alpha and beta decay change the number of protons in the nucleus, so one element changes into another. Gamma decay accounts for some of the energy given off during alpha and beta decay, although, by itself, it does not result in one element changing into another. Alpha decay can travel a few centimeters through air and cannot penetrate paper or cloth. It burns skin but does not penetrate or damage deeper tissues. Beta decay can travel a few meters through air. It can penetrate paper and cloth but not a sheet of aluminum. It can also penetrate skin and damage underlying tissues. Gamma rays can travel thousands of meters through air. They can penetrate aluminum as well as paper and cloth but not several centimeters of lead or several meters of concrete. Gamma rays can penetrate and damage organs deep inside the body.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Radioactive decay releases energy. Other types of nuclear reactions also release energy.

- What other types of reactions might the nucleus undergo?

Other types include nuclear fission and nuclear fusion.

- What might be the pros and cons of using nuclear reactions for energy?

Pros include being nonpolluting. Cons include the risk of nuclear accidents.

11.4 Lesson 11.3 Nuclear Energy

Key Concept

Nuclear fission is the splitting of the nucleus of an atom into two smaller nuclei. This releases a great deal of energy, which can be used to generate electricity. Nuclear fusion is the fusing of two or more smaller nuclei to form a single, larger nucleus. This releases even more energy than fission, but the energy of fusion has not yet been harnessed for generating electricity. Einstein's equation, $E = mc^2$, explains why a tiny amount of mass changes to such large amounts of energy during nuclear reactions.

Standards

- MCR.6-8.SCI.9.6, 11
- NSES.5-8.B.3.5; NSES.5-8.F.3.2
- AAAS.6-8.1.A.3; AAAS.6-8.3.C.1, 3, 5, 7; AAAS.6-8.4.B.9, 12; AAAS.6-8.8.C.2, 4, 10, 11; AAAS.6-8.11.C.3; AAAS.6-8.12.D.6, 11

Lesson Objectives

- Describe nuclear fission and how it is used for energy.
- Describe nuclear fusion and challenges to its use for energy.
- Relate nuclear energy to Einstein's equation, $E = mc^2$.

Lesson Vocabulary

- **nuclear energy:** energy released in a nuclear reaction (nuclear fission or nuclear fusion)
- **nuclear fission:** splitting of the nucleus of an atom into two smaller nuclei
- **nuclear fusion:** fusing of two or more small nuclei to form a single, larger nucleus

Teaching Strategies

Introducing the Lesson

Introduce nuclear reactions with the student-created video at the URL below. It demonstrates a nuclear chain reaction with mousetraps and ping-pong balls and is sure to generate student interest in the topic. Tell students they will learn the science behind the demonstration when they read this lesson.

- http://www.youtube.com/watch?v=0v8i4v1mieU

Discussion

Discuss the pros and cons of using nuclear energy to produce electricity. Compare it to the use of fossil fuels as well as to alternative energy resources such as solar and wind energy. After the discussion, organize a debate about the use of nuclear energy as an alternative to fossil fuels. Ask a few volunteers to choose sides and then debate the issue in front of the class.

Activity

Students can use the excellent simulations at the URL below to explore nuclear fission. In the activity, they can start a nuclear chain reaction and use control rods to limit a nuclear chain reaction in a power plant. Teaching materials are also provided at the Web site.

- http://phet.colorado.edu/en/simulation/nuclear-fission

Building Science Skills

Have students watch and interpret the animated model of nuclear fusion at the following URL. Ask them to identify what the gray and red balls represent in the model (gray balls = neutrons, red balls = protons). Also ask them to identify the reactants and products in the reaction. (The reactants are deuterium and tritium, and the products are helium and a neutron.)

- http://www.atomicarchive.com/Movies/Movie5.shtml

Differentiated Instruction

Partner any English language learners and less proficient readers with other students, and have partners create a Venn diagram comparing and contrasting nuclear fission and nuclear fusion. The area of overlap might include “nuclear reaction” and “releases a lot of energy.” The area limited to fission might include “one large nucleus splits into two smaller nuclei.” The area limited to fusion might include “two small nuclei join into one large nucleus.”

Enrichment

Some students might be interested to learn how nuclear fission was discovered. Have them read and listen to the fascinating first-person account of the story at the URL below. The article is liberally interspersed with recorded statements by some of the main players, including Einstein, Curie, and Meitner. The scientists describe the breakthroughs as they actually happened.

- http://www.aip.org/history/mod/fission/fission1/01.html

Science Inquiry

Students can explore nuclear reactors by making a model of a nuclear reactor with Activity 2 on page 17 in the following PDF document. In the activity, students use simple materials to make their model and then compare the parts of their model to the parts of a real nuclear reactor (Three Mile Island reactor). They will also research and describe the basic processes that take place in a nuclear reactor.

- http://www.efmr.org/edu/nuclear2009.pdf

Real-World Connections

Have students find nuclear power plants in their state or region of the country at the URL below. (They should click on the National Map and then plot all the nuclear power plants.) The map will distinguish operating, proposed, and closed nuclear facilities. Suggest that students do a Web quest to learn more about the nuclear power plant closest to their location.

- http://www.energyjustice.net/map/

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Describe how nuclear fusion occurs.
   - [Nuclear fission is the splitting of the nucleus of an atom into two smaller nuclei. It begins when a nucleus absorbs a neutron. This makes the nucleus very unstable, and it splits in two. The reaction also releases three neutrons and a great deal of energy.]
2. What is a nuclear chain reaction?
   - [A nuclear chain reaction is a process in which one fission reaction leads to others, which leads to others, and so on. It happens when the neutrons released in one fission reaction are captured by other nuclei and cause them to undergo fission as well.]
3. Outline what happens during nuclear fusion.
   - [During nuclear fusion, two or more small nuclei combine to form a single, larger nucleus. For example, two hydrogen nuclei combine to form a helium nucleus. A neutron and a great deal of energy are also released.]
4. What are advantages of using nuclear fusion as opposed to nuclear fission for energy?
   - [Unlike nuclear fission, which involves dangerous radioisotopes, nuclear fusion involves just hydrogen and helium, both of which are harmless. Hydrogen is also very plentiful, whereas the radioactive elements needed for nuclear fission are relatively rare.]
5. Create a flowchart to show how nuclear fission is used to generate electricity.
   - [Flowcharts may vary but should include the following sequence of steps: nuclear fission occurs and releases energy; the energy is used to heat water, which turns to steam; the steam is under pressure and causes a turbine to spin; the spinning turbine runs a generator; the generator produces electricity.]
6. Relate Einstein's equation, $E = mc^2$, to the energy released in nuclear fission and nuclear fusion.
   - [Einstein's equation shows that matter and energy are two forms of the same thing. It also shows how matter and energy are related. When nuclear fission and nuclear fission occur, a tiny amount of matter is converted to energy. According to Einstein's equation, the amount of energy is equal to the mass of the "lost" matter times the square of the speed of light. This is a huge amount of energy from a tiny amount of matter.]

7. Less than one-quarter of the electricity used in the U.S. is generated from nuclear energy. Some people think we should use more nuclear power. Other people think we should use less or even none at all. Take a stand on this issue, and present facts and logical arguments to support your point of view.
    - [Students may take a stand for or against the use of nuclear power. They should present facts and logical arguments to support whichever point of view they take. In their arguments, they should weigh the pros and cons of using nuclear fission to produce electricity, relative to the pros and cons of using fossils fuels. For example, they might argue that the risk of nuclear accidents and the problem of disposing of nuclear wastes outweigh the benefits of less air pollution from the burning of fossil fuels.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 11.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Einstein's equation is part of a larger theory called the theory of relativity. It is concerned with concepts such as motion and forces as well as mass and energy. Motion and forces are the focus of succeeding chapters.

- Based on your real-world experiences, how would you define motion?

Motion is defined as a change of position.

- Forces include gravity and friction. How might these forces be related to motion?

Gravity causes objects to move in certain ways. It causes objects fall to the ground and planets to orbit the sun. Frictio

CHAPTER 12 TE Motion

Chapter Outline

12.1 Chapter 12: Motion

Chapter Overview

Motion is a change of position, but the perception of motion depends on a person's frame of reference. Measures related to motion include distance, speed, velocity, and acceleration. Distance is the length of the route between two points, and its SI unit is the meter. The average speed of an object is calculated as the change in distance divided by the change in time. Velocity is a vector that measures both speed and direction. Acceleration is a measure of the change in velocity of a moving object. It is represented by the slope of a velocity-time graph.

Online Resources

See the following Web sites for appropriate laboratory activities:

Have students do "The Great Tin Race" at the following URL. Students will describe and recognize motion, measure distance, and calculate speed. They will also graph data and make predictions. The activity will help them understand frame of reference and the relationships among speed, distance, and time.

- http://mypages.iit.edu/~smile/phma1400.htm

Students can apply knowledge of motion to sports and measure velocity and acceleration by doing the mini-Olympics activity at the URL below.

- http://mypages.iit.edu/~smile/ph9206.html

In this inquiry lab, students will create and explore accelerometers to develop an understanding of acceleration. The Website provides a student worksheet for the lab.

- http://sciencespot.net/Pages/classphys.html#Anchor-accellab

This Web site may also be helpful:

You and your advanced students can explore motion in greater depth with the tutorials in Lesson 1 at the following URL. The Web site includes student extras such as animations and a teacher's guide.

- http://www.physicsclassroom.com/Class/vectors/index.cfm

Pacing the Lessons

TABLE 12.1: **Pacing the Lessons**

Lesson	Class Period(s) (60 min)
12.1 Distance and Direction	1.0
12.2 Speed and Velocity	2.0
12.3 Acceleration	1.5

12.2 Lesson 12.1 Distance and Direction

Key Concept

Motion is a change of position. The perception of motion depends on a person's frame of reference. Distance is the length of the route between two points. The SI unit for distance is the meter. Direction is just as important as distance in describing motion. A vector is a quantity that has both size and direction. It can be used to represent the distance and direction of motion.

Standards

- SCI.CA.8.PS.1.a
- MCR.6-8.SCI.10.3
- NSES.5-8.B.2.1
- AAAS.6-8.10.A.1; AAAS.6-8.12.B.6

Lesson Objectives

- Define motion, and relate it to frame of reference.
- Describe how to measure distance.
- Explain how to represent direction.

Lesson Vocabulary

- **distance:** length of the route between two points
- **frame of reference:** something that is not moving with respect to an observer that can be used to detect motion
- **motion:** change in position
- **vector:** measure such as velocity that includes both size and direction; may be represented by an arrow

Teaching Strategies

Introducing the Lesson

Introduce motion and frame of reference by showing students the simple, relative-motion animation at the following URL. The animation illustrates how the point of view of the observer affects the perception of motion. Use the animation to launch a discussion of motion and how it might be defined. Call on students to define motion in their own words.

- http://www.classzone.com/books/ml_science_share/vis_sim/mfm05_pg7_relmotion/mfm05_pg7_relmotion.html

Activity

Have students do the activity "Maria's Run" at the URL below to learn the fundamentals of position-time graphs. They will use a motion detector to understand how forward, backward, fast, and slow motions look on a graph. Then they will answer questions about a graph showing the position of a runner as she moves around a track.

- http://concord.org/activities/marias-run

Differentiated Instruction

Start a word wall if you haven't already started one, or add vocabulary terms from this lesson to your word wall. Assign each of four pairs of students one of the lesson vocabulary terms. Then have partners define and illustrate their term and add it to the word wall.

Enrichment

Challenge a few students to learn about the "barber pole illusion" and relate it to frame of reference. Then have them select an animation to show the illusion to the class and explain why it occurs. They can start with the URLs below.

- http://www.sandlotscience.com/Ambiguous/Barberpole_Illusion.htm
- http://web.mit.edu/persci/demos/Motion&Form/demos/barber/barber.html
- http://psylux.psych.tu-dresden.de/i1/kaw/diverses%20Material/www.illusionworks.com/html/barber_pole.html

Science Inquiry

Assign the "Moving Man" guided inquiry activity at the following URL. The activity is based on a simulation at the same Web site. In the activity, students will explore and describe movement using a motion graph. The site provides a downloadable student worksheet and a file of teacher notes.

- http://phet.colorado.edu/en/contributions/view/3113

Common Misconceptions

This lesson focuses on distance, which is often confused with displacement. Explain and illustrate how the two terms differ using the information and examples at this URL: http://www.physicstutorials.org/home/mechanics/1d-kinematics/distance-and-displacement .

Answers to You Try It!

Problem: What is the distance from the post office to the park in **Figure** 12.1?

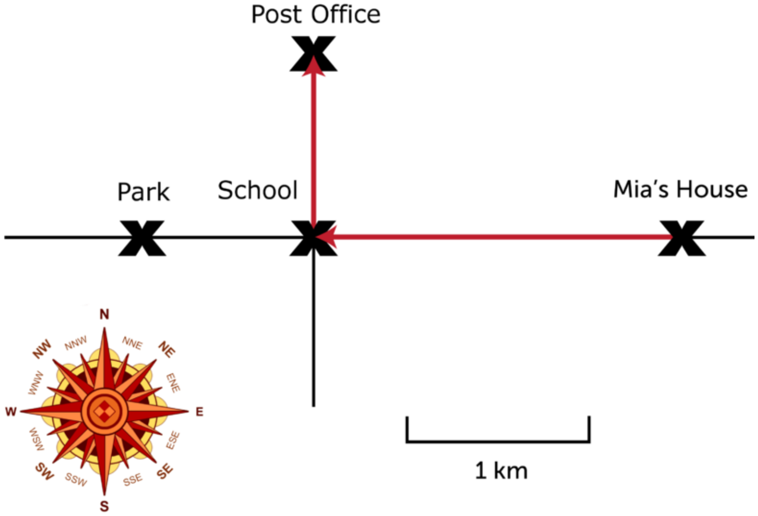


FIGURE 12.1
This map shows the routes from Mia's house to the school, post office, and park.

Solution: The distance is 2 km.

Problem: Draw vectors to represent the route from the post office to the park in **Figure** 12.1.

Solution: The vectors should look like this:

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define motion.
    - [Motion is a change in position.]
2. What is distance?
    - [Distance is the length of the route between two points.]

3. Describe how a vector represents both distance and direction.
   - [A vector uses an arrow to represent both size (distance) and direction. The length of the arrow represents distance, and the way the arrow points represents direction.]
4. In **Figure** 12.1, what is the distance from Mia's house to the park?
   - [The distance from Mia's house to the park is 3 km.]
5. Draw vectors to represent the following route from point A to point B:
   (a) Starting at point A, go 2 km east.
   (b) Then go 1 km south.
   (c) Finally, go 3 km west to point B.
   - [Vectors representing the route from point A to point B should look like this:

]
6. Explain how frame of reference is related to motion.
   - [Frame of reference affects the perception of motion. Frame of reference refers to something that is not moving with respect to an observer that can be used to detect motion. For example, if you are riding on a bus, you perceive the bus's motion if your frame of reference consists of the trees and houses lining the street. However, you may not perceive the bus's motion if your frame of reference consists of other passengers on the bus.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

A snail might travel 2 centimeters in a minute. A cheetah might travel 2 kilometers in the same amount of time. The distance something travels in a given amount of time is its speed.

- How could you calculate the speed of a snail or cheetah?

Speed can be calculated by dividing the distance traveled by the time it takes to travel that distance.

- Speed just takes distance and time into account. How might direction be considered as well?

The measure of both speed and direction is velocity.

12.3 Lesson 12.2 Speed and Velocity

Key Concept

Speed is a measure of how quickly or slowly something moves. The average speed of an object is calculated as the change in distance divided by the change in time. Velocity is a vector that measures both speed and direction. Velocity changes with a change in speed, a change in direction, or both.

Standards

- SCI.CA.8.IE.9.d, e, f; SCI.CA.8.PS.1.b, c, d, f
- MCR.6-8.SCI.10.3
- NSES.5-8.B.2.1
- AAAS.6-8.9.B.2, 3; AAAS.6-8.9.C.3; AAAS.6-8.11.C.3; AAAS.6-8.12.D.1, 2, 4

Lesson Objectives

- Outline how to calculate the speed of a moving object.
- Explain how velocity differs from speed.

Lesson Vocabulary

- **speed:** how quickly or slowly something moves; calculated as distance divided by time
- **velocity:** measure of both speed and direction of motion

Teaching Strategies

Introducing the Lesson

Start students thinking about speed with the interesting information about animal speed at the URL below. The site lists the top speeds of many different animals and calculates how fast they would be moving if they were human sized. For example, a rabbit has a top speed of about 30 m/h, but if a rabbit were 6 feet tall, its top speed would be 121 m/h. After sharing additional examples, tell students they will learn more about speed when they read this lesson.

- http://www.speedofanimals.com/?h=1.65

Activity

Have students do one or both online activities at the URLs below. In the first activity ("How Fast Am I Moving?"), students will learn to use the slope of a position-time graph to find velocity. In the second activity ("Describing Velocity"), students will learn to connect position-time and velocity-time graphs using an animated car icon.

- http://concord.org/activities/how-fast-am-i-moving
- http://concord.org/activities/describing-velocity

With the activity at the URL below, students can watch real soccer players as they move on the field, while distance-time graphs for the movements are created. The activity requires students to describe the motions in words and relate them to the graphs.

- http://www.sycd.co.uk/dtg/

Differentiated Instruction

Guide students in making a Venn diagram for speed and velocity. The diagram should show that the main difference between the two measures is the inclusion of direction in velocity but not in speed.

Enrichment

Some students might be interested in learning about land speed records and the technologies that have been developed to increase the speed of the vehicles involved. The following URLs provide a good introduction as well as a gallery of photos of record-breaking vehicles. Invite students to share what they learn with the rest of the class. Suggest that they make a timeline to summarize the information, and post their timeline in the classroom.

- http://www.fia.com/en-gb/sport/records/Pages/Introduction.aspx
- http://www.popularmechanics.com/cars/news/vintage-speed/4329417
- http://www.time.com/time/photogallery/0,29307,1853267_1785103,00.html

Science Inquiry

Have students solve the thought-provoking speed and velocity problems at the following URLs. Solutions as well as hints are provided at the Web site so students can check their own work.

- http://zebu.uoregon.edu/~dmason/probs/mech/1dkin/avgvel1/avgvel1.html
- http://zebu.uoregon.edu/~dmason/probs/mech/1dkin/loop/loop.html
- http://zebu.uoregon.edu/~dmason/probs/mech/1dkin/avvel/avvel.html

Common Misconceptions

Students commonly think that speed and velocity measure the same thing. At the following URL, you can find a classroom activity and animation to help students distinguish between the two concepts.

- http://ohiorc.org/pm/science/SciCDMisconceptions.aspx?cid=5

Answers to You Try It!

Problem: Terri rode her bike very slowly to the top of a big hill. Then she coasted back down the hill at a much faster speed. The distance from the bottom to the top of the hill is 3 kilometers. It took Terri 15 minutes to make the round trip. What was her average speed for the entire trip?

Solution: Her average speed was 6 km ÷ 15 min = 0.4 km/min.

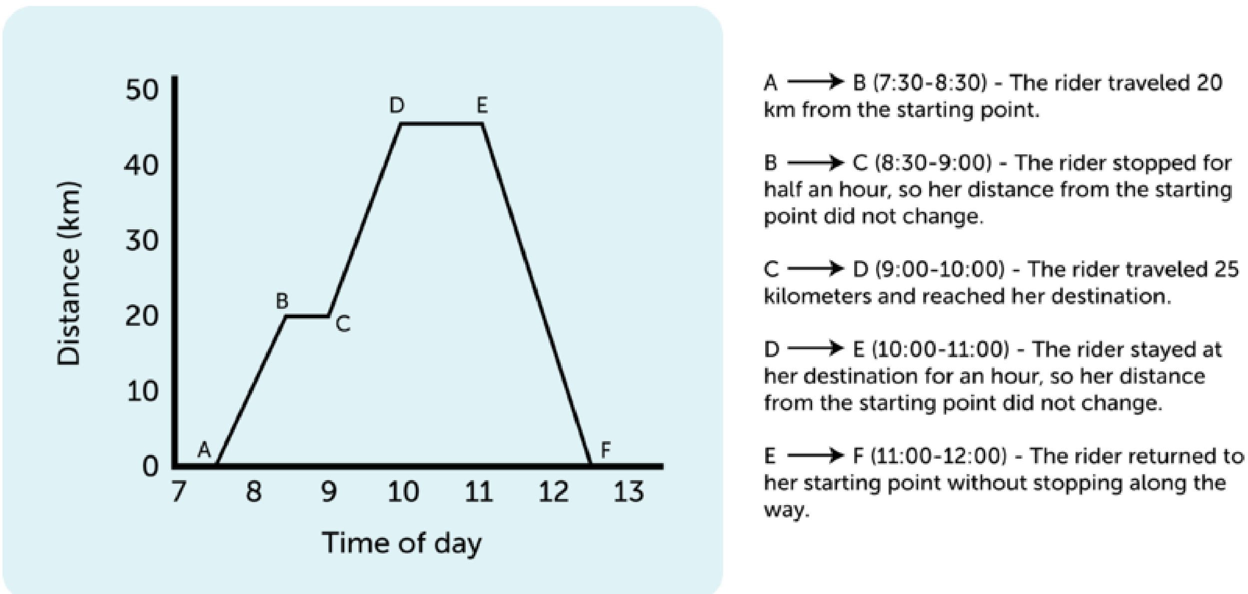


FIGURE 12.2
This graph shows how far a bike rider is from her starting point at 7:30 AM until she returned at 12:30 PM.

Problem: In **Figure** 12.2, calculate the speed of the rider between C and D.

Solution: The speed between C and D was 25 km/h.

Problem: If Maria runs at a speed of 2 m/s, how far will she run in 60 seconds?

Solution: She will run 2 m/s × 60 s = 120 m.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is speed? How is it calculated?
   - [Speed is a measure of how fast or slow something moves. It is calculated as distance divided by time.]
2. Define velocity.
   - [Velocity is a measure of both speed and direction.]
3. Sam ran a 2000-meter race. He started at 9:00 AM and finished at 9:05 AM. He started out fast but slowed down toward the end. Calculate Sam's average speed during the race.
   - [Sam's average speed during the race was 2000 m $\div$ 5 min = 400 m/min.]
4. Create a distance-time graph to represent a typical trip from your home to school or some other route you travel often. You may estimate distances and times.
   - [Graphs will vary but should have distance on the y-axis and time on the x-axis. The origin should represent the starting point and starting time. Distance by time should be plotted from the origin to the school or other end point.]
5. Explain how a distance-time graph represents speed.
   - [The slope, or steepness, of a distant-time graph represents speed. It shows how quickly distance changes with time.]
6. Compare and contrast speed and velocity.
   - [Both speed and velocity tell you how fast an object is moving. Velocity, but not speed, also tells you the direction the object is moving.]
7. Is speed a vector? Why or why not?
   - [Speed is not a vector. A vector is a quantity that includes both size and direction. Speed includes size but not direction.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read that the speed of a moving object equals the distance traveled divided by the time it takes to travel that distance. Speed may vary from moment to moment as an object speeds up or slows down. In the next lesson, you will learn how to measure changes in speed over time.

- Do you know what a change in speed or direction is called?

A change in speed or direction is called acceleration.

- Why might measuring changes in speed or direction be important?

It might be important to measure changes in speed or direction in order to determine the path of a moving object.

12.4 Lesson 12.3 Acceleration

Key Concept

Acceleration is a measure of the change in velocity of a moving object. It may reflect a change in speed, a change in direction, or both. To calculate acceleration without a change in direction, the change in velocity is divided by the change in time. The slope of a velocity-time graph represents acceleration.

Standards

- SCI.CA.8.IE.9.e, f; SCI.CA.8.PS.1.e, f
- MCR.6-8.SCI.10.3
- NSES.5-8.B.2.1
- AAAS.6-8.9.B.2, 3; AAAS.6-8.9.C.3; AAAS.6-8.11.C.3; AAAS.6-8.12.D.1, 2, 4

Lesson Objectives

- Define acceleration.
- Explain how to calculate acceleration.
- Describe velocity-time graphs.

Lesson Vocabulary

- **acceleration:** measure of the change in velocity of a moving object

Teaching Strategies

Introducing the Lesson

Ask students to recall how they felt on an exciting amusement park ride, such as a roller coaster. Encourage them to describe what they experienced as they moved with the ride. Explain that the thrills they felt were caused by acceleration. Call on a few students to state what they think acceleration means. Accept all reasonable responses at this point. Tell students they will learn whether they are correct when they read this lesson.

Using Visuals

Divide the class into six groups, and assign each group one of the pictures in the FlexBook® lesson that demonstrate a change in velocity. Within groups, have students decide how velocity is changing in their assigned picture (e.g., the direction of the skydiver is not changing, but his speed is increasing as he falls). Also have them brainstorm a different example of velocity changing in the same way. Ask a member of each group to share the group's ideas with the class. Discuss any disagreements.

Differentiated Instruction

Pair any students with language or reading difficulties with other students, and ask partners to create a Frayer model for acceleration. They should divide a sheet of paper into four quarters, labeled "Definition," "Drawing," "Example," and "Non-example." Then they should fill in each box.

Enrichment

Some students might be interested in the incredible acceleration and top velocity of 100-meter Olympic sprinter Usain Bolt. Suggest that they read the article at the URL below and watch the video of the exciting race in which he set a new world record of 9.58 seconds. Invite students to share Bolt's achievements with the rest of the class.

- http://access.aasd.k12.wi.us/wp/baslerdale/2009/10/21/acceleration-of-an-olympic-sprinter/

Science Inquiry

Challenge small groups of students to solve the acceleration problems at the following URL. Solutions to the problems are included.

- http://misterguch.brinkster.net/middleschoolworksheets.html

Common Misconceptions

Students commonly think that an object moving at a high velocity also has a high acceleration. Explain why an object moving at a high velocity may have a low, zero, or even negative acceleration. Use a concrete example to demonstrate this point, such as a rapidly moving (high velocity) car that is starting to slow down (negative acceleration) as it approaches a stop sign.

Answer to You Try It!

Problem: Tranh slowed his skateboard as he approached the street. He went from 8 m/s to 2 m/s in a period of 3 seconds. What was his acceleration?

Solution: His acceleration was (2 m/s –8 m/s) $\div$ 3 s = -2 m/s^2.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is acceleration?
   - [Acceleration is a measure of the change in velocity of a moving object. It shows how quickly velocity changes. It may reflect a change in speed, a change in direction, or both.]
2. How is acceleration calculated?
   - [Acceleration is calculated by dividing the change in velocity by the change in time.]
3. What does the slope of a velocity-time graph represent?
   - [The slope of a velocity-time graph represents acceleration.]
4. The velocity of a car on a straight road changes from 0 m/s to 6 m/s in 3 seconds. What is its acceleration?
   - [The acceleration of the car is 6 m/s ÷ 3 s = 2 m/s^2.]
5. Because of the pull of gravity, a falling object accelerates at 9.8 m/s^2. Create a velocity-time graph to represent this motion.
   - [Graphs should have velocity (m/s) on the y-axis and time (s) on the x-axis. The graph line should be a straight line that slopes upward to the right from the origin (0, 0) through the point (1, 9.8).]

Lesson Quiz

Check students' mastery of the lesson with Lesson 12.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Acceleration occurs when a force is applied to a moving object.

- What is force? What are some examples of forces?

Force is a push or pull acting on an object. Examples of forces include gravity and friction.

- What forces might change the velocity of a moving object? (*Hint*: Read the caption to **Figure** 13.12 of the cyclist.)

Gravity or friction might change the velocity of a moving object.

12.5 References

1. Christopher Auyeung (CK-12 Foundation); Compass: Seamus McGill. Compass: http://commons.wikimedia.org/wiki/File:Compass_rose_browns_00.png . CC BY-NC 3.0; Compass: Public Domain
2. Christopher Auyeung. CK-12 Foundation . CC BY-NC 3.0

CHAPTER 13 TE Forces

Chapter Outline

13.1 Chapter 13: Forces

Chapter Overview

Force is a push or pull acting on an object. The SI unit for force is the newton (N). Combined forces are added or subtracted to yield the net force. Specific forces include friction, gravity, and elastic force, all of which affect motion. Friction is a force that opposes motion between surfaces that are touching. Gravity is a force of attraction between objects that have mass. It causes the acceleration of falling objects, projectile motion, and orbital motion. Elastic force is the counter force that resists the stretching or compressing of an elastic material.

Online Resources

See the following Web sites for appropriate laboratory activities:

This inquiry lab is based on a simulation at the same Web site. In the lab, students will identify unbalanced forces and predict how they affect an object's motion. The site provides teacher resources and student worksheets.

- http://phet.colorado.edu/en/contributions/view/3541

These two labs allow students to investigate factors that affect friction, including type of surface and weight.

- http://teachers.net/lessons/posts/3937.html
- http://mypages.iit.edu/~smile/ph9311.html

With the labs at the URLs below, students can explore the effects of gravity on motion, including acceleration due to gravity, projectile motion, and orbital motion.

- http://www.discoveryeducation.com/teachers/free-lesson-plans/gravity-gets-you-down.cfm (acceleration due to gravity)
- http://mypages.iit.edu/~smile/ph9204.html (projectile motion)
- http://phet.colorado.edu/en/contributions/view/3566 (orbital motion)

The lab at the first URL below is an investigation of elastic force using simulated springs. The simulation is provided at the second URL. Students will observe that forces of springs are proportional to the distance they stretch or compress. The scripted version of the lab provides additional teacher resources, including background content, common misconceptions, and a vocabulary list. It provides editable student worksheets.

- http://phet.colorado.edu/en/contributions/view/3543
- http://phet.colorado.edu/en/simulation/mass-spring-lab

These Web sites may also be helpful:

The URLs below have links to several flash animations and other online activities relating to forces and motion. Several of the animations include quizzes that allow students to check their knowledge.

- http://science.k12flash.com/forceandmotion.html
- http://www.cln.org/themes/force_motion.html

There are many common student misconceptions about forces. Several are listed at the following URL. You can use the list of misconceptions as a true-false quiz to identify any misconceptions that your own students hold.

- http://www.physics.montana.edu/physed/misconceptions/forces/forces.html

You can find links to several videos about the force of gravity at this URL: http://www.neok12.com/Gravitation.htm .

Pacing the Lessons

TABLE 13.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
13.1 What Is Force?	1.0
13.2 Friction	1.5
13.3 Gravity	2.0
13.4 Elastic Force	1.0

13.2 Lesson 13.1 What Is Force?

Key Concept

Force is a push or a pull acting on an object. Examples of forces include friction and gravity. Force is a vector because it has both size and direction. The SI unit of force is the newton (N). The combined forces acting on an object are called the net force. When forces act in opposite directions, they are subtracted to yield the net force. When they act in the same direction, they are added to yield the net force.

Standards

- SCI.CA.8.PS.2.a, b, c, d, e, f
- MCR.6-8.SCI.10.4
- NSES.5-8.B.2.3
- AAAS.6-8.4.F.3

Lesson Objectives

- Define force, and give examples of forces.
- Describe how forces combine and affect motion.

Lesson Vocabulary

- **force:** push or pull acting on an object
- **net force:** overall force acting on an object that takes into account all of the individual forces acting on the object
- **newton (N):** SI unit for force; equal to the amount of force that causes a mass of 1 kilogram to accelerate at 1 m/s^2 ($kg \cdot m/s^2$)

Teaching Strategies

Introducing the Lesson

Show students the animated cartoon involving go-carts at the following URL. The animation reviews velocity and acceleration from the previous chapter and introduces the concept of force, which is the focus of this chapter.

- http://mrhardy.wikispaces.com/Forces.swf

Demonstration

Ask two volunteers to help you demonstrate balanced and unbalanced forces with fake arm-wrestling or tug-of-war competitions. Call on other students to go to the board and draw diagrams using force vector arrows to represent each scenario, including the direction in which any resulting motion occurs. Discuss with the class how acceleration occurs in each case.

Activity

Students can explore different types of forces (e.g., tension and torsion) and how they affect real-world structures with the animated simulation activity at the URL below. Students can also investigate the materials and shapes that best withstand different types of forces.

- http://www.pbs.org/wgbh/buildingbig/lab/forces.html

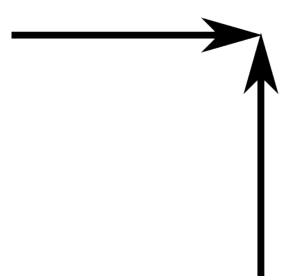
Differentiated Instruction

Have visual and English language learners work through the "Balanced and Unbalanced Forces" animated module at the URL below. Students will be able to explore the effects of both types of forces on motion. A simple quiz at the end of the module allows them to self-check their comprehension.

- http://www.engineeringinteract.org/resources/parkworldplot/flash/concepts/balancedandun.htm

Enrichment

Some students might be interested in learning how to find the net force when force is applied in more than one dimension, as in this simple vector diagram:



Direct students to the excellent Khan Academy URL below. It shows how to visually add vectors in two dimensions:

- http://www.khanacademy.org/science/physics/mechanics/v/visualizing-vectors-in-2-dimensions?playlist=Physics

Science Inquiry

The roller coaster activity at the following URL requires students to explore different combinations of variables that affect the forces and motions of a roller coaster car. The objective of the activity is to find the correct combination of variables that allows the car to make it through the loop and arrive at the stopping point without crashing into the gate at the end of the track. The Web site includes a teacher guide and student worksheet.

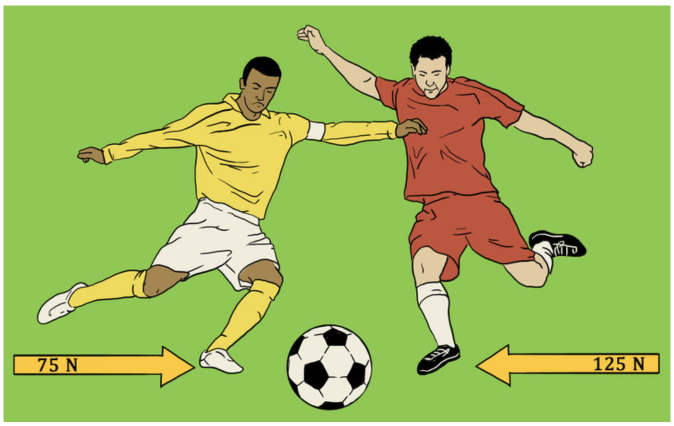
- http://www.glasgowsciencecentre.org/forcesatthefunfair.aspx

Common Misconceptions

A common misconception is that forces cause motion (rather than acceleration). Read the background about this misconception at the URL below. Then present students with the problem at the bottom of the Web page. Take a tally of the number of students who agree with each position. Call on students who made the correct choice to explain it.

- http://www.physicsclassroom.com/class/newtlaws/u2l3b.cfm

Answer to You Try It!



Problem: The boys in the drawing above are about to kick the soccer ball in opposite directions. What will be the net force on the ball? In which direction will the ball move?

Solution: The net force on the ball will be 50 N (125 N –75 N) to the left, so the ball will move to the left.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

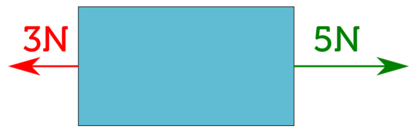
Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define force. Give an example of a force.
   - [Force is a push or pull acting on an object. Examples may vary. *Sample answer*: An example of a force is gravity.]
2. What is a newton?
   - [A newton is the SI unit for force. One newton is the amount of force that causes a mass of 1 kilogram to accelerate at 1 m/s^2.]

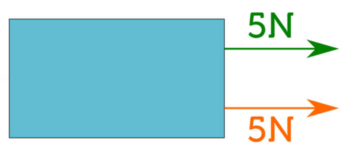
3. What is net force?
   - [Net force is the overall force acting on an object that takes into account all of the individual forces acting on the object.]
4. Describe an example of balanced forces and an example of unbalanced forces.
   - [Examples may vary. *Sample answer*: An example of balanced forces is a book resting on a table. The upward force provided by the table is the same as the downward force of gravity. An example of unbalanced forces is a tug-of-war game in which one team pulls on the rope with greater force than the other team.]
5. What is the net force acting on the block in each diagram below?

(a)



   - [2 N to the right]

(b)



   - [10 N to the right]
6. Explain how forces are related to motion.
   - [Any time the motion of an object changes, force has been applied. Force can cause a stationary object to start moving or a moving object to accelerate. The moving object may change its speed, its direction, or both because of the application of one or more forces. When forces are applied to an object in opposite directions, motion occurs only if the forces are unbalanced.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In the next lesson, "Friction," you will read about the force of friction. You experience this force every time you walk. It prevents your feet from slipping out from under you.

- How would you define friction?

Friction is a force that opposes motion between two surfaces that are touching.

- What do you think causes this force?

Friction occurs because no surface is perfectly smooth. Bumps and depressions on surfaces catch and grab the bumps

13.3 Lesson 13.2 Friction

Key Concept

Friction is a force that opposes motion between two surfaces that are touching. It is greater when objects have rougher surfaces or are heavier. Types of friction include static friction, sliding friction, rolling friction, and fluid friction.

Standards

- SCI.CA.8.PS.2.d
- MCR.6-8.SCI.10.4

Lesson Objectives

- Describe friction and how it opposes motion.
- Identify types of friction.

Lesson Vocabulary

- **fluid:** substance that can flow and take the shape of its container; either liquid or gas
- **friction:** force that opposes motion between two surfaces that are touching

Teaching Strategies

Introducing the Lesson

Introduce friction with a friction toy car. The URL below explains the role of friction in winding the spring that powers the car. Challenge students to explain how the car works, and then point out the role that friction plays. Ask a volunteer to try to wind the spring by rolling the car backward on several different surfaces that vary in roughness, such as tile, wood, fabric, and glass. Tell the class they will learn the physics behind the friction car when they read this lesson.

- http://www.ehow.com/how-does_5199953_do-friction-toy-cars-work_.html

Demonstration

Use a simple demonstration to introduce students to the concept of friction as a force that impedes motion when two surfaces are in contact. The URL below describes the demonstration and also provides background information for teachers. The demonstration is a good lead-in to the Science Inquiry activity described below.

- http://www.teachengineering.org/view_lesson.php?url=collection/duk_/lessons/duk_friction_smary_less/duk_-friction_smary_less.xml

Activity

With the simulation "Forces in 1 Dimension" at the following URL, students can explore the forces at work when trying to push a filing cabinet or other object. The simulation allows them to create an applied force and see the resulting friction force and total force acting on the cabinet. The simulation also generates graphs that show forces, position, velocity, and acceleration vs. time.

- http://phet.colorado.edu/en/simulation/forces-1d

Differentiated Instruction

Work with students to make a compare/contrast table for static, sliding, and rolling friction. Headings in the table might include "Type of Friction," "When It Occurs," Example," and "Relative Strength."

Enrichment

Friction can be used to start a fire, not only with a match but without a match as well, because friction always generates heat. Ask a few students to investigate the physics behind starting a fire without a match (first URL below) and then to learn about some of the materials and methods that can be used to start a fire with friction (second URL below). Have them present their investigation to the class in an oral report and demonstrate how to start a fire with a fire bow or other friction-based method. (For safety reasons, students should not actually start a fire in the classroom.)

- http://dsc.discovery.com/fansites/mythbusters/articles/friction-start-a-fire.html
- http://adventure.howstuffworks.com/survival/wilderness/how-to-start-a-fire.htm

Science Inquiry

Have groups of students do the Associated Activity "Sliding and Stuttering" at the URL below. They will measure frictional force and experiment with different types of surfaces to determine which surfaces generate more or less friction.

- http://www.teachengineering.org/view_lesson.php?url=collection/duk_/lessons/duk_friction_smary_less/duk_-friction_smary_less.xml

Real-World Connection

Students can investigate and report on friction in their daily lives with the activity at the following URL. The Web site provides background information, a student worksheet, teacher notes, and a sample report.

- http://teacher.scholastic.com/dirtrep/friction/index.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is friction?
   - [Friction is a force that opposes motion between two surfaces that are touching.]
2. List factors that affect friction.
   - [Factors that affect friction include the smoothness of the surfaces that are touching and the amount of force that is pressing them together.]
3. How does friction produce heat?
   - [Friction produces heat by causing the molecules on rubbing surfaces to move faster. As a result, they have more heat energy.]
4. Identify two forms of friction that oppose the motion of a moving car.
   - [Two forms of friction that oppose the motion of a moving car are rolling friction between the tires and the road and fluid friction between the car and the air.]
5. Explain why friction occurs.
   - [Friction occurs because no surface is perfectly smooth. The bumps and depressions on one surface catch and grab the bumps and depressions on another surface that contacts it. This creates friction.]
6. Compare and contrast the four types of friction described in this lesson.
   - [The four types of friction are static, sliding, rolling, and fluid friction. In each type, friction works opposite the force applied to move an object. Static friction acts on objects when they are resting on a surface. Sliding friction acts on objects when they are sliding over a surface. Rolling friction acts on objects when they are rolling over a surface. Sliding friction is weaker than static friction, and rolling friction is weaker than static or sliding friction. Fluid friction acts on objects that are moving through a fluid. The strength of fluid friction depends on the size and speed of the moving object.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

A skydiver like the one in the figure above falls to the ground despite the fluid friction of his parachute with the air. Another force pulls him Earthward. That force is gravity, which is the topic of the next lesson.

- What do you already know about gravity?

***Sample answers*: Earth and other heavenly bodies have gravity; bigger bodies have greater gravity; gravity pulls every**

- What do you think causes gravity?

Students may think that gravity is a force of attraction that is inherent in matter, which is similar to Newton's idea of g

13.4 Lesson 13.3 Gravity

Key Concept

Gravity is traditionally defined as a force of attraction between two masses, and it is measured by weight. Newton's law of universal gravitation states that gravity acts between all objects in the universe and the strength of gravity depends on mass and distance. Einstein's theory of gravity states that gravity is an effect of curves in space and time. Gravity causes falling objects to accelerate, and it also causes projectile and orbital motion.

Standards

- SCI.CA.8.PS.2.d, f, g
- MCR.6-8.SCI.10.1
- NSES.5-8.D.3.3
- AAAS.6-8.1.A.4; AAAS.6-8.4.B.3; AAAS.6-8.4.F.4; AAAS.6-8.4.G.1, 2; AAAS.6-8.12.D.9

Lesson Objectives

- Define gravity.
- State Newton's law of universal gravitation.
- Explain how gravity affects the motion of objects.

Lesson Vocabulary

- **gravity:** as traditionally defined, force of attraction between things that have mass
- **law of universal gravitation:** law stating that gravity is a force of attraction between all objects in the universe and that the strength of gravity is greater when masses of objects are greater or distances between objects are shorter
- **orbit:** path of one object around another, such as the path of the moon around Earth or of Earth around the sun
- **projectile motion:** motion of an object that has initial horizontal velocity but is also pulled down toward Earth by gravity

Teaching Strategies

Introducing the Lesson

Because of the ubiquity of Earth's gravity, it can be difficult to appreciate its effects on us. Introduce the lesson by helping students realize the effects of gravity. First remind them that Earth's gravity pulls all objects toward the center of Earth. Then have them try to imagine what it would be like to live on Earth if it had no gravity. Ask each student in turn to describe at least one thing that would be different (e.g., if you jumped up you would keep going up and not come back down). Tell students they will learn more about gravity in this lesson.

Activity

Students can explore the concept of gravity on their own by doing the "What in the World Is Gravity?" Web quest at the following URL. Students are presented with the task of creating a brochure to explain Earth's gravity to aliens that have just landed on their roof. The Web site includes a teacher page.

- http://www.zunal.com/webquest.php?w=50254

Using Visuals

Have students compare the figures in the lesson that illustrate projectile motion of a cannon ball and orbital motion of the moon. Ask them to identify similarities between the two types of motion. (In both cases, an object follows a curved path because of forces acting on it in two different dimensions.) Explain that if a cannon ball were shot out of a cannon at the correct angle and with great enough force, it could orbit Earth like the moon.

Differentiated Instruction

Have the class do a gallery walk relating to the effects of gravity on motion. First, post at least one critical thinking question about each of the following topics on different walls of the classroom: acceleration due to gravity, projectile motion, and orbital motion. Beside each set of questions, place a large sheet of blank paper. Divide the class into groups, and have groups move around the room from one topic to the next, discussing and recording answers to the questions on the large sheets of blank paper. Each group should also record any comments they have about the answers posted by other groups. (Have each group record their answers and comments with a different color of ink so they will be easy to distinguish.) After the gallery walk, discuss the answers and comments as a class. Ask students to identify common themes and also any misconceptions.

Enrichment

Some students may be interested to learn more about Einstein's theory of gravity, including how it fits in with his theory of general relativity and how recent NASA discoveries provide support for the theory. Direct these students to the URLs below as starting points in their investigation. Ask them to create a Web site, poster, or other visual presentation as a way to share what they learn with the class.

- http://www.pbs.org/wgbh/nova/physics/relativity-and-the-cosmos.html
- http://raja-suvendra.com/Suvendra/node17.htm
- http://theory.uwinnipeg.ca/mod_tech/node60.html
- http://news.nationalgeographic.com/news/2011/05/110505-einstein-theories-confirmed-gravity-probe-nasa-space-science/

Science Inquiry

Have students do the experiment described at the URL below. They will test the acceleration due to gravity of objects with different masses. The experiment will give them a chance to apply many basic science skills.

- http://mypages.iit.edu/~smile/phma1700.htm

Common Misconceptions

Several common student misconceptions about gravity are listed below. Discuss the misconceptions with your students and explain why they are incorrect.

Gravity exists only on Earth so there is no gravity in space.

- [Students often think that there is no gravity in space because they have seen astronauts appear weightless in movies and in pictures. The astronauts are not really weightless. They only appear so because the space shuttle and the astronauts inside of it are in a constant state of free fall around Earth.]

Gravity is selective and acts differently on some matter.

- [Gravity acts in the same way on everything. Only the strength of gravity varies.]

Planets far from the Sun have less gravity.

- [Gravity depends not only on the distance between objects. It also depends on the mass of the objects.]

Gravity can push as well as pull.

- [Students have learned that a force is a push or a pull. However, gravity is an attractive force only. It pulls objects together but does not push them apart.]

Weight and mass measure the same thing.

- [Mass is the amount of matter in an object. Weight is the force with which gravity pulls the object. Weight depends not only on the object's mass but also on the force of gravity. This explains why the weight of a given mass is less on the moon than on Earth.]

Biology Connection

Discuss how Earth's gravity is related to life on Earth. Explain how, throughout the history of Earth, life has evolved to survive changing conditions, such as changes in the climate and habitat. One of the few constant factors in evolution since life first began on Earth is the force of gravity. As a consequence, all living things have adapted to the ever-present force of gravity and even small variations in this force can have a significant impact on the health and function of organisms. For example, plant roots grow toward the pull of gravity and plant shoots grow away from the pull of gravity. For animals, there is a limit on how large they can become because of the pull of gravity. If they were to become too large, they would be crushed by their own weight.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is the traditional definition of gravity?
   - [Gravity has traditionally been defined as a force of attraction between two masses.]
2. How is weight related to gravity?
   - [Weight measures the force of gravity pulling on an object.]
3. Summarize Newton's law of universal gravitation.
   - [According to Newton's law of universal gravitation, gravity is a force of attraction between all objects in the universe, and the strength of gravity depends on the masses of the objects and the distance between them. Gravity is stronger when objects have greater masses or are closer together.]
4. Describe Einstein's idea of gravity.
   - [Einstein thought that gravity results from curves in space and time around massive objects such as Earth. In this view, objects curve toward one another because of the curves in space and time.]
5. Create a poster to illustrate the concept of projectile motion.
   - [Posters will vary, but they should show that projectile motion is the motion of an object that starts out moving horizontally but curves down toward the ground because of the pull of gravity.]
6. In the absence of air, why does an object with greater mass fall toward Earth at the same acceleration as an object with less mass?
   - [In the absence of air, an object with greater mass falls toward Earth at the same acceleration as an object with less mass because the more massive object is harder to move. As a result, it ends up moving at the same acceleration as the less massive object.]
7. Explain why the moon keeps orbiting Earth.
   - [The moon keeps orbiting Earth because of its own forward velocity combined with the pull of Earth's gravity. The moon has enough forward velocity to partly counter Earth's gravity. It constantly falls toward Earth, but it stays far enough away from Earth so it actually falls around the planet.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The scale you saw in the figure above contains a spring. When an object hangs from the scale, the spring exerts an upward force that partly counters the downward force of gravity. The type of force exerted by a spring is called elastic force, which is the topic of the next lesson.

- Besides springs, what other objects do you think might exert elastic force?

Examples include rubber bands, bungee cords, and trampolines.

- What other ways might you use elastic force?

You might use elastic force to hold objects together.

13.5 Lesson 13.4 Elastic Force

Key Concept

Elasticity is the ability of a material to return to its original shape after being stretched or compressed. Elastic force is the counter force that resists the stretching or compressing of an elastic material. Elastic force is very useful. It is used in rubber bands, bungee cords, and bed springs, to name just a few uses.

Standards

- SCI.CA.8.PS.2.d
- NSES.5-8.A.1.7
- AAAS.6-8.12.D.8

Lesson Objectives

- Define elasticity and elastic force.
- Describe uses of elastic force.

Lesson Vocabulary

- **elastic force:** counter force exerted by an elastic material when it is stretched or compressed
- **elasticity:** ability of a material to return to its original shape after being stretched or compressed

Teaching Strategies

Introducing the Lesson

Introduce the lesson by giving students a chance to experience elastic force. Pass around a few items with elasticity, such as a rubber band, a bungee cord, and an elastic shoelace. Tell students to stretch the items and describe the resistance they feel. Explain that the resistance is elastic force, which they will learn about in this lesson.

Discussion

Discuss how elastic force and the stretching or compressing of elastic materials are related to kinetic and potential energy. You can demonstrate with a rubber ball. When you throw the ball, it has kinetic energy. If you throw it against the floor, it compresses. The compression gives it potential energy. As the rubber returns to its original shape, the ball bounces back up from the floor, so it has kinetic energy again.

Differentiated Instruction

Partner struggling students with students who are doing well in the class, and ask partners to do a think-pair-share activity. Provide them with the questions below to think about individually as they read the lesson. Then, after they read the lesson, have partners work together to answer the questions.

1. What is elasticity?
2. What are some things that are elastic?
3. How is elastic force defined?
4. How can you use elastic force?

Enrichment

Challenge a few students to make use of elastic force by designing, building, and testing a rubber band-powered car. They can follow the steps outlined in the activity at the URL below. After students complete the activity, ask them to demonstrate their car to the class and explain how it works. Also ask them to relate the winding up and release of the rubber band to elastic force and kinetic and potential energy.

- http://www.pbs.org/wgbh/nova/education/activities/3308_darpa.html

Science Inquiry

Have small groups of students do the elasticity inquiry project described at the following URL. They will use objects with different weights to stretch a rubber band and measure how far it stretches with each weight. Then they will plot their results in a graph. Before they begin the project, have students predict the outcome of the experiment. When the finish, they should conclude whether or not their initial prediction was correct.

- http://www.ehow.com/way_5423013_science-projects-using-rubber-bands.html

Common Misconceptions

Students may incorrectly assume that anything that stretches has elasticity. Stress that the ability to return to its original shape after being stretched is also necessary for a material to have elasticity. Describe an example of something that can be stretched (or compressed) but does not return to its original shape, such as modeling clay. Ask students if they can think of other examples.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is elasticity?
   - [Elasticity is the ability of a material to return to its original shape after being stretched or compressed.]
2. Describe elastic force.
   - [Elastic force is the counter force exerted by an elastic material when it resists being stretched or compressed. It causes the material to spring back to its original shape as soon as the stretching or compressing force is released.]
3. Identify uses of elastic force.
   - [Answers may vary. *Sample answer*: Elastic force is used in objects that need to be stretched and then return to their original shape, such as rubber bands, hair scrunchies, waistbands, and resistance bands. It is also used in objects that have springs, such as spring scales, cars, and beds.]
4. Think of a way you could demonstrate elastic force to a younger student. Describe the procedure you would follow and the materials you would use.
   - [Answers may vary but should show that students understand elastic force well enough to demonstrate it to a younger student who has no prior knowledge of forces or elasticity. Their answer should clearly outline the procedure they would follow and the materials they would use. For example, they might describe how they would have the younger student stretch an elastic material and feel the resistance and then equate the resistance to elastic force.]
5. Explain how springs are used in scales to measure weight.
   - [In a spring scale, the elastic force of the spring partly counters the downward force of gravity that pulls on an object attached to the spring. The scale detects the resistance to gravity of the elastic force. In this way, it measures the weight of the object.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 13.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read about Newton's law of universal gravitation. Newton developed several other laws as well. In the next chapter, "Newton's Laws of Motion," you'll read about his three laws of motion. Recall what you already know about motion.

- What is motion? What are examples of motion?

Motion is a change in position. Examples of motion may vary but might include a car traveling down a street and a spr

- What causes changes in motion? What are changes in motion called?

Forces cause changes in motion. Changes in the speed or direction of motion are called acceleration.

CHAPTER 14 TE Newton's Laws of Motion

Chapter Outline

14.1 Chapter 14: Newton's Laws of Motion

Chapter Overview

According to Newton's first law of motion, an object's motion will not change unless it is acted upon by an unbalanced force. This tendency of an object to resist a change in motion is called inertia. Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass. The acceleration of a mass due to gravity is measured by weight. Newton's third law of motion states that every action has an equal and opposite reaction. During an action and reaction, momentum may be transferred from one mass to another, but overall momentum is conserved.

Online Resources

See the following Web sites for appropriate laboratory activities:

The lab at the following URL shows that resistance to motion depends on the mass of the body being accelerated rather than its weight.

- http://www.nuffieldfoundation.org/practical-physics/inertia-balance-or-wig-wag

In the lab at the following URL, students will verify Newton's second law by subjecting a body to multiples of a force and then subjecting two bodies to the same force. Students will collect, analyze, and graph data collected during the lab.

- http://mypages.iit.edu/~smile/ph9527.html

The URL below offers six mini-labs on all three of Newton's laws of motion.

- http://teachers.net/lessons/posts/661.html

These Web sites may also be helpful:

You can teach Newton's three laws of motion using part or all of the lesson plan at the following URL. The lesson includes background information and 11 class activities.

- http://www.clas.ufl.edu/users/ufhatch/NSF-PLANS/2-2_NEWTON.htm

Go to the URL below for a wealth of middle school materials on forces and motion, many of them dealing explicitly with Newton's laws of motion. The materials include activities, labs, slideshows, online quizzes, study and review games, and interactive Web sites.

- http://www.science-class.net/Physics/force_motion.htm

Pacing the Lessons

TABLE 14.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
14.1 Newton's First Law	1.5
14.2 Newton's Second Law	2.0
14.3 Newton's Third Law	2.5

14.2 Lesson 14.1 Newton's First Law

Key Concept

Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object. If the object is at rest, it will stay at rest. If the object is in motion, it will stay in motion. Inertia is the tendency of an object to resist a change in its motion. The inertia of an object depends on its mass. Objects with greater mass have greater inertia. To overcome inertia, an unbalanced force must be applied to an object.

Standards

- SCI.CA.8.PS.2.c
- MCR.6-8.SCI.10.4, 5
- NSES.5-8.B.2.2, 3
- AAAS.6-8.1.A.1; AAAS.6-8.4.F.3; AAAS.6-8.11.C.1

Lesson Objectives

- State Newton's first law of motion.
- Define inertia, and explain its relationship to mass.

Lesson Vocabulary

- **inertia:** tendency of an object to resist a change in its motion
- **Newton's first law of motion:** law stating that an object's motion will not change unless an unbalanced force acts on the object

Teaching Strategies

Introducing the Lesson

Introduce inertia (and Newton's first law) with one of the simple inertia demonstrations describe at the URL below. Tell students they will understand what happened in the demonstration after they read this lesson. At the end of the lesson, call on students to explain what they observed in the demonstration.

- http://www.nuffieldfoundation.org/practical-physics/more-inertia-experiments

Demonstration

Have students participate in the demonstration described at the following URL. They will observe that mass resists changes in motion and that unbalanced forces produce changes in motion.

- http://www.nuffieldfoundation.org/practical-physics/inertia-low-friction-surface

Differentiated Instruction

Help focus students' attention on the main points in the lesson by having them complete the following cloze sentences as they read. Tell them that each blank requires at least a few words to fill correctly. Sample answers are given in brackets below.

1. Newton's first law of motion states that __________. [an object's motion will not change unless an unbalanced force acts on the object]
2. Inertia is __________. [the tendency of an object to resist a change in its motion]
3. If an object is at rest, its inertia will __________. [keep it at rest]
4. If an object is moving, its inertia will __________. [keep it moving]
5. The inertia of an object depends on __________. [its mass]

Enrichment

Ask a few advanced students to help you place Newton's laws of motion in a broader context. Have them do the activity described at the URL below. They will role-play interviews with three prominent scientists (Aristotle, Galileo, and Newton) who made major contributions to our understanding of motion. They will also identify how ideas about motion changed over time.

- http://www.middleschoolscience.com/motioninterview.htm

Science Inquiry

Have students do one or more of the five activities on Newton's first law of motion at the following URL. The Web site provides Student Activity pages and Notes to Teachers. The activities will give students the opportunity to learn aspects of about the law in ways that are fun and interesting. The activities may be done individually or in groups. It is recommended that students create a logbook in which they take notes and track their findings from the activities.

- http://swift.sonoma.edu/education/newton/newton_1/html/newton1.html

Common Misconceptions

A misconception about motion that dates back to Aristotle is that an object keeps moving only if force is continuously applied to it. Help overcome this misconception with a simple demonstration. Slide a book across a table and have students watch as it slides to a rest position. Explain that the book stopped moving not because of the absence of force. Instead, it was the presence of force—the force of friction—that caused the book to stop moving. Add that in the absence of friction or some other force, the book would continue in motion with the same speed and direction forever (or at least to the end of the tabletop where the force of gravity would changes its motion).

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. State Newton's first law of motion.
   - [Newton's first law of motion states that an object's motion will not change unless an unbalanced force acts on the object.]
2. Define inertia.
   - [Inertia is the tendency of an object to resist a change in its motion.]
3. How does an object's mass affect its inertia?
   - [An object with greater mass has greater inertia. An object with less mass has less inertia.]
4. Assume you are riding a skateboard and you run into a curb. Your skateboard suddenly stops its forward motion. Apply the concept of inertia to this scenario, and explain what happens next.
   - [When the skateboard runs into the curb and suddenly stops, you will keep moving forward because of your inertia. You may slide forward off the skateboard and land on the ground in front of it.]
5. Why is Newton's first law of motion also called the law of inertia?
   - [Newton's first law of motion is also called the law of inertia because inertia explains why the motion of an object will not change unless an unbalanced force acts on it.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that the mass of an object determines its inertia. You also learned that an unbalanced force must be applied to an object to overcome its inertia, whether it is moving or at rest. An unbalanced force causes an object to accelerate.

- Predict how the mass of an object affects its acceleration when an unbalanced force is applied to it.

For a given unbalanced force, a larger mass results in a lower rate of acceleration.

- How do you think the acceleration of an object is related to the strength of the unbalanced force acting on it?

The stronger the unbalanced force acting on an object, the greater its rate of acceleration.

14.3 Lesson 14.2 Newton's Second Law

Key Concept

Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass. Weight is a measure of the force of gravity pulling on an object of a given mass. It equals the mass of the object (in kilograms) times the acceleration due to gravity (9.8 m/s^2).

Standards

- SCI.CA.8.PS.2.e, f
- NSES.5-8.B.2.3
- AAAS.6-8.4.B.3; AAAS.6-8.4.F.3; AAAS.6-8.9.A.5; AAAS.6-8.11.C.3; AAAS.6-8.12.B.8, 9; AAAS.6-8.12.D.11

Lesson Objectives

- State Newton's second law of motion.
- Identify the relationship between acceleration and weight.

Lesson Vocabulary

- **Newton's second law of motion:** law stating that the acceleration of an object equals the net force acting on the object divided by the object's mass

Teaching Strategies

Introducing the Lesson

With the help of a student volunteer, introduce students to Newton's second law of motion with a simple demonstration. While the class observes, ask the student to blow through a drinking straw held about an inch away from a ping-pong ball to start the ball rolling across a tabletop. Replace the ping-pong ball with a golf ball, and ask the student to repeat the procedure, blowing with about the same amount for force. Then ask the student to blow on each ball in succession with as much force as possible. Call on other students at random to describe what they observe and to identify the variables involved in the demonstration (force, mass, and acceleration). Tell the class they will learn how the variables are related when they read this lesson.

Activity

Newton's second law may be easier for students to understand if they do the interactive shopping cart activity at the URL below. They will see how acceleration is calculated, using different forces and masses, and also see a shopping cart actually accelerating at the calculated rates.

- http://www.classzone.com/books/ml_science_share/vis_sim/mfm05_pg50_newton/mfm05_pg50_newton.html

Differentiated Instruction

Students who need extra help with Newton's second law of motion can read the tutorial and try the practice problems at the following URL. Solutions to the problems are provided.

- http://gbhsweb.glenbrook225.org/gbs/science/phys/Class/newtlaws/u2l3a.html

Enrichment

Challenge interested students to think of a creative way to demonstrate Newton's second law of motion to much younger students. Have them write a detailed description of the demonstration they would present. Then, if possible, arrange for the students to present their demonstration to an elementary-level class.

Science Inquiry

Have students do the guided inquiry activity described at the URL below. They will gather data on force, mass, and acceleration of a sliding mug and infer the relationships among the three factors from their data.

- http://www.education.com/reference/article/newton-law-motion2/?page=2

Real-World Connection

When you discuss Newton's second law of motion, describe real-world scenarios that show how the acceleration of an object depends directly on the net force applied to the object and inversely on the object's mass. Some examples you might use are listed below. Ask students to describe the resulting acceleration in each case.

- A book resting on a table (zero net force)
- Bunting a baseball (small force)
- Swinging at a baseball (large force)
- Pushing a bike with a flat tire (small mass)
- Pushing a car that has run out of gas (large mass)

Answers to You Try It!

Problem: Assume that you add the weights to the trunk in **Figure** 14.1. If you push the trunk and weights with a force of 20 N, what will be the trunk's acceleration?

Solution: The trunk and weights have a combined mass of 20 kg, so the acceleration is 20 N ÷ 20 kg = 1 N/kg, or 1 m/s^2.

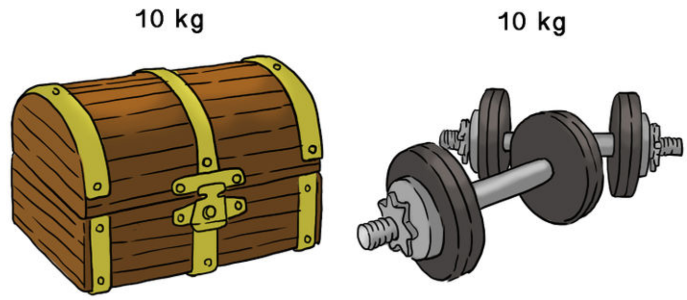


FIGURE 14.1
This empty trunk has a mass of 10 kilograms. The weights also have a mass of 10 kilograms. If the weights are placed in the trunk, what will be its mass? How will this affect its acceleration?

Problem: Daisy's dad has a mass of 70 kg, which is twice Daisy's mass. Predict how much Daisy's dad weighs. Then calculate his weight to see if your prediction is correct.

Solution: Daisy weighs 343.0 N. Daisy's dad has twice as much mass as Daisy, so he should weigh twice as much as Daisy, or 686.0 N. His weight can be calculated as 70 kg $\times$ 9.8 m/s^2 = 686.0 N.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. State Newton's second law of motion.
   - [Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass.]
2. Describe how the net force acting on an object is related to its acceleration.
   - [The net force acting on an object is directly related to its acceleration. The greater the net force that is applied to an object of a given mass, the more the object will accelerate.]
3. If the mass of an object increases, how is its acceleration affected, assuming the net force acting on the object remains the same.
   - [If the mass of an object increases, its acceleration decreases, assuming the net force acting on the object remains the same.]
4. What is weight?
   - [Weight is a measure of the force of gravity pulling on an object of a given mass.]
5. Tori applies a force of 20 newtons to move a bookcase with a mass of 40 kg. What is the acceleration of the bookcase?
   - [The acceleration of the bookcase is $a = \frac{20\text{ N}}{40\text{ kg}} = \frac{0.5\text{ N}}{\text{kg}} = \frac{0.5\text{ kg}\cdot\text{m/s}^2}{\text{kg}} = 0.5\text{ m/s}^2$.]

6. Ollie has a mass of 45 kilograms. What is his weight in newtons?
    - [Ollie's weight in newtons is $F = 45 \text{ kg} \times 9.8 \text{ m/s}^2 = 441 \text{ kg} \cdot \text{m/s}^2 = 441 \text{ N}$.]
7. If you know your weight in newtons, how could you calculate your mass in kilograms? What formula would you use?
    - [If you know your weight in newtons you could calculate your mass in kilograms by using this formula: $m = \frac{F}{a}$, where F = your weight and a = the acceleration due to gravity, which is 9.8 m/s^2.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Assume that a 5-kilogram skateboard and a 50-kilogram go-cart start rolling down a hill. Both are moving at the same speed. You and a friend want to stop then before they plunge into a pond at the bottom of the hill.

- Which will be harder to stop: the skateboard or the go-cart?

The go-cart will be harder to stop.

- Can you explain why?

The go-cart will be harder to stop because its larger mass will give it greater momentum.

14.4 Lesson 14.3 Newton's Third Law

Key Concept

Newton's third law of motion states that every action has an equal and opposite reaction. Momentum is a property of a moving object that makes it hard to stop. It equals the object's mass times its velocity. When an action and reaction occur, momentum may be transferred from one object to another, but their combined momentum remains the same. This is the law of conservation of momentum.

Standards

- SCI.CA.8.PS.2.e, f
- NSES.5-8.B.2.3
- AAAS.6-8.4.F.3; AAAS.6-8.11.C.3; AAAS.6-8.12.B.8; AAAS.6-8.D.4, 6, 9, 11

Lesson Objectives

- State Newton's third law of motion.
- Describe momentum and the conservation of momentum.

Lesson Vocabulary

- **law of conservation of momentum:** law stating that, when an action and reaction occur, the combined momentum of the objects remains the same
- **momentum:** property of a moving object that makes it hard to stop; equal to the object's mass times its velocity
- **Newton's third law of motion:** law stating that every action has an equal and opposite reaction

Teaching Strategies

Introducing the Lesson

Use two toy cars to demonstrate actions and reactions as a way to introduce lesson content. Push one toy car to start it rolling and aim it so that its front end collides with the back end of the other toy car, which is stationary. Students will observe that the moving car slows down after the collision, while the stationary car starts moving. Challenge students to explain their observations using terms such as force, velocity, and acceleration.

Building Science Skills

Challenge students to apply Newton's third law to common activities such as jumping on a trampoline or hitting a golf ball with a golf club. In each case, ask students to identify the action and reaction forces and the objects to which the forces are applied. Also ask them to describe how the objects change in motion.

Demonstration

Use the animated collisions at the URL below to demonstrate conservation of momentum. Ask students to explain in words how momentum is conserved in each collision.

- http://www.physicsclassroom.com/mmedia/

Differentiated Instruction

Do a think-pair-share activity after students read the lesson. First, ask students to think about the questions listed below. Then, divide the class into pairs, pairing students who need extra help with students who can provide it. Finally, have partners work together to answer the questions (sample answers are given below in brackets).

1. What are actions and reactions? [equal and opposite forces]
2. What is an example of an action and reaction not described in the lesson? [*Sample answer*: hammering a nail into wood]
3. In your example, what is the action and what is the reaction? [action: the hammer hitting the nail; reaction: the nail pushing into the wood]
4. How is momentum involved in your example? [Some of the momentum of the hammer is transferred to the nail.]

Enrichment

Ask a group of students to brainstorm a creative way to demonstrate how mass and velocity affect an object's momentum. With your approval, have the students make a video of their demonstration to share with the class.

Science Inquiry

Have small groups of students discuss and try to solve the problems at the URL below (answers are provided). The problems require students to apply Newton's third law of motion and the concept of momentum.

- http://www.physicsclassroom.com/class/momentum/u4l2a.cfm

Real-World Connection

Many sports provide real-world examples of Newton's third law of motion. Have students watch the video below to see how Newton's third law applies to football.

- http://www.nsf.gov/news/special_reports/football/newtonthirdlaw.jsp

Answer to You Try It!

Problem: Which football player has greater momentum?

Player A: mass = 60 kg; velocity = 2.5 m/s

Player B: mass = 65 kg; velocity = 2.0 m/s

Solution: Player A's momentum is 60 kg × 2.5 m/s = 150 kg • m/s, and player B's momentum is 65 kg × 2.0 m/s = 130 kg • m/s, so player A has greater momentum.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. State Newton's third law of motion.
   - [Newton's third law of motion states that every action has an equal and opposite reaction.]
2. Define momentum.
   - [Momentum is a property of a moving object that makes the object hard to stop. It equals the object's mass times its velocity.]
3. If you double the velocity of a moving object, how is its momentum affected?
   - [If you double the velocity of a moving object, its momentum also doubles.]
4. A large rock has a mass of 50 kg and is rolling downhill at 3 m/s. What is its momentum?
   - [The momentum of the rock is 50 kg × 3 m/s = 150 kg • m/s.]
5. Create a diagram to illustrate the transfer and conservation of momentum when a moving object collides with a stationary object.
   - [Sketches will vary but should show that students have a correct understanding of how momentum is transferred and conserved when a moving object collides with a stationary object. One of the objects should have an initial velocity of 0 m/s before the other object collides with it. The combined momentum
6. of the two objects should be the same before and after the collision occurs.]
7. The reaction to an action is an equal and opposite force. Why doesn't this yield a net force of zero?
   - [Although the reaction to an action is an equal and opposite force, it doesn't yield a net force of zero because the forces apply to different objects. Therefore, the forces do not cancel each other out.]
8. Momentum is a property of an object, but it is different than a physical or chemical property, such as boiling point or flammability. How is momentum different?
   - [Unlike physical and chemical properties, momentum is not unique for a given object, nor is it unchanging. Many objects can have the same momentum, and momentum changes whenever an object's velocity or mass changes.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 14.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you learned about forces and motions of solid objects, such as balls and cars. In the next chapter, "Fluid Forces," you will learn about forces in fluids, which include liquids and gases.

- How do fluids differ from solids?

Unlike solids, fluids can flow and take the shape of their container.

- What might be examples of forces in fluids? For example, what force allows some objects to float in water?

A force in fluids is buoyant force, which is the force that allows some objects to float in water.

14.5 References

1. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0

CHAPTER 15 TE Fluid Forces

Chapter Outline

15.1 Chapter 15: Fluid Forces

Chapter Overview

All fluids exert pressure because their particles are constantly moving. Pressure is the amount of force per unit area, expressed in the SI unit N/m^2, which is called the pascal (Pa). Factors that affect the pressure of fluids include depth and density. According to Pascal's law, a fluid transmits pressure equally throughout the fluid. According to Bernoulli's law, the faster a fluid is moving, the less pressure it exerts. Buoyancy is the ability of a fluid to exert an upward force, called buoyant force. According to Archimedes' law, buoyant force on an object equals the weight of the fluid displaced by the object.

Online Resources

See the following Web sites for appropriate laboratory activities:

With the inquiry lab at the following URL, students will design an experiment that demonstrates Bernoulli's law.

- http://www.nvscience.org/files/Bernoulli_Doesn_t_Suck_It_Blows1.doc

In the lab at the URL below, students are challenged to make a mini-submarine that behaves in certain ways (sinks to the bottom, stays down for at least 10 seconds, rises back up to the surface). The lab requires students to design their own experiment, identify independent and dependent variables, outline their procedure, and demonstrate their mini-submarine.

- http://serc.carleton.edu/sp/mnstep/activities/27604.html

These Web sites may also be helpful:

The following URL provides several interesting activities that demonstrate the properties of fluids under a variety of circumstances. They show the role of pressure in fluid behavior and also relate fluid pressure to everyday experiences.

- http://mypages.iit.edu/~smile/ph95p1.html

At the following URL, you can find several simple demonstrations that will help students understand basic principles relating to air pressure.

- http://mypages.iit.edu/~smile/ph8901.html

Use the ideas and activities at the URL below to teach the physics of the Bernoulli effect.

- http://mypages.iit.edu/~smile/phma2000.htm

The following URL provides a collection of lessons relating to fluid pressure and buoyancy. The lessons begin with a discussion of fluid pressure, buoyant force, and Archimedes' law. Interesting demonstrations and activities using common objects support the discussion. The activities give students hands-on experience with fluid forces.

- http://www.sbceo.org/~impact2/pdf/pkts2011/RyanHubbard/RyanHubbardComplete.pdf

Pacing the Lessons

TABLE 15.1: Pacing the Lessons

Lesson	**Class Period(s) (60 min)**
15.1 Pressure of Fluids	1.5
15.2 Buoyancy of Fluids	3.0

15.2 Lesson 15.1 Pressure of Fluids

Key Concept

All fluids exert pressure because their particles are constantly moving. Pressure is calculated as the amount of force per unit area, and the SI unit for pressure is the pascal (Pa), or N/m^2. The pressure of fluids is greater at greater depths, and denser fluids exert greater pressure than less dense fluids. Pascal's law states that a change in pressure at any point in an enclosed fluid is transmitted equally throughout the fluid. Bernoulli's law states that pressure in a moving fluid is less when the fluid is moving faster.

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.8.a
- NSES.5-8.D.1.8
- AAAS.6-8.1.A.4; AAAS.6-8.3.A.3; AAAS.6-8.3.C.3; AAAS.6-8.9.B.3; AAAS.6-8.11.C.3; AAAS.6-8.12.D.4, 11

Lesson Objectives

- Describe pressure and how to calculate it.
- Relate fluid depth and density to pressure.
- State Pascal's and Bernoulli's laws.

Lesson Vocabulary

- **Bernoulli's law**: law stating that pressure in a moving fluid is less when the fluid is moving faster
- **pascal (Pa):** SI unit for pressure, equal to 1 newton per square meter (N/m^2)
- **Pascal's law:** law stating that a change in pressure at any point in an enclosed fluid is transmitted equally throughout the fluid

Teaching Strategies

Introducing the Lesson

Introduce fluid pressure with the simple but effective "Water in a Cup" demonstration, which is described at the following URL. It demonstrates the effects of air pressure and shows that it acts in all directions. The document includes teacher notes and follow-up questions for class discussion.

- http://pzweb.harvard.edu/ucp/curriculum/pressure/s2_reinforcement_cup.pdf

Demonstration

Help students visualize Pascal's law with the demonstration described at the URL below. The demonstration could be done as a student activity instead. It clearly shows how pressure is transmitted throughout a fluid.

- http://www.sciencefair-projects.org/physics-projects/pascals-law.html

Building Science Skills

The class activity described at the following URL demonstrates Bernoulli's law. After the demonstration of the airfoil, give students a change to experiment with the position of the airfoil, the size of the contact surface at the front, and the length of the airfoil as an inquiry activity to build science skills. A question and answer session should close the activity. Ask, for example, what would happen if the airfoil was turned over (curved surface on bottom) and air was applied.

- http://epic.physics.missouri.edu/PDF%20files/Bernoulli_s_Principle_.pdf

Differentiated Instruction

Give less proficient readers the following cloze prompts to complete as they read the lesson. This will help focus their attention on the most important ideas. Make sure students know that most of the blanks require at least a few words to fill in adequately. Sample answers are given in brackets.

1. Fluids are ___________. [liquids and gases]
2. All fluids exert pressure because ___________. [their particles are constantly moving and bumping into things]
3. Pressure can be represented by the equation ___________. [Pressure $= \frac{\text{Force}}{\text{Area}}$]
4. The SI unit for pressure is ___________. [N/m^2, or the pascal (Pa)]
5. Two factors that affect pressure in fluids are ___________. [depth and density]
6. As you go deeper in the ocean, the pressure exerted by the water ___________. [increases]
7. As you go higher in the atmosphere, the pressure exerted by the air ___________. [decreases]
8. Pascal's law states that ___________. [a change in pressure at any point in an enclosed fluid is transmitted equally throughout the fluid]
9. An example of Pascal's law is ___________. [ketchup squirting out of the open end of a packet when the opposite end is squeezed]
10. Bernoulli's law states that ___________. [pressure in a moving fluid is less when the fluid is moving faster]
11. Bernoulli's law explains how ___________. [the wings of birds and airplanes create lift and allow them to fly]

Enrichment

Students who are interested in engineering might want to explore hydraulics in greater depth. Direct them to the first URL below, which starts with a video showing how hydraulic machines are used on a crab boat. They can also read about the use of hydraulics in large construction machines, including shovel excavators, skid loaders, and dump trucks. Videos showing each type of machine in operation are included. After students read the article and watch the videos, suggest that they take the hydraulic machines quiz at the second URL below.

- http://science.howstuffworks.com/transport/engines-equipment/hydraulic.htm
- http://science.howstuffworks.com/transport/engines-equipment/hydraulic-machine-quiz1.htm?answerId=2192

Science Inquiry

Have small groups of students do the inquiry activity "Fluid Pressure—An Inquiry Introduction," which you can find at the following URL. The activity uses the first tab of the simulation "Fluid Pressure and Flow" (at the same URL). Students will investigate how pressure changes in air and water. They will also discover how they can change fluid pressure, and they will predict fluid pressure in a variety of situations.

- http://phet.colorado.edu/en/simulation/fluid-pressure-and-flow

Common Misconceptions

Misconceptions about gases and pressure are common. Read the following list of misconceptions to the class. For each statement, ask students to raise their hands if they think the statement is true. Call on other students to restate the misconception so it is true and to explain why.

- Gas is not a fluid; only liquids are fluids.
- Gases do not have properties of mass and weight.
- Air pressure is greater in a downward direction.
- Moving air has pressure only in the direction it is moving; if there is no movement, there is no pressure.

Answer to You Try It!

Problem: If the break dancer lies down on the ground on her back, her weight is spread over an area of 0.75 m^2. How much pressure does she exert on the ground in this position?

Solution: She exerts 450 N/0.75 m^2 = 600N/m^2, or 600 Pa

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define pressure.
   - [Pressure is the result of force acting on a given area. It can be represented by the equation Pressure = $\frac{\text{Force}}{\text{Area}}$.]
2. What is the SI unit for pressure?
   - [The SI unit for pressure is the pascal (Pa), which equals 1 N/m^2.]
3. Identify two factors that affect the pressure of fluids.
   - [Two factors that affect the pressure of fluids are the depth and density of fluids.]

4. Describe how pressure changes with depth in fluids.
    - [As fluid depth increases, pressure increases.]
5. Apply Pascal's law to explain why squeezing one end of a toothpaste tube causes toothpaste to squirt out the other end.
    - [Pascal's law states that a change in pressure at any point in an enclosed fluid is transmitted equally throughout the fluid. Toothpaste is a fluid. Therefore, if you squeeze one end of a toothpaste tube, the pressure is transmitted throughout the toothpaste, causing toothpaste to squirt out the other end.]
6. A box weighing 200 N is resting on the ground on an area of 1 m^2. How much pressure is the box exerting on the ground?
    - [The pressure of the box on the ground is equal to its weight divided by the area of the box that is resting on the ground: pressure $= \frac{200 \text{ N}}{1 \text{ m}^2} = 200 \text{ N/m}^2$, or 200 Pa.]
7. Explain why fluids exert pressure.
    - [The particles of fluids are constantly moving in all directions at random. As the particles move, they keep bumping into each other and into anything else in their path. These collisions cause pressure and explain why all fluids exert pressure.]
8. Relate Bernoulli's law to lift in an airplane.
    - [Bernoulli's law states that pressure in a moving fluid is less when the fluid is moving faster. This law explains how the wings of an airplane create lift. The wings cause air to flow more quickly—and air pressure to be lower—above the wings than below them. This allows the wings to lift the plane above the ground.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

If you've ever floated in water, you may have noticed that filling your lungs with air helps to keep you afloat.

- Why do you think having more air in your lungs helps you float in water?

Air has lower density than water.

- What other things float in water? What things don't float? How do they differ?

Other objects that float in water include corks and empty plastic bottles. Things that don't float include iron tools and

15.3 Lesson 15.2 Buoyancy of Fluids

Key Concept

Buoyancy is the ability of a fluid to exert an upward force on any object placed in the fluid. The upward force is called buoyant force. The buoyant force acting on an object in a fluid equals the weight of the fluid displaced by the object. This is known as Archimedes' law.

Standards

- SCI.CA.8.PS.2.a, b; SCI.CA.8.PS.8.a, c, d
- AAAS.6-8.1.A.4; AAAS.6-8.3.A.3; AAAS.6-8.3.C.3; AAAS.6-8.9.B.3

Lesson Objectives

- Describe the nature of buoyant force.
- State Archimedes' law.

Lesson Vocabulary

- **Archimedes' law:** law stating that the buoyant force acting on an object equals the weight of the fluid displaced by the object
- **buoyancy:** ability of a fluid to exert an upward force on any object placed in the fluid
- **buoyant force:** upward force exerted by a fluid on any object placed in it

Teaching Strategies

Introducing the Lesson

Introduce buoyancy of fluids with a large tub of tap water and a few common objects, some of which will sink (e.g., metal toy car, golf ball) and some of which will float (rubber duck, ping-pong ball). Before placing each object in the tub of water, ask students to predict whether it will sink or float. After placing all the objects in the water, challenge students to explain why some of the objects sink and some of the objects float. Tell students they will learn the answers when they read this lesson.

Activity

Help students understand buoyancy and buoyant force by having them do the activity at the following URL. Students will construct a graph that illustrates Archimedes' law and learn that the buoyant force on an object equals the weight of the fluid it displaces.

- http://mypages.iit.edu/~smile/ph9524.html

Differentiated Instruction

Using an overhead transparency, work with students to make a cluster diagram for buoyant force. The central circle of the diagram should be labeled "Buoyant Force." Surrounding circles might be labeled "Pressure," "Weight," "Density," and "Archimedes' Law." Guide students in filling in important details in each circle.

Enrichment

Challenge students to explain how Archimedes' law relates to the displacement method of measuring the volume of irregularly shaped objects (the displacement method is described in FlexBook® Chapter 3, "Introduction to Matter"). (*Sample answer*: Archimedes determined that an object displaces a volume of fluid equal to its own volume. If the volume of the displaced fluid can be measured, it will give the volume of the object.)

Science Inquiry

Students may have a better understanding of Archimedes' law if they do the "Penny Boat Challenge" at the URL below. The goal is to design an aluminum-foil boat that can hold the greatest number of pennies without sinking. Make sure students answer the Reflection questions at the end of the activity. The questions require them to write about the strategies they used to solve the problem, what worked and what didn't, and what they would change if they did the activity again.

- http://www.middleschoolscience.com/pennyboat.pdf

Common Misconceptions

A common misconception is that buoyant force is greater on a floating object than a submerged object. Explain to the class why this is not necessarily true. A submerged object will have a greater buoyant force acting on it if it displaces more fluid than a floating object. However, the weight of the submerged object is greater than the buoyant force acting on it, and this explains why it sinks rather than floats.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is buoyancy?
   - [Buoyancy is the ability of a fluid to exert an upward force on any object placed in the fluid.]
2. Describe how weight and buoyant force determine whether an object sinks or floats.
   - [If an object's weight is greater than the buoyant force acting on it, then the object sinks. If an object's weight is less than the buoyant force acting on it, then the object floats.]
3. How is density related to buoyancy?
   - [Density, or the amount of mass in a given volume, is related to buoyancy because density affects weight. A given volume of a denser substance is heavier than the same volume of a less dense substance. As a result, less dense substances generally float in a denser fluid. For example, ice cubes float in a glass of water because ice is less dense than liquid water.]
4. Apply Archimedes' law to explain why some very heavy objects float in water.
   - [Archimedes' law states that the buoyant force acting on an object equals the weight of the fluid displaced by the object. This law explains why a ship floats in water even though it is very heavy. The shape of the hull causes it to displace a volume of water that weighs more than the weight of the ship, so the buoyant force acting on the ship is greater than the ship's weight.]
5. Relate displacement of a fluid by an object to the buoyant force acting on the object.
   - [The displacement of a fluid by an object occurs because the object and fluid cannot occupy the same space at the same time. The volume of fluid displaced equals the volume of the object. The weight of the displaced fluid equals the buoyant force acting on an object.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 15.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you saw how pressure and buoyancy of fluids can be used to make work easier—from raising a car on a lift to floating a ship on the ocean. Devices that make work easier are called machines in physics.

- What are some examples of machines?

Examples include washing machines and cars.

- How do these machines make work easier?

They provide more power than a person can apply to do the same job.

CHAPTER 16 TE Work and Machines

Chapter Outline

16.1 Chapter 16: Work and Machines

Chapter Overview

Work is the use of force to move an object. It is calculated as the product of force and distance and is measured in joules (J). Power is a measure of the amount of work that can be done in a given amount of time and is measured in watts (w). A machine is any device that makes work easier by increasing force, increasing the distance over which force is applied, and/or changing the direction of force. The efficiency of a machine is a measure of how well it reduces friction. The mechanical advantage is the number of times a machine multiplies the input force. There are six types of simple machines: inclined plane, wedge, screw, lever, wheel and axle, and pulley. They differ in their mechanical advantage and how they make work easier. Compound machines, such as bicycles and scissors, consist of two or more simple machines. They generally have lower efficiency but greater mechanical advantage than simple machines.

Online Resources

See the following Web sites for appropriate laboratory activities:

With the simple lab at the URL below, students can investigate the scientific meaning of work.

- http://www.science-class.net/Lessons/Physics/Simple%20Machines/work_V2S.pdf

In this lab, students will investigate how moving the fulcrum of a lever changes the way the lever works and also its mechanical advantage.

- http://www.science-class.net/Lessons/Physics/Simple%20Machines/Types%20of%20Levers.pdf

Students can investigate pulleys with the lab at the URL below. They will build pulleys and develop and test a hypothesis to answer the question: "How does the type of pulley system affect mechanical advantage?"

- http://camillasenior.homestead.com/Investigating_pulleys1.pdf

The applied lab activity described at the following URL requires students to design a complex machine that consists of multiple simple machines.

- http://sciencespot.net/Pages/classphys.html#Anchor2

These Web sites may also be helpful:

This URL provides a complete lesson plan on work and machines. It includes vocabulary, teacher background, assessments, and numerous activities.

- http://camillasenior.homestead.com/files/machines_unit.pdf

You can find a teacher-created activity on each of several simple machines at the URL below.

- http://mypages.iit.edu/~smile/ph9005.html

These URLs provide many useful resources and links to other sites dealing with simple machines:

- http://www.thomasnet.com/articles/machinery-tools-supplies/simple-machine-guide
- http://tabstart.com/directory/education/simple-machines-%E2%80%93-levers-worksheet-activity-1419
- http://www.science-class.net/Physics/simple_machines.htm

Pacing the Lessons

TABLE 16.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
16.1 Work	2.0
16.2 Machines	2.0
16.3 Simple Machines	3.0
16.4 Compound Machines	1.0

16.2 Lesson 16.1 Work

Key Concept

Work is the use of force to move an object. It can be calculated as the product of force and distance. The SI unit for work is the joule (J). Power is a measure of the amount of work that can be done in a given amount of time. The SI unit for power is the watt (W).

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.2.a
- AAAS.6-8.11.C.3; AAAS.6-8.12.B.8, 9

Lesson Objectives

- Define work, and state how to calculate it.
- Explain how power is related to work.

Lesson Vocabulary

- **joule (J):** SI unit for work, equal to the amount of work that is done when 1 newton of force moves an object over a distance of 1 meter
- **power:** measure of the amount of work that can be done in a given amount of time
- **watt (W):** SI unit for power, equal to 1 joule of work per second
- **work:** use of force to move an object; calculated as force multiplied by distance

Teaching Strategies

Introducing the Lesson

Play a word association game to introduce the concept of work to the class. Ask each student in turn to say the first word that comes to mind when they hear the word work. Based on their responses, discuss how the word is used in everyday language. Tell students they will learn in this lesson that work has a somewhat different and very specific meaning in physical science than it does in everyday usage.

Activity

Students will develop an understanding of the concept of work as it is used in physics by doing the quick and simple group activity "Let's Share the Work" (pages 10–11 in the document below). Through the activity (which involves moving books in boxes), students will realize that work means using a force to move a mass over a distance.

- http://camillasenior.homestead.com/files/machines_unit.pdf

Differentiated Instruction

Match English language learners and less proficient readers with students who excel in English, and ask partners to make a Frayer model for the word work. They should draw a box, divide it into four parts, and label the parts "Definition," "Drawing," "Example," and "Non-example." Then they should fill in each part of the box for the term. Invite students to present their models to the rest of the class.

Enrichment

Students with a strong interest in cars might want to learn more about the power of car engines. Suggest that they interview someone with expert knowledge in this area, such as an automotive technician. They might ask the expert about how the power of car engines is measured, how the power of different types of vehicles compares, how power is increased in car engines, and the pros and cons of more powerful engines.

Science Inquiry

Assign pairs of students to do the guided inquiry activity at the following URL. They will make predictions and then use themselves as subjects (by climbing stairs) to gather data and calculate work and power. The document below includes vocabulary, background information, the activity procedure, a materials list, and follow-up questions.

- http://camillasenior.homestead.com/Work_power.pdf

Common Misconceptions

Students may form the misconception that any force times any distance is work. Make sure they understand that work is done only when the force is applied in the same direction that a mass moves. Give them a counter example of a force and distance that does not result in work being done, such as walking while holding a heavy object. Explain how the direction of the force (upward against the pull of gravity) is not the same as the direction in which the object is moving. Therefore, no work is done, regardless of the distance the object moves, its weight, or other factors.

Math Connection

Students can practice using equations to solve physics problems by solving the problems at the URL below. They will compute values for work, power, mechanical advantage, and efficiency.

- http://camillasenior.homestead.com/files/work__power_and_mechanical_efficiency_-_information_and_problems.pdf

Answers to You Try It!

Problem: Lara lifted a 100 N box 1.5 meters above the floor. How much work did she do?

Solution: The work Lara did is: Work = 100 N × 1.5 m = 150 N • m, or 150 J

Problem: How much work is done in 30 seconds by a 1000 watt microwave?

Solution: The work done by the microwave is: Work = 1000 J/s × 30 s = 30,000 J.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How is work defined in physics?
   - [In physics, work is defined as the use of force to move an object.]
2. What does power measure?
   - [Power measures the amount of work that can be done in a given amount of time.]
3. Identify the SI units for work and power.
   - [The SI unit for work is the joule (J), or Newton • meter. The SI unit for power is the watt (W), or joule/second.]
4. Jana lifted a 200-newton weight over her head to a distance of 2 meters above the ground. How much work did she do?
   - [The work Jana did is 200 N × 2 m = 400 N • m, or 400 J.]
5. Pieter picked up a 20-newton book from the floor. Then he passed it to Ahmad, who carried it for 20 meters. How much work did Ahmad do?
   - [Ahmad did no work because he applied an upward force to the book while the book moved in a horizontal direction as he carried it.]
6. If an electric mixer does 10,000 joules of work in 10 seconds, what is its power?
   - [The power of the mixer is 10,000 J ÷ 10 s = 1000 J/s, or 1000 W.]
7. Explain how power is related to work.
   - [Power is related to the time needed to do work. Compared with a less powerful device, a more powerful device can either do more work in the same time or do the same work in less time.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Machines such as the tractor and leaf blower you read about in this lesson help people do work.

- What are other examples of machines?

***Sample answer*: Other examples of machines include cars, drills, and washing machines.**

- What do all these machines have in common?

All these machines make work easier.

16.3 Lesson 16.2 Machines

Key Concepts

A machine is any device that makes work easier by changing a force. A machine may increase force, increase the distance over which force is applied, and/or change the direction of force. The efficiency of a machine is a measure of how well it reduces friction. It is calculated as the percent of input work that becomes output work. The mechanical advantage of a machine is the number of times it multiplies the input force. The ideal mechanical advantage is the multiplication of force that would be achieved in the absence of friction. It is calculated as the input distance divided by the output distance.

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.2.a
- AAAS.6-8.10.J.1, 2; AAAS.6-8.11.C.3; AAAS.6-8.12.B.2, 8, 9

Lesson Objectives

- Explain how machines help us do work.
- Define efficiency, and state how it is calculated.
- Define mechanical advantage, and state how it is calculated.

Lesson Vocabulary

- **efficiency:** measure of how well a machine reduces friction; calculated as the percent of input work that becomes output work
- **mechanical advantage:** number of times a machine multiplies the input force; calculated as the output force divided by the input force
- **machine:** any device that makes work easier by changing a force

Teaching Strategies

Introducing the Lesson

Introduce machines by pointing out various objects in the classroom and asking students whether or not they think each object is a machine. Examples of machines you might point out could include a pencil sharpener, door knob, hinge, and screw. Students are likely to be surprised that such simple devices are indeed examples of machines. This discovery will disavow students of the common notion that only complex devices are machines. It may also pique their curiosity about what makes an object a machine.

Slide Show

Use the slides at the following URL to teach the concepts of efficiency and mechanical advantage. The slides present the material in a very clear, easy-to-understand format that incorporates visuals. The slides also include practice problems for students to solve as you go through presentation. The problems allow students to apply the concepts as they learn them to test and reinforce their understanding.

- http://www.slideshare.net/jbishopgcms/mechanical-advantage-and-efficiency

Differentiated Instruction

The common meanings of the terms efficiency and advantage are closely related to the meanings of efficiency and mechanical advantage in physics. Plumb students' conceptions of the common meanings of the words to help them understand the physics terms. Call on them to explain in their own words what they think efficiency and advantage mean, or have them use the words in sentences. For example, a student might define efficiency as "doing a job without any wasted effort" and advantage as "something that helps you play a sport or do some other task better." Relate their definitions to the meanings of efficiency and mechanical advantage as used in this lesson.

Enrichment

Students who are cycling enthusiasts may be interested in learning why the bicycle is the most efficient means of transportation. Suggest that they read the article at the URL below.

- http://www.exploratorium.edu/cycling/humanpower1.html

Science Inquiry

Challenge students to develop a research plan to investigate how the mechanical advantage of a ramp is affected by changing the ramp's slope. They should first develop a hypothesis based on the formula for finding the ideal mechanical advantage of a ramp. They should also identify independent and dependent variables, make a list of materials they would need, and outline the procedure they would use to test their hypothesis. If time permits, have students carry out their investigations and write a brief report on their results.

Common Misconceptions

Many people believe that machines put out more work than we put in and do not realize that machines simply change the form of the work we do. Explain how there is always a tradeoff between force and distance when work is done by a machine. A machine that increases force applies the force over a shorter distance, and vice-versa. Give students several concrete examples to help them see how these trade-offs apply to the use of machines.

Answer to You Try It!

Problem: Rani puts 10,000 joules of work into a car jack. The car jack, in turn, puts out 7000 joules of work to raise up the car. What is the efficiency of the jack?

Solution: The efficiency of the jack is:

$\text{Efficiency} = \frac{7000 \text{ J}}{10{,}000 \text{ J}} \times 100\% = 70\%$

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a machine?
   - [A machine is any device that makes work easier by changing a force.]
2. Identify three different ways that machines may change force.
   - [Machines may increase the amount of force applied, increase the distance over which force is applied, or change the direction in which force is applied.]
3. What does efficiency measure?
   - [Efficiency measures how well a machine reduces friction.]
4. Define actual mechanical advantage.
   - [Actual mechanical advantage is the number of times a machine multiplies the input force, taking into account the amount of input force that is needed to overcome friction.]
5. How does ideal mechanical advantage differ from actual mechanical advantage? How is ideal mechanical advantage calculated?
   - [Ideal mechanical advantage represents the multiplication of input force that would be achieved in the absence of friction. It is greater than actual mechanical advantage because all machines use up some work to overcome friction. Ideal mechanical advantage is calculated by dividing the input distance by the output distance.]
6. In the picture below, a screwdriver is being used to pry the lid off a paint can. The tip of the screwdriver is resting on the top edge of the can. When the handle of the screwdriver is pushed down, the tip of the screwdriver pushes up on the edge of the lid. Draw a simple labeled sketch to show the input and output distances involved in this work. How does the input distance compare with the output distance? Is the ideal mechanical advantage of the screwdriver greater than, less than, or equal to 1?

- [Sketches should show that the screwdriver is being used as a lever, where the fulcrum (not labeled as such) is the part of the screwdriver that rests on the edge of the paint can. The length of the screwdriver from the hand to the fulcrum should be labeled input distance. The length of the screwdriver from the fulcrum to the end that pushes up against the lid should be labeled output distance. The input distance is longer than the output distance, so the ideal mechanical advantage is greater than 1.]

7. Assume that a machine puts out 8000 joules of work when the user puts in 10,000 joules of work. What is the efficiency of the machine?
   - [The efficiency of the machine is 8000 J $\div$ 10,000 J $\times$ 100% = 80%.]
8. The mechanical advantage of a machine is related to how it changes force. Explain this relationship.
   - [For machines that increase force, the output force is greater than the input force, so the mechanical advantage is greater than 1. For machines that increase the distance over which force is applied, the output force is less than the input force, so the mechanical advantage is less than 1. For machines that change only the direction of force, the output force is the same as the input force, so the mechanical advantage equals 1.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The canoe paddles, nutcracker, and hammer that you read about in this lesson have something in common. All three are examples of a type of simple machine called a lever.

- Based on these three examples, how would you describe a lever?

A lever consists of a bar that rotates around a fixed point.

- How do you think a lever changes the force applied to it?

A lever may increase the applied force and it may change the direction of the force.

16.4 Lesson 16.3 Simple Machines

Key Concepts

An inclined plane is a simple machine consisting of a sloping surface that connects lower and higher elevations. A wedge is a simple machine that consists of two inclined planes. A screw is a simple machine that consists of an inclined plane wrapped around a cylinder or cone. A lever is a simple machine that consists of a bar that rotates around a fixed point called the fulcrum. There are three classes of levers. A wheel and axle is a simple machine that consists of two connected rings or cylinders, one inside the other, which both turn in the same direction around a single center point. Force can be applied to the inner axle or outer wheel. A pulley is a simple machine that consists of a rope and grooved wheel. Single pulleys may be fixed or moveable. Single and moveable pulleys may be combined in a compound pulley.

Standards

- AAAS.6-8.12.D.4

Lesson Objectives

- Explain how an inclined plane changes force.
- List common examples of wedges and screws.
- Compare and contrast the three classes of levers.
- Describe two ways that a wheel and axle can be used.
- Identify three types of pulleys.

Lesson Vocabulary

- **inclined plane:** simple machine consisting of a sloping surface that connects lower and higher elevations
- **lever:** simple machine consisting of a bar that rotates around a fixed point called the fulcrum
- **pulley:** simple machine that consists of a rope and grooved wheel
- **screw:** simple machine that consists of an inclined plane wrapped around a cylinder or cone
- **wedge:** simple machine that consists of two inclined planes
- **wheel and axle:** simple machine that consists of two connected rings or cylinders, one inside the other, which turn in the same direction around a center point

Teaching Strategies

Introducing the Lesson

Show students several examples of levers (e.g., pry bar, scissors, pliers, broom, fork, stapler, bottle opener, baseball bat, hockey stick). Call on volunteers to demonstrate how each item is used. Tell the class that all of the items are levers, a type of simple tool they will read about in this lesson.

Activity

Students can prove to themselves that a screw contains an inclined plane with the simple activity at the first URL below. They will make a paper inclined plane and wrap it around a pencil to make a screw. Seeing and measuring the inclined plane by itself first will help them understand the structure and function of a screw. At the second and third URLs below, students can find an activity that allows them to investigate inclined planes of actual screws.

- http://sln.fi.edu/qa97/spotlight3/screwdemo.html
- http://camillasenior.homestead.com/Plane_Pretenders.pdf
- http://camillasenior.homestead.com/Plane_Pretenders._Part_2_pdf.pdf

Building Science Skills

Have students apply their understanding of simple machines by identifying the types of simple machines that would be most appropriate for various jobs. You can find a list of ideas at this URL:

- http://camillasenior.homestead.com/files/machines.pdf

Differentiated Instruction

Kinesthetic learners and any students with language difficulties may benefit from a hands-on exploration of simple machines. Provide them with an opportunity to use at least one common example of each type of simple machine and experience how each simple machine makes work easier. For example, they might climb some steps (inclined plane), use a chisel (wedge) to remove some wood from a board, use a wood screw (screw) and screw driver to pierce a board, use the claw end of a hammer (lever) to pry a nail out of a board, turn a door knob (wheel and axle) to open a door, and raise a flag on a flagpole with a pulley (pulley). Discuss with the students how much more difficult each task would be without the simple machine.

Enrichment

Challenge pairs of students to do the activity at the following URL, in which they investigate how the human forearm acts as a third-class lever. At the end of the activity, students will create a project display that can be presented to the rest of the class.

- http://www.education.com/science-fair/article/human-machine/

Science Inquiry

The inquiry activity at the URL below allows students to investigate levers and discover the mechanical advantage of levers in each class. They will apply process skills of observing, inferring, and measuring. They will also draw conclusions about appropriate applications for levers in each class.

- [http://www.teachhealthk-12.uthscsa.edu/curriculum/levers/levers02a.asp

Real-World Connection

Have students do a simple machines scavenger hunt in which they find as many simple machines as possible in the classroom or at home. Students can work alone, in pairs, or in small groups. Give students a chance to share their lists of the simple machines they found. Discuss which simple machines seem to be most common in their everyday lives.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is an inclined plane?
   - [An inclined plane is a simple machine consisting of a sloping surface that connects lower and higher elevations.]
2. Give an example of a wedge. What work does it do?
   - [Answers may vary. *Sample answer*: An example of a wedge is a chisel. It splits apart rocks or other hard objects.]
3. How does force change when it is applied to the axle of a wheel and axle?
   - [When force is applied to the axle of a wheel and axle, it changes by being applied over a greater distance.]
4. What determines the ideal mechanical advantage of a pulley?
   - [The ideal mechanical advantage of a pulley is determined by the number of rope segments pulling up on the object.]
5. A leaf rake is a type of lever. Where is the fulcrum and where are the input and output forces applied? Which class of lever is a rake? Explain your answer.
   - [The fulcrum of a rake is the point where the rake is held by the upper hand. The input force is applied at the point held by the lower hand. The output force is applied by the tines at the bottom of the rake. The rake is a third-class lever, because the input force is located between the fulcrum and output force.]
6. Explain why inclined planes, wedges, and screws always have an ideal mechanical advantage greater than 1.
   - [The ideal mechanical advantage of an inclined plane, wedge, or screw equals the length of the sloping inclined plane surface (input distance) divided by its maximum height (output distance). The length of the plane is always greater than its height, so its mechanical advantage is always greater than 1.]
7. Compare and contrast the three classes of levers.

- [In a first-class lever, the fulcrum is located between the input and output forces. The ideal mechanical advantage of a first-class lever may be greater than, equal to, or less than 1. In a second-class lever, the output force is located between the fulcrum and the input force. The ideal mechanical advantage of a second-class lever is always greater than 1. In a third-class lever, the input force is located between the fulcrum and the output force. The ideal mechanical advantage of a third-class lever is always less than 1. First-class levers change the direction of the applied force; second- and third-class levers do not.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that a compound pulley consists of two or more single pulleys. Many other machines also consist of two or more simple machines.

- Can you think of additional examples of machines that consist of more than one simple machine? Which simple machines do they contain?

Examples include a wheelbarrow, which contains a lever and a wheel and axle, and an axe, which contains a lever and

- How might combining simple machines into a more complex machine affect efficiency and mechanical advantage?

Combining simple machines into more complex machines generally decreases efficiency and increases mechanical adv

16.5 Lesson 16.4 Compound Machines

Key Concepts

A compound machine consists of two or more simple machines. Examples of compound machines include bicycles, cars, scissors, and fishing rods with reels. Compound machines generally have lower efficiency but greater mechanical advantage than simple machines.

Lesson Objectives

- Give examples of compound machines.
- Describe the efficiency and mechanical advantage of compound machines.

Lesson Vocabulary

- **compound machine:** machine that consists of more than one simple machine

Teaching Strategies

Introducing the Lesson

Show students a pair of scissors and tell them to watch closely as you use the scissors to cut a piece of paper. Ask students if they can identify any simple machines in the scissors (two levers and two wedges). Explain that scissors are an example of a compound machine, or a machine that consists of two or more simple machines. Tell students they will learn more about compound machines, including scissors, when they read this lesson.

Activity

Students can make their own compound machines to do specific jobs by following the instructions at the URLs below.

- http://www.ehow.com/how_4687302_make-compound-machine.html
- http://www.ehow.com/how_7343932_build-compound-machine-pop-balloon.html

Using Visuals

Have students look closely at Rube Goldberg's "self-operating napkin," which opens the chapter. Challenge them to identify the simple machines that make up this silly compound machine. Ask them to describe the job that each simple machine performs.

Differentiated Instruction

Work with students to make a Venn diagram that compares and contrasts compound machines and simple machines. You can find a sample Venn diagram at this URL: http://learningideasgradesk-8.blogspot.com/2011/05/simple-and-compound-machines-venn.html .

Enrichment

Ask a small group of students to select a compound machine they find at home and identify the simple machines it contains. Compound machines they might select could include a skateboard, pencil sharpener, egg beater, or can opener. Have the students determine how the simple machines they identify work together to accomplish the task for which the compound machine was designed. Invite students to bring the complex machine to class and share their analysis of it.

Science Inquiry

Students can investigate the problem, "what is a compound machine," with the guided inquiry activity at the following URL. Students will build a compound machine that contains gears and a wheel and axle, and they will use their machine to lift a load. Then they will explore how increasing the number of teeth on one gear changes the speed of the second gear. They will also investigate how increasing the radius of the wheel and axle affects their results.

- http://www.education.com/science-fair/article/combined/

Real-World Connection

Point out that a very complex machine with hundreds of moving parts is likely to have low efficiency. For example, a car engine typically has an efficiency of only about 15–30 percent. In other words, only about this percentage of the energy released by burning gas in the engine is available to move the car. At the first URL below, you can see what happens to the rest of the energy produced by gasoline combustion. At the second URL, you can find tips for driving that make a vehicle run more efficiently. Share the information at these URLs with the class. Then check students' understanding of the concept of efficiency by asking the following question:

Question: What is the efficiency of a car when it is idling at a red light?

Answer: The efficiency is 0% because none of the energy is being used to do the work of moving the car.

- http://www.fueleconomy.gov/feg/atv.shtml
- http://www.fueleconomy.gov/feg/driveHabits.shtml

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a compound machine?
    - [A compound machine is a machine that consists of more than one simple machine.]
2. Give two examples of compound machines.
    - [Answers may vary. *Sample answer*: Two examples of compound machines are scissors and fishing rods with reels.]
3. How is the mechanical advantage of a compound machine calculated?
    - [The mechanical advantage of a compound machine is calculated by multiplying the mechanical advantages of all its component simple machines.]
4. The can opener in the picture below is a compound machine. Identify two simple machines it contains.

    - [Answers may include any two of the following three simple machines: wedge, wheel and axle, and/or lever.]
5. Explain why the efficiency of compound machines is generally less than the efficiency of simple machines.
    - [The efficiency of compound machines is generally less than the efficiency of simple machines because compound machines have more moving parts. Therefore, they generally have more friction to overcome. The greater friction is, the lower is the efficiency of the machine.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 16.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Some of the machines you read about in this chapter require electricity in order to work. Electricity is a form of energy.

- What is energy?

Energy is the ability to do work or, more generally, to cause changes in matter.

- Besides electricity, what might be other forms of energy?

Some other forms of energy include mechanical, light, and sound energy.

CHAPTER 17 TE Introduction to Energy

Chapter Outline

17.1 Chapter 17: Introduction to Energy

Chapter Overview

Energy, or the ability to do work, can exist in different forms. Forms of energy include mechanical, chemical, electrical, nuclear, thermal, electromagnetic, and sound energy. These forms of energy can occur as either kinetic or potential energy. Any form of energy can change into any other form or forms, but energy is always conserved when it changes form. Nonrenewable energy resources are limited in supply and cannot be replaced except over millions of years, and they also release pollutants and contribute to global climate change. Renewable energy resources are virtually limitless in supply or can be replaced in a relatively short period of time, and they cause little if any pollution or global climate change. Most of the energy used worldwide, especially in richer nations, comes from fossil fuels. There are many ways that people can conserve energy.

Online Resources

See the following Web sites for appropriate laboratory activities:

The kinetic and potential energy lab at the first URL below uses the simulations at the URLs that follow. In the lab, students will explore the interaction between kinetic and potential energy in three different situations.

- http://phet.colorado.edu/en/contributions/view/3186
- http://phet.colorado.edu/simulations/sims.php?sim=Energy_Skate_Park
- http://phet.colorado.edu/simulations/sims.php?sim=Pendulum_Lab
- http://phet.colorado.edu/simulations/sims.php?sim=Lunar_Lander

For Lesson 17.3, use the lab "How Can We Generate Electricity?" on pages 37–40 of the following document. Students will learn how electricity is made and make a turbine to rotate an electromagnet. Students will realize that to make electricity, something has to turn a turbine, such as wind, falling water, or steam from burning coal.

- http://www.nrel.gov/docs/gen/fy01/30927.pdf

In the lab "Which Has More Heat?" (pages 61–64) students will learn that different types of fuels produce different amounts of thermal energy.

- http://www.nrel.gov/docs/gen/fy01/30927.pdf

These Web sites may also be helpful:

The following document contains excellent background for teachers as well as many student activities on several important chapter concepts.

- http://www.nrel.gov/docs/gen/fy01/30927.pdf

The tutorials at the following URL develop chapter concepts in greater detail. They provide a good review for teachers and more challenging reading for student enrichment.

- http://www.nfcrc.uci.edu/EnergyTutorial/energy.html

If you want to delve deeper into energy conservation with your students, you can use the lesson plan and associated resources at this URL: http://ase.org/resources/lesson-plan-conscientious-consumer .

Pacing the Lessons

TABLE 17.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
17.1 Types of Energy	2.0
17.2 Forms of Energy	2.0
17.3 Energy Resources	2.0

17.2 Lesson 17.1 Types of Energy

Key Concept

Energy is the ability to do work, and it can exist in different forms, such as electrical or chemical energy. Most forms of energy can also be classified as kinetic or potential energy. Kinetic energy is the energy of moving matter. Potential energy is the energy stored in an object because of its position or shape, and it includes gravitational potential energy and elastic potential energy. Energy conversion occurs when energy changes from one type or form of energy to another. Energy is always conserved during energy conversions.

Standards

- SCI.CA.8.IE.9.f
- MCR.6-8.SCI.9.1, 2
- NSES.5-8.B.3.1
- AAAS.6-8.4.E.1, 2, 4; AAAS.6-8.5.E.6; AAAS.6-8.8.C.1; AAAS.6-8.12.D.11

Lesson Objectives

- Relate energy to work.
- Describe kinetic energy.
- Identify two types of potential energy.
- Give examples of energy conversions between potential and kinetic energy.

Lesson Vocabulary

- **energy conversion:** process in which energy changes from one type or form to another
- **potential energy:** stored energy an object has because of its position or shape

Teaching Strategies

Introducing the Lesson

Introduce kinetic and potential energy with the Wile E. Coyote and Roadrunner cartoon at the following URL. Labels identify types of energy and energy conversions as they occur in the cartoon. Challenge students to form operational definitions of kinetic and potential energy after they watch the cartoon but before they read the lesson.

- http://www.schooltube.com/video/f147084ab011fc64a890/

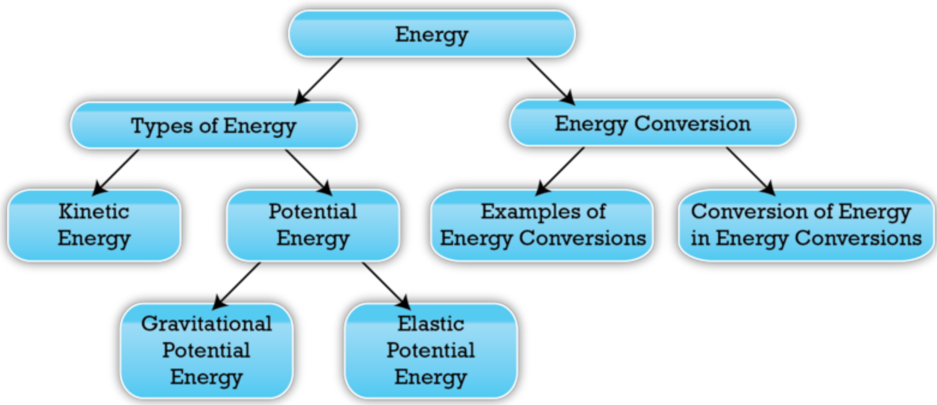
Activity

Have students use the interactive animation at the URL below to see how energy changes between kinetic and potential energy on a roller coaster.

- http://www.teachersdomain.org/asset/mck05_int_rollercoaster/

Differentiated Instruction

Work with students who need extra help to make a concept map organizing lesson concepts. A sample concept map is shown below.



Enrichment

Challenge a small group of students to brainstorm an activity in which energy changes back and forth between kinetic and potential energy. Then ask the students to create a display or diagram to show the energy changes that occur during the activity. Possible activities might include skateboarding or skydiving.

Science Inquiry

Assign the inquiry activity "Energy Conversion" on pages 31–34 of the following document. Students will use sensory experiences to create an energy conversion grid.

- http://www.nrel.gov/docs/gen/fy01/30927.pdf

Common Misconceptions

The following energy misconceptions are widely held by students. Use them as a true-false quiz to identify which of the misconceptions your own students hold. Then discuss the misconceptions with the class. Explain why each statement is false, and call on students to reword the statements so they are true.

- Energy and force are interchangeable terms.
- Things use up energy.
- Energy is not conserved because we are "running out of it."

- An object at rest has no energy.
- Energy is a thing.
- Energy is only associated with movement.
- Energy is a fuel.
- Energy is recycled.

Answers to You Try It!

Problem: What is Juan's kinetic energy if he runs at a velocity of 4 m/s?

Solution: KE = $\frac{1}{2}$ × 50 kg × (4 m/s)^2 = 400 kg • m^2/s^2 = 400 N • m, or 400 J

Problem: Juan's dad has a mass of 100 kg. How much kinetic energy does he have if he runs at a velocity of 2 m/s?

Solution: KE = $\frac{1}{2}$ × 100 kg × (2 m/s)^2 = 200 kg • m^2/s^2 = 200 N • m, or 200 J

Problem: Kris is holding a 2-kg book at a height of 1.5 m above the floor. What is the gravitational potential energy of the book?

Solution: The weight of the book is its mass multiplied by the acceleration due to gravity: weight = 2 kg × 9.8 m/s^2 = 19.6 kg • m/s^2, or 19.6 N. The gravitational potential energy of the book is: GPE = 19.6 N × 1.5 m = 29.4 N • m, or 29.4 J.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define kinetic energy and give an example.
   - [Kinetic energy is the energy of moving matter. Examples may vary and can include any example of something in motion.]
2. What is potential energy?
   - [Potential energy is stored energy that an object has because of its position or shape.]
3. Describe how energy changes on a swing.
   - [On a swing, gravity gives the swing maximum potential energy when the swing is highest above the ground at each end of the arc of the swing. This potential energy changes to kinetic energy as the swing moves closer to the ground. As the swing starts to rise again, it regains its potential energy.]
4. Explain how energy changes in the spring toy below when it goes downstairs.

- [When the spring toy goes downstairs, gravity gives it potential energy that changes to kinetic energy as it goes from one step down to the next. As it lands on the next step, the spring compresses, which gives it elastic potential energy, in addition to its remaining gravitational potential energy. The potential energy changes to kinetic energy as the spring goes down another step. The process keeps repeating until the spring reaches the bottom of the stairs.]

5. How is energy related to work?
   - [Energy can be defined as the ability to do work. When work is done, energy is transferred form one object to another. Both energy and work are measured in the same unit, the joule (J), or N • m.]
6. Compare and contrast gravitational potential energy and elastic potential energy.
   - [Both gravitational potential energy and elastic potential energy refer to energy that is stored in objects. Gravitational potential energy is due to the position of an object above Earth's surface. This position gives the object the potential to fall toward the ground because of the pull of gravity. Elastic potential energy is due to an object's shape. This energy results when elastic objects are stretched or compressed. Elasticity gives them the potential to return to their original shape.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The examples of kinetic and potential energy you read about in this lesson are types of mechanical energy. Mechanical energy is one of several forms of energy you can read about in the next lesson, "Forms of Energy."

- Based on the examples in this lesson, how would you define mechanical energy?

Mechanical energy is the energy of an object that is moving or has the potential to move.

- What might be other examples of mechanical energy?

Another example is a child climbing the steps of a playground slide (kinetic energy) and then sitting at the top of the sl

17.3 Lesson 17.2 Forms of Energy

Key Concept

Forms of energy include mechanical, chemical, electrical, nuclear, thermal, electromagnetic, and sound energy. These forms of energy can occur as either kinetic or potential energy. Any form of energy can change into any other form or forms, but energy is always conserved when it changes form.

Standards

- MCR.6-8.SCI.9.1, 2, 4, 5, 6, 8
- NSES.5-8.B.3.1, 4, 5, 6
- AAAS.6-8.4.E.1, 2, 4; AAAS.6-8.4.F.5, 9; AAAS.6-8.5.E.6, 7, 8; AAAS.6-8.8.C.1, 4, 8

Lesson Objectives

- Identify different forms of energy.
- Describe how energy changes form.

Lesson Vocabulary

- **chemical energy:** energy that is stored in the bonds between atoms that make up compounds
- **electrical energy:** energy of moving electrons
- **electromagnetic energy :** energy, such as sunlight, that travels across space or through matter as electric and magnetic waves
- **mechanical energy:** energy of an object that is moving or has the potential to move; calculated as the sum of an object's kinetic and potential energy
- **sound energy:** energy that travels in waves through matter from a vibrating object
- **thermal energy:** total kinetic energy of all the atoms that make up an object

Teaching Strategies

Introducing the Lesson

Review kinetic and potential energy from the previous lesson ("Types of Energy") and introduce forms of energy with the brief animated video at this URL: http://www.schooltube.com/video/617c60f7739a4a8c53b3/ .

Building Science Skills

You may want to use the lesson plan "The Science of Energy" at the URL below to teach this lesson. The lesson plan includes a teacher demonstration and six lab stations dealing with different forms of energy. A different group of students is assigned to each station, and groups are responsible for learning and teaching the other groups about the experiments at their assigned stations. Instructions, guides, masters, and explanatory articles are provided for teachers and students.

- http://www.need.org/needpdf/Science%20of%20Energy.pdf

Differentiated Instruction

Have visual and English language learners do the poster activity (Part 2: "On the Trail of Energy") at the following URL. They will list different forms of energy that they identify in a poster.

- http://science.dadeschools.net/middleSchool/documents/resourceGuides/6-8/lessons/SC.B.1.3.1TheManyFormsofEnergy.pdf

Enrichment

Assign each of seven students one of the forms of energy described in the lesson. Then have the students learn more about their assigned form of energy and create a PowerPoint show or poster to convey the information to the other students in class.

Science Inquiry

Students can explore energy transformations in different modes of transportation with the inquiry activities at the URL below. Although developed for high school students, the activities are also suitable for middle schoolers.

- http://www.pbs.org/americanfieldguide/teachers/transportation/transportation_sum.html

Common Misconceptions

Students may be confused about conservation of energy when energy changes form. On the one hand, they learn that energy cannot be created or destroyed according to the law of conservation of energy. On the other hand, they also learn that some energy is generally "lost" due to friction when energy transformations occur. Make sure students understand that energy may be "lost" from a system when it is released to the environment as thermal energy, but the total amount of energy still remains the same.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define mechanical energy.
   - [Mechanical energy is the energy of an object that is moving or has the potential to move. It is calculated as the sum of an object's kinetic and potential energy.]
2. Give an example of chemical energy.
   - [Answers may vary. *Sample answer*: An example of chemical energy is the stored energy in wood, which is released as thermal energy when the wood burns.]
3. What is electrical energy?
   - [Electrical energy is the kinetic energy of moving electrons.]
4. Name two processes that release nuclear energy.
   - [Two processes that release nuclear energy are nuclear fission and nuclear fusion.]
5. List three types of electromagnetic energy.
   - [Answers may vary but should include three types of electromagnetic energy. *Sample answer*: Three types of electromagnetic energy are radio waves, microwaves, and X rays.]
6. If you were on the moon, no sound energy would be able to reach your ears. Explain why. (*Hint*: The moon has no atmosphere.)
   - [No sound energy would be able to reach your ears on the moon because particles of matter are needed to transmit sound waves and the moon has no atmosphere.]
7. State how energy is converted by the following electrical devices: light bulb, alarm clock, hair dryer.
   - [Energy is converted from electricity to light energy and thermal energy in a light bulb; from electricity to sound energy and light energy in an alarm clock; and from electricity to thermal energy, sound energy, and mechanical energy in a hair dryer.]
8. Relate the thermal energy of an object to the object's atoms.
   - [The constant motion of atoms of matter gives matter thermal energy. The amount of thermal energy in an object depends on how fast its atoms are moving and how many atoms the object has.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read about electrical appliances that convert electrical energy to other forms of energy, such as thermal energy or sound energy.

- What form of energy is converted to electrical energy when electric current is generated?

The mechanical energy of a moving turbine is converted to electrical energy by an electric generator.

- What natural resources might provide the energy needed to generate electricity?

Energy needed to generate electricity might come from fossil fuels, wind, sunlight, or moving water.

17.4 Lesson 17.3 Energy Resources

Key Concept

Nonrenewable energy resources, which include fossil fuels and uranium, are natural resources that are limited in supply and cannot be replaced except over millions of years. They also release pollutants and contribute to global climate change. Renewable energy resources—which include sunlight, moving water, wind, biomass, and geothermal energy—are natural resources that can be replaced in a relatively short period of time or are virtually limitless in supply. They cause little if any pollution or global climate change. Most of the energy used worldwide comes from fossil fuels. Richer nations use far more energy resources, especially fossil fuels, than poorer nations do. There are several ways that people can conserve energy in their daily lives.

Standards

- MCR.6-8.SCI.9.4, 11
- AAAS.6-8.4.B.9; AAAS.6-8.8.C.2, 5, 6, 10, 11; AAAS.6-8.12.D.2, 4, 6

Lesson Objectives

- Describe nonrenewable energy resources.
- Identify several renewable energy resources.
- Outline world energy use and ways to conserve energy.

Lesson Vocabulary

- **conservation:** saving resources by using them more efficiently or not using them at all
- **fossil fuel:** mixture of hydrocarbons that formed over millions of years from the remains of dead organisms (petroleum, natural gas, or coal)
- **natural resource:** anything people can use that comes from nature
- **nonrenewable resource:** natural resource that is limited in supply and cannot be replaced except over millions of years
- **renewable resource:** natural resource that can be replaced in a relatively short period of time or is virtually limitless in supply

Teaching Strategies

Introducing the Lesson

Introduce energy resources by asking students which energy resources they use in their daily lives. For example, ask them which energy resources they use to heat their homes and provide transportation. Also ask about alternative energy resources, such as the solar energy that commonly provides energy for calculators and outdoor lighting. Tell the class they will learn about energy resources such as these when they read this lesson.

Activity

Students can learn more about the wind as a source of energy with interactive animated presentation at the URL below. Flash animations present the characteristics of wind power as a source of clean energy and allow students to examine how a modern wind turbine works by pausing and clicking on its components.

- http://www.teachersdomain.org/asset/psu06-e21_int_windstory/

In the activity described at the following URL, students can learn more about hydroelectricity and make a model of a water turbine.

- http://www.educationworld.com/a_lesson/00-2/lp2124.shtml

Building Science Skills

Have groups of students collect data to create an energy map of their school (see URL below). Students can chart how energy is used on campus and infer ways that energy might be conserved.

- http://ase.org/resources/school-energy-map

Differentiated Instruction

Pair beginning English language learners (ELL) with advanced ELL students or native speakers of English. Then have partners work together to make a Venn diagram that compares and contrast nonrenewable and renewable energy resources. Display their completed Venn diagrams in the classroom. You can find a sample Venn diagram on page 2 of this document:

- http://www.esf.edu/outreach/k12/edunits/units/willow/VennDiagrams.pdf

Enrichment

Ask a few interested students to research the partial nuclear meltdown that occurred at the Three Mile Island reactor in Pennsylvania in 1979. Have the students create a PowerPoint presentation, Web page, or diorama to share what they learn with the class.

Science Inquiry

The inquiry activity "Which Grass Produces More Biomass?" (pages 65–69 in the document below) will reinforce science inquiry skills and demonstrate that different plants produce different amounts of biomass.

- http://www.nrel.gov/docs/gen/fy01/30927.pdf

Common Misconceptions

Students may think that current reserves of fossil fuels are so great that we are in no danger of running out of them or, if we do, that we can always find more. Provide students with projections of the time left until different fossil fuels run out. You can find estimates at the URLs below. Discuss the role of conservation in extending the length of time that these fuels will be available to future generations.

- http://www.fossilfuel.co.za/Fossil_Fuel_Facts_Figures-.aspx
- http://www.carboncounted.co.uk/when-will-fossil-fuels-run-out.html
- http://www.eco-info.net/fossil-fuel-depletion.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a natural resource?
   - [A natural resource is anything that people can use that comes from nature.]
2. Identify three fossil fuels.
   - [Three fossil fuels are petroleum (oil), natural gas, and coal.]
3. Describe how fossil fuels form.
   - [Fossil fuels contain stored chemical energy that came originally from the sun. Ancient plants changed energy in sunlight to stored chemical energy in food, which was eaten by other organisms. After the plants and other organisms died, their remains gradually changed to fossil fuels over millions of years, as they were pressed beneath layers of sediments. Petroleum and natural gas formed from marine organisms, and coal formed from giant tree ferns and other swamp plants.]
4. What are drawbacks of using fossil fuels?
   - [Using fossil fuels has several drawbacks. They are nonrenewable so they will eventually run out. Burning them also releases carbon dioxide, which causes global warming, and air pollution, which can damage materials and living things.]
5. State why nuclear energy is a nonrenewable resource.
   - [Nuclear energy is a nonrenewable resource because it uses uranium as fuel. Uranium is limited in supply and cannot be replaced once it is used up.]
6. Create a Web page or poster that encourages people to conserve energy and gives tips for how to do it.
   - [Web pages or posters will vary but should promote the use of energy-saving measures and provide tips for how to conserve energy, such as the tips given in the lesson. Students' work should show that they

know it is important to conserve energy resources in order to slow their rate of depletion and to reduce the pollution they cause when they are used.]

7. Compare and contrast nonrenewable and renewable energy resources.
    - [Both nonrenewable and renewable energy resources can be converted to forms of useable energy, such as electrical energy. However, nonrenewable energy resources will eventually be used up and cannot be replaced except over millions of years, whereas renewable energy resources are virtually limitless in supply or can be replaced in a relatively short period of time. Nonrenewable resources also release carbon dioxide, which causes global climate change, and air pollutants, which damage the environment. Renewable resources, on the other hand, do not have these drawbacks.]
8. Argue for the use of any two renewable energy resources.
    - [Answers will vary. Students should correctly identify the advantages of using any two renewable energy resources and provide logical arguments in support of their use.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 17.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read that energy is transferred when work is done. You also read about thermal energy.

- You can use the thermal energy of a stove to cook food. How is thermal energy transferred from the hot stovetop to a pot on the stove?

Thermal energy is transferred by conduction from the hot stovetop to a pot on the stove.

- You can feel the thermal energy of a campfire, even when you are sitting a few feet away. How does thermal energy travel through the air from the fire to you?

Thermal energy travels through the air from the fire by radiation.

CHAPTER 18 TE Thermal Energy

Chapter Outline

18.1 Chapter 18: Thermal Energy

Chapter Overview

Thermal energy is the total kinetic energy of the particles of an object. Temperature measures the average kinetic energy of the particles of an object. Heat is the transfer of thermal energy from an object with a higher temperature to an object with a lower temperature. This can occur by conduction, convection, or radiation. A heating system burns fuel to produce thermal energy and circulates it throughout a building. A cooling system does work on a refrigerant to reverse the normal direction of thermal energy transfer. A combustion engine burns fuel to produce thermal energy and then uses the thermal energy to do work.

Online Resources

See the following Web sites for appropriate laboratory activities:

At the following URL, you can find labs on the transfer of thermal energy by conduction and convection. Students can compare the rate of energy transfer by each method and the effect of differences in specific heat on rate of heating.

- http://www.woodrow.org/teachers/esi/2001/princeton/project/zerba/activities/activities.htm

In the inquiry lab described in the document below, students will design an experiment on conduction, convection, radiation, or insulation using the equipment provided. They will develop a research problem and hypothesis, identify variables and controls, and write an experimental procedure. Then they will carry out their experiment, collect and graph data, analyze their results, and draw conclusions.

- http://www.nsta.org/pdfs/pdlinks/ss0302_38.pdf

Students can investigate thermal energy transfer with the lab "Hot Water in Cold Water Experiment," which can be found on pages 8–14 of the following document. In the lab, students will be introduced to heat transfer through a conduction experiment, and they will use energy transfer charts to explain conduction. The document includes both pre- and post-experiment assessments.

- http://www.biol.wwu.edu/donovan/SciEd491/HeatTempUnit.pdf

In this inquiry lab, students will test a hypothesis regarding whether thermal energy can be used to do work. Then they will design a device to put thermal energy to work lifting a heavy object or generating electricity.

- http://www.education.com/science-fair/article/thermal-energy/

These Web sites may also be helpful:

The tutorial below was prepared for middle school teachers and helps provide a context for chapter content. Topics addressed by the tutorial include temperature, the development of thermometers and temperature scales, heat and thermodynamics, the kinetic theory, thermal radiation, and the temperature of the universe.

- http://eo.ucar.edu/skymath/tmp2.html

The Web site below provides several resources, including quizzes and videos, that address heat, temperature, and thermal energy transfer.

- http://www.neok12.com/Heat-Temperature.htm

This unit on temperature and heat is made up of four lesson plans, which include student activities, labs, pre- and post-assessments, and other resources.

- http://www.biol.wwu.edu/donovan/SciEd491/HeatTempUnit.pdf

At the URL below, you can find links to many useful resources for teaching this chapter. Included are lessons, activities, labs, tutorials, and videos.

- http://www.scilinks.org/harcourt_hsp/hspstudentretrieve.aspx?code=hsp607

Pacing the Lessons

TABLE 18.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
18.1 Temperature and Heat	1.5
18.2 Transfer of Thermal Energy	2.5
18.3 Using Thermal Energy	2.0

18.2 Lesson 18.1 Temperature and Heat

Key Concept

Temperature is the average kinetic energy of particles of an object. It is measured with a thermometer. Heat is the transfer of thermal energy from an object with a higher temperature to an object with a lower temperature. Specific heat is the amount of energy needed to raise the temperature of 1 gram of a substance by 1 °C.

Standards

- SCI.CA.8.PS.3.e
- MCR.6-8.SCI.9.1
- AAAS.6-8.4.D.5; AAAS.6-8.4.E.4

Lesson Objectives

- Explain the relationship between temperature and thermal energy.
- Define heat and specific heat.

Lesson Vocabulary

- **heat:** transfer of thermal energy between objects that have different temperatures
- **specific heat:** amount of energy (in joules) needed to raise the temperature of 1 kilogram of a substance by 1 °C

Teaching Strategies

Introducing the Lesson

Introduce thermal energy and temperature with the interactive Shockwave animation at the URL below. It shows how atoms of a substance increase in kinetic energy as the temperature of the substance rises. Tell students they will learn more about temperature and what it measures when they read this lesson.

- http://ippex.pppl.gov/interactive/fusion/controlatomtemp.html

Building Science Skills

You can use the first three lessons ("What Is Heat?", "What Is Temperature?", and "Heat vs. Temperature") at the URL below to teach FlexBook® lesson concepts. The lessons include a script, great infrared images, activities, and labs.

- http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/heat.html

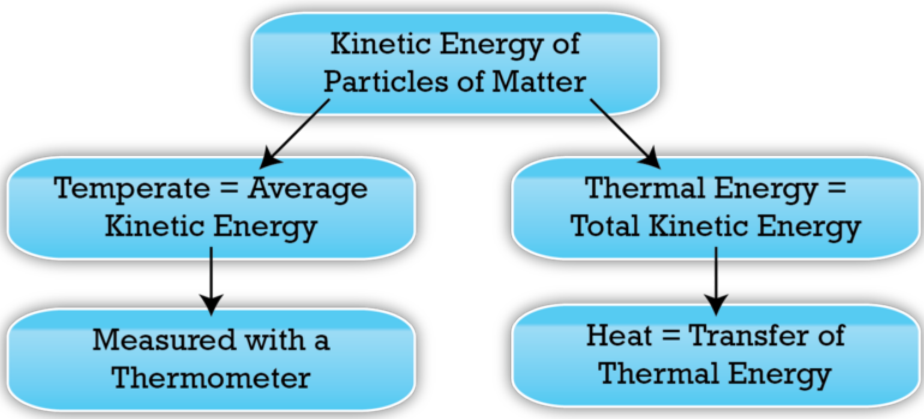
Demonstration

Use the video at the following URL to demonstrate the high specific heat of water. In the video, a class of middle school students takes a leap of faith (in science) that a thin film of water will protect their hands from a ball of burning methane gas. Thanks to the high specific heat of water, they walk away unscathed. Explain to your class the connection between the demonstration and the specific heat of water.

- http://vimeo.com/4498373

Differentiated Instruction

Have pairs of students make a concept map that includes the following terms: kinetic energy, temperature, thermometer, thermal energy, and heat. A sample concept map is shown below.



Enrichment

Have interested students do the online activity "A Comparison of Land and Water Temperature" at the URL below. Students will examine NASA satellite observations of surface temperature and investigate seasonal changes in land and water temperatures. The URL provides all necessary links for students and also notes for teachers. Schedule time for the students to present their work to the class.

- http://mynasadata.larc.nasa.gov/preview_lesson.php?&passid=36

Common Misconceptions

Below are listed several common misconceptions students may hold about heat and temperature. Discuss the misconceptions with your students, and explain why each one is false.

- Heat is a substance.
- Temperature is a property of a particular material or object. For example, metal is naturally cooler than plastic.
- The temperature of an object depends on its size.
- Heat and cold are different, rather than being opposite ends of a continuum.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is temperature?
    - [Temperature is the average kinetic energy of the particles of an object.]
2. How is temperature measured?
    - [Temperature is measured with a thermometer, which shows how hot or cold something is relative to two reference temperatures, usually the freezing and boiling points of water.]
3. Define heat.
    - [Heat is the transfer of thermal energy between objects that have different temperatures.]
4. Give an example of heat that you didn't read about in this lesson.
    - [Examples may vary. *Sample answer*: An example of heat is the transfer of thermal energy from a steam iron to a shirt.]
5. Glass has a specific heat of 0.84 J/g • °C. Copper has a specific heat of 0.39 J/g • °C. Which material takes more energy to warm up?
    - [Glass takes more energy to warm up because it has a higher specific heat.]
6. Explain how a cooler object can have more thermal energy than a warmer object.
    - [A cooler object can have more thermal energy than a warmer object if its mass is greater. That's because the thermal energy of an object is the total kinetic energy of all its particles. It depends not only on how fast the object's particles are moving (temperature) but also on how many moving particles there are (mass).]
7. Relate heat to temperature.
    - [Heat, or the transfer of thermal energy, always flows from an object with a higher temperature to an object with a lower temperature. Therefore, the temperatures of two objects determine whether and how thermal energy will be transferred between them.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that heat is the transfer of thermal energy from one object to another.

- How do you think the transfer of thermal energy occurs? For example, how does thermal energy move from hot sand to bare feet when someone walks on a beach?

Thermal energy moves from hot sand to bare feet through direct contact by conduction.

- Do you think there might be more than one way that thermal energy can be transferred? For example, how does thermal energy move from a bonfire to a nearby person who isn't touching the flames?

Thermal energy can also be transferred by convection or radiation. Thermal energy moves from a bonfire to a nearby

18.3 Lesson 18.2 Transfer of Thermal Energy

Key Concept

Thermal energy can be transferred by conduction, convection, and radiation. Conduction is the transfer of thermal energy between particles of matter that are touching. Convection is the transfer of thermal energy by particles moving through a fluid in convection currents. Radiation is the transfer of thermal energy by waves that can travel through space.

Standards

- MCR.6-8.SCI.9.3, 4, 8
- NSES.5-8.B.3.1, 3, 6
- AAAS.6-8.4.E.1, 2, 3, 5

Lesson Objectives

- Describe the conduction of thermal energy.
- Explain how convection transfers thermal energy.
- Give an example of the radiation of thermal energy.

Lesson Vocabulary

- **conduction:** transfer of thermal energy between particles of matter that are touching
- **convection:** transfer of thermal energy by particles moving through a fluid
- **convection current:** flow of particles in a fluid that occurs because of differences in temperature and density
- **thermal conductor:** material that is a good conductor of thermal energy
- **thermal insulator:** material that is a poor conductor of thermal energy

Teaching Strategies

Introducing the Lesson

Introduce the transfer of thermal energy by asking a few volunteers to hold an ice cube and describe how it feels. Then have the volunteers dip their fingers in very warm water and describe how it feels. Challenge the rest of the class to explain why the ice cube makes the students' hands feel cold and the warm water makes their hands feel warm. Accept all reasonable responses at this point. Then tell the class they will learn the correct answers when they read this lesson.

Activity

In this interactive activity, students can explore the methods of heat transfer (conduction, convection, and radiation). They will read a description of each method, watch an animated illustration of it, and then answer a challenge question about it.

- http://www.wisc-online.com/objects/SCE304/SCE304.swf

Demonstration

Use this simple demonstration to show students how thermal energy is transferred to matter on Earth by solar radiation. In the demonstration, students will observe how chocolate melts faster in the sun than in the shade. The URL includes background and discussion sections.

- http://www.srh.noaa.gov/jetstream/atmos/ll_melts.htm

Differentiated Instruction

Struggling students may benefit by working through the tutorial on thermal energy transfer at the following URL. The tutorial explains how thermal energy is transferred by the processes of radiation, conduction, and convection. It is written in "bite-size" pieces so that learners can grasp the concepts more easily and connect information with prior knowledge. Each page is supplemented with multiple images and animations, which makes the tutorial a good resource for visual learners, less proficient readers, and English language learners.

- http://www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/energy/heatrev1.shtml

Enrichment

Challenge one or more students to write a song or rap about thermal energy transfer. They should include information on all three methods of thermal energy transfer described in the lesson. Ask the students to teach their song or rap to the rest of the class.

Science Inquiry

After a brief discussion of heat transfer processes in general, the inquiry activity at the URL below focuses on radiation. Students will investigate how different surfaces absorb heat. Then they will apply their experience with the surfaces to interpret real-world situations.

- http://www.ucar.edu/learn/1_1_2_5t.htm

Real-World Connection

Use the popcorn lesson described at the following URL to show students real-world examples of the transfer of thermal energy. They will observe three different ways of popping corn, each of which makes use of a different method of thermal energy transfer. After the demonstration, have the class brainstorm other ways they use the transfer of thermal energy in their daily lives.

- http://aspire.cosmic-ray.org/labs/atmosphere/popcorn.html

Common Misconceptions

Three misconceptions about heat transfer are listed below. Ask students whether they think each misconception is true or false. Have students who think the misconceptions are false explain why.

- Objects with different temperatures that are touching do not necessarily come to have the same temperature.
- The kinetic theory does not explain heat transfer.
- Objects that readily become warm (conductors of heat) do not just as readily become cold.

Reinforce and Review

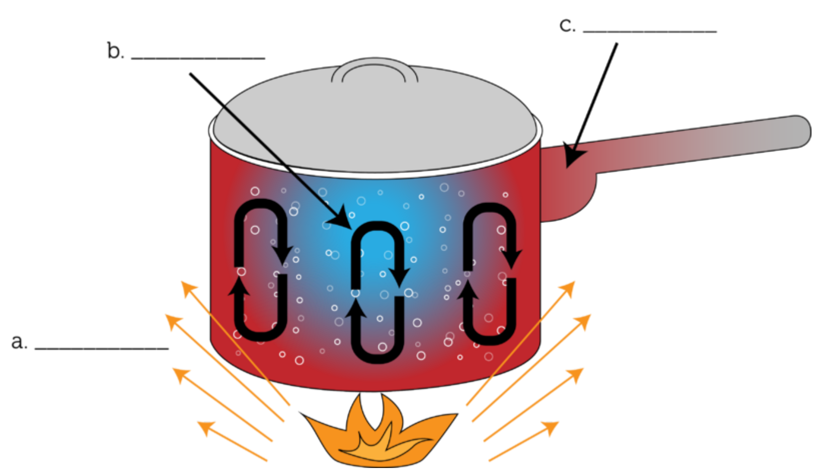
Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define conduction.
   - [Conduction is the transfer of thermal energy between particles of matter that are touching.]
2. What is convection?
   - [Convection is the transfer of thermal energy by particles moving through a fluid.]
3. Describe the radiation of thermal energy.
   - [In radiation, thermal energy is transferred by waves that can travel through space.]
4. Fill in each blank in the diagram below with the correct method of heat transfer.



   - [a. radiation; b. convection; c. conduction]
5. How could you insulate an ice cube to keep it from melting? What materials(s) would you use?

- [Answers may vary but should demonstrate that students understand the nature of thermal insulators and how they prevent the transfer of thermal energy. *Sample answer*: I would wrap the ice cube in a material that does not transfer thermal energy, such as foam rubber, and then put in an insulated cooler.]

6. Why does convection occur only in fluids?
   - [Convection occurs only in fluids because it involves the movement of particles of matter from one place to another and only fluids have particles that can move in this way.]
7. George said that insulation keeps out the cold. Explain why this statement is incorrect. What should George have said?
   - [The statement is incorrect because thermal energy always moves from a warmer to a colder object. George should have said that insulation keeps in the warmth.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

Thermal energy is very useful. For example, we use thermal energy to keep our homes warm and our motor vehicles moving.

How does thermal energy heat a house? What devices and systems are involved?

- [Most home heating systems burn fuel to produce thermal energy and then circulate the thermal energy throughout the house. These types of systems include a furnace or boiler, ducts or pipes, and air vents or radiators.]

How does thermal energy run a car? How does burning gas in the engine cause the wheels to turn?

- [A car's internal combustion engine burns gas to produce thermal energy and uses the thermal energy to move pistons up and down. The movement of the pistons turns the crankshaft, which turns the driveshaft. The turning driveshaft causes the wheels to turn.]

18.4 Lesson 18.3 Using Thermal Energy

Key Concept

Hot-water and warm-air heating systems burn fuel for thermal energy, transfer the energy to water or air, and circulate the water or air throughout the house. Cooling systems such as refrigerators reverse the normal direction of heat flow by doing work. They use a refrigerant to transfer thermal energy from the refrigerator to the room. A combustion engine burns fuel to produce thermal energy and then uses the thermal energy to do work. Combustion engines may by external or internal combustion engines, depending on where the fuel is burned.

Standards

- NSES.5-8.F.5.3

Lesson Objectives

- Identify common home heating systems.
- Explain how a cooling system transfers thermal energy.
- Outline how a combustion engine works.

Lesson Vocabulary

- **combustion engine:** complex machine that burns fuel to produce thermal energy and uses the thermal energy to do work
- **refrigerant:** substance with a low boiling point that is used to transfer thermal energy in a cooling system such as a refrigerator

Teaching Strategies

Introducing the Lesson

Demonstrate the use of hot air and hot water with a hair dryer and hot water bottle. Ask students if they can think of other ways that hot air or hot water can be used. Tell them they will learn in this lesson how hot air and hot water can be used to heat a house.

Demonstration

Use simulations to help students understand how thermal energy is used in the home. You can find two examples at the URLs below. The first animation demonstrates how a solar water heater works. The second animation demonstrates how a thermostat controls a home heating system.

- http://www.revisionenergy.com/blog/how-solar-hot-water-works/
- http://www.simtools.com/Heating.html

Use the excellent animations at the following URLs to demonstrate how external and internal combustion engines work. Along with the animations, the Web pages include a step-by-step illustrated explanation of how the engines work.

- http://www.animatedengines.com/locomotive.html (external combustion engine)
- http://www.animatedengines.com/twostroke.html (internal combustion engine)

Using Visuals

Use the lesson diagram showing how a refrigerator works when you explain how a cooling system transfers thermal energy. Show students the animated version of the diagram at this URL: http://www.ior.org.uk/ior_/fantastic_fridges_site/science/fridge1/fridgediag.htm .

Differentiated Instruction

Before students read the lesson, have them think about how thermal energy might be used to heat a home or run an automobile. After they read the lesson, pair English language learners with native English speakers, and have partners discuss the ways of using thermal energy that they read about in the lesson.

Enrichment

Ask one or more interested students to interview an automobile repair technician or other expert about how an internal combustion engine works. They should prepare a list of questions in advance. Have the students summarize what they learn in an oral presentation to the class.

Science Inquiry

Students can explore the use of thermal energy from the sun by building and using a solar cooker. The activity will teach them the basic principles of solar-thermal and passive-solar heating.

- http://www.solar4rschools.org/sites/all/files/Activity%201%20-%20Solar%20Cookers.pdf

Real-World Connection

Suggest that students learn about the heating system in their own home. Through inspection and asking parents or other adult members of the household, they should find out which type of heating system it is and, if it burns fuel, which type of fuel it uses. They also might learn how the fuel is stored or supplied, where heating vents or radiators are located, and the locations of ducts or pipes.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How does a hot-water radiator transfer thermal energy to the nearby air?
   - [A hot-water radiator transfers thermal energy to the nearby air by conduction and radiation.]
2. What is a refrigerant?
   - [A refrigerant is a substance with a low boiling point, such as Freon™, that changes between liquid and gaseous states as it flows through a cooling system. As a liquid, a refrigerant absorbs thermal energy and changes to a gas. As a gas, it releases thermal energy and changes back to a liquid.]
3. What is the direction of thermal energy flow in a refrigerator?
   - [Thermal energy flows from the cool air inside the refrigerator to the warm air outside the refrigerator.]
4. How does a combustion engine use thermal energy?
   - [A combustion engine uses thermal energy to do the work of moving a piston.]
5. Create a sketch to model a home heating system. You may model either a hot-water system or a warm-air system.
   - [Sketches may vary. They should represent either a hot-water or a warm-air heating system, like the drawings in the lesson.]
6. Compare and contrast external and internal combustion engines.
   - [Both external and internal combustion engines burn fuel to produce thermal energy and then use the energy to do work. However, an external combustion engine burns fuel outside the engine, whereas an internal combustion engine burns fuel inside the engine.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 18.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read that thermal energy can travel in waves by radiation. You can learn more about waves in Chapter 19.

- What other forms of energy travel in waves? (Hint: How does sound energy travel?)

Both sound energy and electromagnetic energy travel in waves.

- Think about ocean waves. How do the waves move? How do you think they carry energy?

In ocean waves, particles of water vibrate in place as the energy of the waves passes through them. The moving particl

CHAPTER 19 TE Waves

Chapter Outline

19.1 Chapter 19: Waves

Chapter Overview

Mechanical waves are waves that transfer energy through matter. Types of mechanical waves include transverse, longitudinal, and surface waves. Several parameters can be used to measure waves, including wave amplitude, wavelength, wave frequency, and wave speed. Waves with greater amplitude, shorter wavelength, or higher frequency have greater energy. Types of wave interactions include reflection, refraction, and diffraction. Waves may interact with constructive or destructive interference.

Online Resources

See the following Web sites for appropriate laboratory activities:

The labs at this URL are designed to introduce students to various types of waves and the language used to describe them. They will explore transverse, longitudinal, electromagnetic, and water waves through simple and practical experiments.

- http://www.nuffieldfoundation.org/practical-physics/variety-waves

If you have access to a ripple tank, you can choose from the collection of wave labs at the following URL. Several of the labs focus on wave reflection.

- http://www.thephysicsfront.org/items/detail.cfm?ID=8715

These Web sites may also be helpful:

A large number of middle school resources pertaining to waves are available at this URL. The resources include online quizzes, slideshows, activities, labs, and games.

- http://www.science-class.net/Physics/waves.htm

You can find several PowerPoint presentations on waves at the following URL: http://www.freeclubweb.com/powerpoints/science/sound.html .

The tutorial at the URL below incorporates excellent animations and simulations of wave properties and wave interference. You may find it useful for content support.

- http://www.thephysicsfront.org/items/detail.cfm?ID=8739

This tutorial provides deeper content for teachers on the energy and amplitude of waves: http://www.physicsclassroom.com/Class/waves/U10L2c.cfm .

Another refresher on waves for teachers is available at the URL below. It is a four-lesson animated tutorial that covers all chapter topics.

- http://www.physicsclassroom.com/Class/waves/

Pacing the Lessons

TABLE 19.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
19.1 Characteristics of Waves	2.0
19.2 Measuring Waves	2.0
19.3 Wave Interactions and Interference	2.0

19.2 Lesson 19.1 Characteristics of Waves

Key Concept

Mechanical waves are waves that transfer energy through matter, called the medium. Types of mechanical waves include transverse, longitudinal, and surface waves. In a transverse wave, the medium vibrates at right angles to the direction that the wave travels. In a longitudinal wave, the medium vibrates in the same direction that the wave travels. A surface wave travels along the surface of a medium and combines a transverse wave and a longitudinal wave.

Standards

- MCR.6-8.SCI.9.7, 8
- AAAS.6-8.4.E.2; AAAS.6-8.4.F.5; AAAS.6-8.12.D.4

Lesson Objectives

- Define mechanical wave.
- Describe transverse waves.
- Identify longitudinal waves.
- Describe surface waves.

Lesson Vocabulary

- **longitudinal wave:** wave in which particles of the medium vibrate in the same direction that the wave travels
- **mechanical wave:** disturbance in matter that transfers energy from one place to another
- **surface wave:** combined transverse and longitudinal wave that travels along the surface of a medium
- **transverse wave:** wave in which particles of the medium vibrate at right angles to the direction that the wave travels

Teaching Strategies

Introducing the Lesson

As students enter the classroom and settle into their seats, pique their interest in waves by playing a video of surfers exploiting huge ocean waves (you can choose from the videos below). While students watch the video, ask them to describe the waves and form a preliminary definition of the term wave. Tell students that they will learn about waves—including ocean waves—when they read this chapter.

- http://www.youtube.com/watch?v=IlrqyHIE4wc
- http://www.youtube.com/watch?v=C04htNNYb9A
- http://www.youtube.com/watch?v=BThvvt2DDHg

Demonstration

You may want to use the PowerPoint presentation at the following URL to teach lesson concepts. It includes excellent visuals and incorporates a simple activity for generating transverse and longitudinal waves with a spring toy. You can have students generate the waves or you can generate them yourself while the class watches.

- http://www.science-class.net/PowerPoints/slinky_waves_files/frame.htm

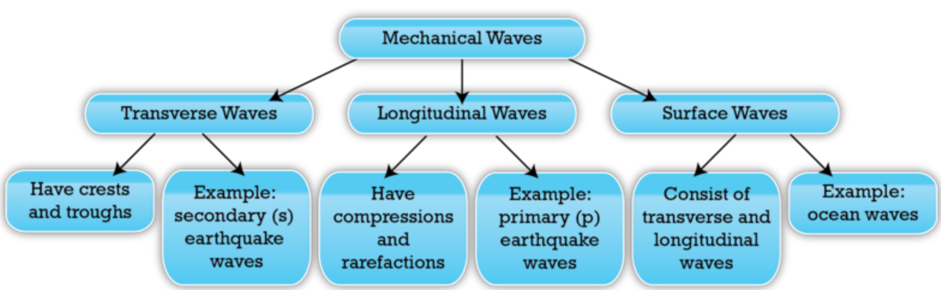
Activity

The kinesthetic wave activity described in the document below can be done indoors or outdoors. It is an excellent exercise for introducing students to waves. In the activity, students will line up and do "the wave" while you discuss what a wave is and other basic wave concepts. The document explains how students can vary wave measures such as wavelength and amplitude, which are covered in the next lesson, "Measuring Waves."

- http://sciencespot.net/Media/waveexercise.pdf

Differentiated Instruction

Help students focus on the main concepts in the lesson by having them make a concept map for the lesson. Pairs of students can work together to make concept maps, or you can work with the class to make a concept map on an overhead transparency. A sample concept map is shown below.



Enrichment

Ask one or more advanced students to learn more about seismic waves and then teach the topic to the class. The URLs below are a good place to start. Tell students to use visuals or online animations in their presentation.

- http://www.allshookup.org/quakes/wavetype.htm
- http://www.geo.mtu.edu/UPSeis/waves.html (includes animations of the waves)

Science Inquiry

Tell the class that transverse waves can travel only through solids whereas longitudinal waves can travel through fluids as well as solids. Then divide the class into groups and ask groups to discuss why transverse and longitudinal waves differ in this way. After groups have developed their own explanations, have a spokesperson for each group present its explanation to the class. The correct explanation can be found at the following URL.

- http://www.physicsclassroom.com/class/waves/u10l1c.cfm

Common Misconceptions

Four common student misconceptions about waves are listed below. Ask students whether each statement is true or false, and have students who correctly identify a statement as false explain why it is false. Continue to keep the misconceptions in mind as you teach lesson content.

- Waves transport matter.
- Waves do not have energy.
- All waves travel the same way.
- All waves require a medium in order to travel.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a mechanical wave?
   - [A mechanical wave is a disturbance in matter that transfers energy from place to place.]
2. Identify the medium of the wave in **Figure** 19.1.
   - [The medium of the wave in the figure is water.]
3. Describe compressions and rarefactions of a longitudinal wave.
   - [In a longitudinal wave, compressions are places where particles of the medium are crowded together, and rarefactions are places where the particles are spread apart.]
4. What are surface waves? Give an example.
   - [Surface waves are waves that travel along the surface of a medium. They combine transverse and longitudinal waves. An example is an ocean wave.]
5. State how a particle of the medium moves when a surface wave passes through it.
   - [When a surface wave passes through a particle of the medium, the particle moves both up and down and back and forth. Overall, the particle moves in a circle.]

6. Draw a sketch of a transverse wave. Label the crests and troughs, and add an arrow to show the direction the wave is traveling.
   - [Sketches may vary, but they should correctly represent a transverse wave. The crests and troughs should be labeled, and there should be an arrow showing the direction the wave is traveling.]
7. Compare and contrast P waves and S waves of earthquakes.
   - [P waves and S waves are both mechanical waves that travel through the ground in an earthquake. P waves are longitudinal waves, so particles of the ground move back and forth in the same direction that the waves are traveling. S waves, in contrast, are transverse waves, so particles of the ground move up and down at right angles to the direction that the waves are traveling.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 19.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

When an earthquake occurs under the ocean, it sends waves through the water as well as the ground. When the energy of the earthquake reaches shore, it forms a huge wave called a tsunami.

- Do you know how large tsunamis are? How might the size of these and other waves be measured?

The size of waves can be measured by wave amplitude.

- What causes some waves to be bigger than others?

The energy of the disturbance that causes a wave determines the wave's amplitude.

19.3 Lesson 19.2 Measuring Waves

Key Concept

Wave amplitude is the maximum distance the particles of a medium move from their resting positions as the energy of a wave passes through them. Wavelength is the distance between two corresponding points of adjacent waves. Wave frequency is the number of waves that pass a fixed point in a given amount of time. Waves with greater amplitude, shorter wavelength, or higher frequency have greater energy. Wave speed is calculated as wavelength multiplied by wave frequency. It is affected by the medium through which a wave travels.

Standards

- SCI.CA.8.IE.9.f
- MCR.6-8.SCI.9.7, 8; MCR.6-8.SCI.12.7
- NSES.5-8.A.1.5
- AAAS.6-8.4.F.5, 8; AAAS.6-8.12.D.4, 6, 11

Lesson Objectives

- Define wave amplitude and wavelength.
- Relate wave speed to wave frequency and wavelength.

Lesson Vocabulary

- **hertz (Hz):**SI unit of wave frequency, where 1 hertz equals 1 wave passing a fixed point per second
- **wave amplitude:** maximum distance the particles of a medium move from their resting positions when a wave passes through
- **wave frequency:** number of waves that pass a fixed point in a given amount of time
- **wavelength:** distance between two corresponding points of adjacent waves, such as the distance between two adjacent crests of a transverse wave
- **wave speed:** how far a wave travels in a given amount of time; calculated as wavelength multiplied by wave frequency

Teaching Strategies

Introducing the Lesson

Begin the lesson by showing students waves of different amplitudes. You can generate transverse waves in a rope or longitudinal waves in a spring toy. Whichever you do, try to keep the frequency (and wavelength) of the waves the same so that only their amplitudes vary. Challenge students to explain how and why the waves differ. Tell students they will learn about this and other ways that waves may vary when they read this lesson.

Activity

Suggest that students simulate waves with different amplitudes and wavelengths with the animation at the URL below.

- http://zonalandeducation.com/mstm/physics/waves/introduction/introductionWaves.html

Differentiated Instruction

Visual and English language learners may have a better understanding of wave amplitude and frequency by interacting with the animation at the following URL. They can change the amplitude and frequency of ocean waves and see how the waves affect a boat floating on the water. An animated graphic of the wave also forms as they watch.

- http://www.classzone.com/books/ml_science_share/vis_sim/wslm05_pg18_graph/wslm05_pg18_graph.html

Enrichment

The activity at the URL below allows students to investigate wave frequency and amplitude using real-time data from various global agencies monitoring tsunami activity. In the activity, students also develop a "preparedness plan" using evidence from the data they collect.

- http://www.ciese.org/curriculum/tsunami/index.shtml

Science Inquiry

Have groups of students do the guided inquiry activity at the first URL below to learn about wave amplitude, wavelength, and wave frequency. In the activity, they will use a simulation of a wave in a string (see second URL below).

- http://phet.colorado.edu/en/contributions/view/3581
- http://phet.colorado.edu/en/simulation/wave-on-a-string

Common Misconceptions

Students may hold the misconception that “big” (high-amplitude) waves travel more quickly than “small” (low-amplitude) waves in the same medium. Explain why wave speed does not depend on wave amplitude, but instead is a product reflection of wavelength and wave frequency.

Reinforce and Review

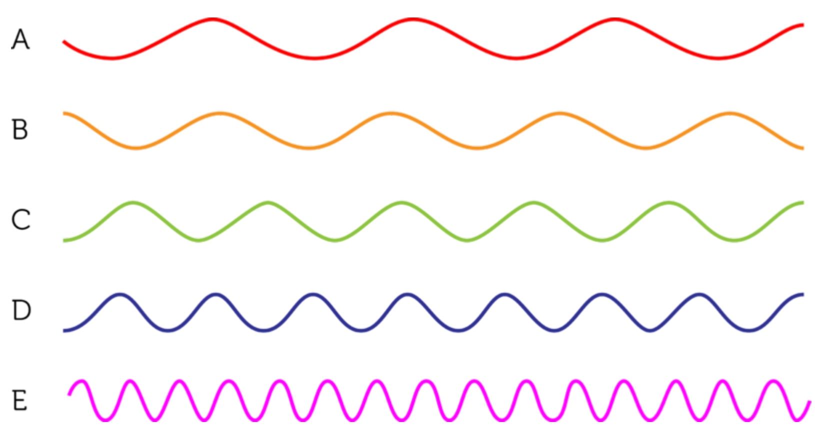
Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How is wave amplitude measured in a transverse wave?
   - [In a transverse wave, wave amplitude is measured as the maximum distance the particles of the medium move from their resting position when the wave passes through.]
2. Describe the wavelength of a longitudinal wave.
   - [The wavelength of a longitudinal wave is the distance between two corresponding points of adjacent waves, such as the distance between two adjacent compressions.]
3. Define wave frequency.
   - [Wave frequency is the number of waves that pass a fixed point in a given amount of time.]
4. All of the waves in the sketch below have the same amplitude and speed. Which wave has the longest wavelength? Which has the highest frequency? Which has the greatest energy?



   - [Wave A has the longest wavelength. Wave e has the highest frequency and also the most energy.]
5. A wave has a wavelength of 0.5 m/s and a frequency of 2 Hz. What is its speed?
   - [The speed of the wave is its wavelength times its frequency, or 0.5 m/s $\times$ 2 waves/s = 1 m/s.]
6. Relate wave amplitude, wavelength, and wave frequency to wave energy.
   - [All three factors are related to the energy of a wave. A wave with greater amplitude, higher frequency, or shorter wavelength has more energy than a wave with lesser amplitude, lower frequency, or longer wavelength.]
7. Waves A and B have the same speed, but wave A has a shorter wavelength. Which wave has the higher frequency? Explain how you know.
   - [Wave A is traveling at the same speed as wave B, so the product of wave A's frequency and wavelength is the same as the product of wave B's frequency and wavelength. Because wave A has a shorter wavelength than wave B, wave A's frequency must be higher than wave B's.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 19.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You read in this lesson that waves travel at different speeds in different media.

- When a wave enters a new medium, it may speed up or slow down. What other properties of the wave do you think might change when it enters a new medium?

The wave may refract, or change direction, when it enters a new medium at an angle.

- What if a wave reaches a type of matter it cannot pass through? Does it just stop moving? If not, where does it go?

The wave may be reflected by the barrier, or it may travel around the barrier.

19.4 Lesson 19.3 Wave Interactions and Interference

Key Concept

Reflection occurs when waves bounce back from a barrier they cannot pass through. Refraction occurs when waves change direction as they enter a new medium at an angle. Diffraction occurs when waves spread out around an obstacle or after passing through an opening in an obstacle. Wave interference occurs when waves interact with other waves. Constructive interference increases wave amplitude. Destructive interference decreases wave amplitude.

Standards

- MCR.6-8.SCI.9.8
- AAAS.6-8.12.D.4, 9

Lesson Objectives

- Describe wave reflection, refraction, and diffraction.
- Explain how wave interference affects the amplitude of waves.

Lesson Vocabulary

- **diffraction:** bending of a wave around an obstacle or through an opening in an obstacle
- **reflection:** bouncing back of waves from a barrier they cannot pass through
- **refraction:** bending of waves as they enter a new medium at an angle and change speed
- **standing wave:** wave appearing to stand still that forms when a wave and its reflected wave interfere
- **wave interference:** interaction of waves with other waves

Teaching Strategies

Introducing the Lesson

Introduce wave interference with a simple demonstration. While students observe, drop a pebble into a large shallow pan of water. As the waves start to spread out from the disturbance in concentric circles, drop another pebble into the water at the other side of the pan. Point out how the waves caused by the two pebbles meet and interfere with each other. Call on students to describe how the waves change when this happens. Conclude the demonstration by telling students they will learn about wave interference in this lesson.

Activity

Students can simulate wave interference with the activity at the following URL. The simulation allows students to move step by step through wave interference so they can clearly see how interference affects wave amplitude.

- http://www.thephysicsfront.org/items/detail.cfm?ID=8741

Differentiated Instruction

Pair less proficient readers and English language learners with other students, and have partners work together to make a table comparing and contrasting the three types of wave interactions described in the lesson: reflection, refraction, and diffraction. Tell them to include definitions, examples, and sketches of each type of wave interaction.

Enrichment

Ask a few students to set up and present a demonstration of the effect the size of the opening in an obstacle on the diffraction of waves. Suggest that they generate water waves in a shallow pan with an obstacle placed across the middle of the pan. The obstacle should have an adjustable opening. One possibility for the obstacle is a row of children's play blocks. Students could remove one block at a time to show how increasing the opening size changes the amount of diffraction of the waves. Schedule time for the students to present their demonstration to the rest of the class. Have the other students make simple sketches of what they observe each time the size of the opening changes.

Science Inquiry

Give students a hands-on opportunity to explore wave interactions and wave interference using the activities collectively titled "Four Important Properties of Waves" at the URL below. In each activity, students perform a guided inquiry activity and then answer a series of questions to form a deeper understanding of the wave phenomenon in question.

- http://csip.cornell.edu/Curriculum_Resources/CSIP/Oberst/Oberst_HS.html

Common Misconceptions

Students often incorrectly think that when waves interact with a solid surface, the waves are destroyed. Remind students that waves transfer energy and that energy cannot be destroyed. Discuss wave interactions as energy transfers at boundaries between two different media. You can learn more about boundary behaviors of waves at this URL: http://www.physicsclassroom.com/Class/sound/U11L3c.html .

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is reflection? Give an example.
   - [Reflection is the bouncing back of waves from a barrier they cannot pass through. An example is an echo.]
2. Define constructive interference.
   - [Constructive interference is an interaction of two waves in which the crests of one wave overlap the crests of the other wave.]
3. State how destructive interference affects wave amplitude.
   - [Destructive interference decreases wave amplitude.]
4. What is a standing wave?
   - [A standing wave is a wave that appears to be standing still. It occurs because of a combination of constructive and destructive interference between a wave and its reflected wave.]
5. Create a sketch of sound waves to show why you can hear a sound on the other side of a brick wall.
   - [Sketches may vary, but they should correctly depict the diffraction of sound waves around a brick wall so that a person on the other side of the wall can hear the sound.]
6. Explain why the pencil in the figure above appears broken.
   - [The pencil in the figure appears broken because of the refraction of light. Light travels more slowly through water than air. When light enters the water from the air at an angle, the light changes direction and seems to bend.]
7. A sound wave meets an obstacle it cannot pass through. Relate the amount of diffraction of the sound wave to the length of the obstacle and the wavelength.
   - [If the length of the obstacle is greater than the wavelength of the sound wave, there is minor diffraction of the wave. If the length of the obstacle is less than the wavelength of the sound wave, there is major diffraction of the wave.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 19.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You were introduced to sound waves in this chapter, and you will learn more about them in the next chapter.

- How do you think we hear sound waves?

Sound waves cause structures in the ear to vibrate. Other structures in the ear change the vibrations to electrical signa

- What properties of sound waves might determine how loud a sound is?

The amplitude of sound waves and how far they have traveled from the sound source determine how loud a sound is.

CHAPTER 20 TE Sound

Chapter Outline

20.1 Chapter 20: Sound

Chapter Overview

Sound is the transfer of energy from a vibrating object in waves that travel through matter. Properties of sound include speed, loudness, and pitch. The ear is the organ that allows us to hear sound. Structures of the ear catch and amplify sound waves, and change the sound waves to electrical signals, which travel to the brain. Loud sounds can cause hearing loss unless hearing protectors are worn. One way of using sound is by making music. Musical instruments make sound by causing something to vibrate. They also amplify the sound waves and change the pitch. There are several uses of ultrasound, including sonar, echolocation, and ultrasonography.

Online Resources

See the following Web sites for appropriate laboratory activities:

Use the guided inquiry lab at the first URL below to introduce students to sound and its properties. The lab is based on the simulation at the second URL. In the lab, students will explore and draw conclusions about the nature, properties, and behaviors of sound waves. They will use the simulation to develop their own definition of frequency and amplitude, and they will also describe how frequency and amplitude affect the sounds we hear.

- http://phet.colorado.edu/en/contributions/view/3453
- http://phet.colorado.edu/en/simulation/sound

The tuning fork lab at the following URL allows students to compare the frequency of sound waves and the pitch of sounds produced by different tuning forks. It also allows them to observe the behavior of sound waves in different media.

- http://www.middleschoolscience.com/tunefork.htm

With the PBS unit "Sounds Good" at the URL below, students can explore sound by making stringed instruments and headphones and then playing tunes. Students will be able to identify the science concepts exhibited in their work (e.g., sound energy, pitch, waves, amplitude, frequency, and wavelength). They will also explain how the design process encourages them to think creatively, and they will identify how they are thinking and working like engineers.

- http://pbskids.org/designsquad/parentseducators/guides/teachers_guide.html#sound

The "Sound Waves Lab" at the following URL provides instructions and worksheets for four guided inquiry activities that allow students to explore sound waves and the properties of sound. The activities use readily available materials and have straightforward procedures. After doing each activity, students are asked to propose explanations for their results and draw conclusions.

- http://nyserdagreenny.org/home-performance?gclid=CLz07cDB27ICFcyj4AodsS0ASw

These Web sites may also be helpful:

The following URL is an index to several lessons on sound, hearing, and musical instruments. The lessons provide a good refresher for teachers.

- http://www.physicsclassroom.com/Class/sound/

At this URL, you can find several videos and other resources on sound that are suitable for middle school students.

- http://www.neok12.com/Sound.htm

Pacing the Lessons

TABLE 20.1: **Pacing the Lessons**

Lesson	**Class Period(s) (60 min)**
20.1 Characteristics of Sound	2.0
20.2 Hearing Sound	2.0
20.3 Using Sound	2.0

20.2 Lesson 20.1 Characteristics of Sound

Key Concept

Sound is the transfer of energy from a vibrating object in waves that travel through matter. Properties of sound include speed, loudness, and pitch. The speed of sound varies in different media. The loudness of sound depends on the intensity of sound waves. The pitch of sound depends on the frequency of sound waves.

Standards

- MCR.6-8.SCI.9.7, 8
- AAAS.6-8.1.A.4; AAAS.6-8.4.F.5; AAAS.6-8.12.D.4

Lesson Objectives

- Describe sound waves.
- Identify properties of sound.

Lesson Vocabulary

- **decibel (dB):** unit of intensity of sound
- **Doppler effect:** change in the frequency and pitch of sound that occurs when the source of the sound is moving relative to the listener
- **infrasound:** sound with a frequency below the range of human hearing (less than 20 hertz)
- **intensity:** measure of the amount of energy in sound waves, which is determined by the amplitude of the waves and how far they have traveled and spread out from the source of the sound
- **loudness:** how a listener perceives the intensity of sound
- **pitch:** how high or low a sound seems to a listener
- **sound:** transfer of energy from a vibrating object in longitudinal waves that travel through matter
- **ultrasound:** sound with a frequency above the range of human hearing (greater than 20,000 hertz)

Teaching Strategies

Introducing the Lesson

Ask a volunteer to demonstrate vocal sounds that vary in pitch and loudness. First have the student sing one pitch and vary the loudness. Then have the student sing different pitches at the same loudness. Call on other students to describe how the sounds differ and challenge them to explain why they differ. Accept all reasonable explanations at this point. Then tell the class they will learn the correct explanations when they read this lesson.

Demonstration

Have students watch the short video "Visualizing Sound Waves" at the first URL below. The video provides a graphical demonstration of sound waves that vary in frequency (pitch) and amplitude (loudness), and students can hear the actual sounds the graphs represent. More complex sounds, such as the human voice, are also represented graphically. The simulation at the second URL below shows sound waves for three different voices saying the same word. Help students compare and contrast the graphs and relate them to differences in how the voices sound.

- http://www.cposcience.com/home/ForStudents/MiddleSchoolPhysicalScience/tabid/248/default.aspx?MediaFileId=3010
- http://www.cposcience.com/home/Portals/2/Media/post_sale_content/three_voices.html

Activity

At the following URL, students can do an interactive sound lab in which they create their own sound waves and listen to what the waves sound like. They can also hear several preset sound waves. The activity will help students identify the properties of sound and how we perceive the different properties.

- http://library.thinkquest.org/19537/Physics2.html

Building Science Skills

In the scripted activity below, students can experiment with various sound sources, including their own voices, to gain an understanding of the connection between sound and vibration.

- http://www.exploresound.org/home/teachers-parents/good-vibrations.aspx

Differentiated Instruction

Pair less proficient readers and English language learners with students who excel in science, and ask each pair to add one of the lesson vocabulary terms to the word wall (or start a word wall if you haven't already). Tell partners to include the definition of their term and a drawing to represent it.

Enrichment

Challenge interested students to do a Web quest to learn about supersonic speeds, breaking the "sound barrier," and sonic booms. Ask the students to create a presentation to share what they learn with the class.

Science Inquiry

Use the scripted activity at the URL below to explore sound intensity and loudness in depth. In the activity, students will develop hypotheses and make and test predictions about sound intensity. They will use a sound level meter to measure, compare, and graph sound levels in different environments.

- http://www.exploresound.org/home/teachers-parents/sound-measures.aspx

Common Misconceptions

Students commonly think that sound travels faster in air and other gases than in liquids or solids because air is "thinner" and forms less of a barrier. Make sure students have a thorough understanding of how sound waves are transmitted from one particle of matter to another to dispel this misconception.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How is sound defined in physics?
   - [In physics, sound is defined as the transfer of energy from a vibrating object in waves that travel through matter.]
2. Identify two factors that determine the intensity of sound.
   - [Two factors that determine the intensity of sound are the amplitude of the sound waves and how far they have traveled from the source of the sound.]
3. What is the pitch of sound?
   - [Pitch is how high or low a sound seems to a listener.]
4. A wind chime produces both high-pitched and low-pitched sounds. If you could see the sound waves from the wind chime, what would they look like?
   - [The high-pitched sounds would have high-frequency sound waves, like the sound wave for the piccolo in **Figure** 20.5. The low-pitched sounds would have low-frequency sound waves, like the sound wave for the tuba in **Figure** 20.5.]
5. Look back at **Figure** 20.6. Does the siren change pitch to the police office driving the car? Why or why not?
   - [The siren does not change pitch to the driver of the car because the driver is moving at the same speed as the sound source. Therefore, the waves do not crowd together or spread out relative to the driver as they do relative to the stationary listeners outside the car.]
6. Explain why sound tends to travel faster in solids than in liquids or gases.
   - [Sound tends to travel faster in solids than in liquids or gases because the particles of solids are closer together. Therefore, they can pass the energy of vibrations to nearby particles more quickly than the particles of liquids or gases.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 20.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson you learned that high-intensity, high-amplitude sound waves make dangerously loud sounds. In the next lesson, "Hearing Sound," you'll read how loud sounds can cause loss of hearing.

- How do you think loud sounds cause hearing loss?

Loud sounds damage delicate hair cells in the ears, and these cells are needed to convert sound waves to electrical sign

- What can you do to protect your ears from loud sounds?

You can avoid exposure to loud sounds and also wear hearing protectors to protect your ears from loud sounds.

20.3 Lesson 20.2 Hearing Sound

Key Concept

The ear is the organ that allows us to hear sound. The outer ear catches sound waves and funnels them to the middle ear. The middle ear amplifies the sound waves and passes them to the inner ear. The inner ear changes the sound waves to electrical signals, which travel to the brain. Loud sounds can cause hearing loss, which can be prevented by wearing hearing protectors.

Standards

- SCI.CA.8.IE.9.e
- AAAS.6-8.4.F.2; AAAS.6-8.8.D.2; AAAS.6-8.12.D.1, 2, 4

Lesson Objectives

- Explain how we hear sound.
- Relate loud sounds to hearing loss.
- State how hearing can be protected.

Teaching Strategies

Introducing the Lesson

Introduce the ear and hearing by having students listen to a constant sound, such as the hum of a tuning fork, both with and without cupping their ears with their hands. They will observe that the sound is louder when they cup their ears. Explain that cupping the ears helps them catch sound waves so they are easier to hear. Tell the class they will learn in this lesson how their ears allow them to hear sound.

Demonstration

The video below ("How We Hear") provides an excellent, grade-appropriate animation that demonstrates parts of the ear and how they respond to sound waves and allow us to hear.

- http://www.neok12.com/php/watch.php?v=zX504f675163514c7b0c5267&t=Sound

Differentiated Instruction

Work with students to make a flow chart showing how sound waves travel from the outer to inner ear and how they are converted to nerve impulses that travel to the brain. Use an overhead transparency and call on students to help you fill in the correct sequence of structures that the sound waves pass through and the function of each structure in hearing.

Enrichment

Encourage one or more students to interview an expert on the ear, hearing, and hearing loss. Possible experts might include an otolaryngologist (ear, nose, and throat specialist) or audiologist. Students might inquire how hearing is tested, how hearing loss is diagnosed, and how hearing problems are treated. Have them report back to the class on what they learn.

Science Inquiry

With the activity "Now Hear This" at the following URL, students can build a model of the human ear and use their model to observe the transfer of sound waves from the outer to inner ear.

- http://mypages.iit.edu/~smile/chbi9924.htm

Health Connection

Tell students about cochlear implants when you talk about hearing loss caused by damage to hair cells. A cochlear implant is a surgically implanted electronic device that provides a sense of sound to a person who is deaf or nearly deaf because of hair cell damage. Cochlear implants are often referred to as bionic ears. You can learn more about these amazing devices and how they work at the following URL.

- http://www.nidcd.nih.gov/health/hearing/pages/coch.aspx

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is the function of the outer ear?
   - [The function of the outer ear is to catch sound waves, funnel them into the ear, and pass them to the middle ear.]
2. How does the middle ear amplify sound?
   - [The arrangement of the three tiny bones in the middle ear allows them to work together as a lever. The lever action increases the amplitude of the waves as they pass to the inner ear.]

3. Describe the structure of the cochlea.
    - [The cochlea is a shell-like structure that is full of fluid and lined with nerve cells called hair cells.]
4. State how hair cells detect sound waves.
    - [Hair cells detect sound waves with their tiny hair-like projections. The "hairs" bend when the fluid inside the cochlea moves due to sound vibrations.]
5. Write a public service announcement warning people of the danger of loud sounds. Include tips for protecting the ears from loud sounds.
    - [Public service announcements may vary. They should convey the message that loud sounds cause permanent hearing loss and that this type of hearing loss can be prevented by protecting the ears from loud sounds.]
6. In **Figure** 20.9, how are permissible exposure times related to sound intensity? Create a graph to show the relationship.
    - [The figure shows that permissible exposure times decrease as sound intensities increase. Students should create a graph to show this relationship. They might plot time on the y-axis and sound intensity (in decibels) on the x-axis. The graph should represent the inverse relationship between the two variables.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 20.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read about loud sounds and their dangers. Rock concerts often produce very loud sounds. Both the screaming fans and the highly amplified musical instruments contribute to the high decibel levels. Playing musical instruments is one way we use sound. You'll read about musical instruments in "Using Sound," the next lesson.

- How do you think musical instruments produce sound? In other words, how do you think they cause air to vibrate?

In every musical instrument, the musician causes a part of the instrument to vibrate, such as reed or string. The vibra

- How do musical instruments change the pitch of sound?

The method varies by type of instrument. The pitch of string instruments, for example, can be changed by changing th

20.4 Lesson 20.3 Using Sound

Key Concept

One way of using sounds is by making music. Musical instruments include percussion, wind, and string instruments. They all make sound by causing something to vibrate, which sends sound waves through the air. Most instruments use resonance to amplify sound waves, and most have a way to change pitch. Although we cannot hear ultrasound, it has several uses, including echolocation, sonar, and ultrasonography.

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.1.c
- MCR.6-8.TECH.6
- NSES.5-8.E.2.3
- AAAS.6-8.3.A.2, 3; AAAS.6-8.12.D.4, 9

Lesson Objectives

- Explain how musical instruments produce sound.
- Identify uses of ultrasound.

Lesson Vocabulary

- **resonance:** vibration of an object in response to sound waves of a certain frequency
- **sonar:** sound navigation and ranging; use of reflected ultrasound waves to locate objects under water

Teaching Strategies

Introducing the Lesson

Introduce students to a blind 14-year old named Ben who has taught himself to use echolocation to make his way safely through the world. The video at the URL below shows his incredible ability to sense his environment by using his hearing instead of sight. Tell students they will learn in this lesson how dolphins and certain other animals also use this ability to "see" without their eyes.

- http://www.wideo.fr/video/iLyROoaft87F.html

Demonstration

The 40-second video at the following URL is a good way to demonstrate the concept of resonance. The video shows how resonance can be used to break a wine glass. Students will actually see the wine glass vibrating until it shatters.

- http://www.neok12.com/php/watch.php?v=zX030f42446f554e757b0777&t=Sound

Building Science Skills

Have students make their own instruments using commonplace materials, as described at the URL below. The instruments should include wind, percussion, and string instruments. Students can experiment to determine how to change the pitch of their instruments.

- http://mypages.iit.edu/~smile/ph9416.html

Activity

You can use the lesson at the following URL to teach the topics of echolocation and sonar. The scripted lesson includes an activity in which students role-play dolphins and fish. In the activity, the "dolphins" use "echoes" to try to locate the "fish."

- http://www.exploresound.org/home/teachers-parents/echolocation-and-sonar.aspx

Differentiated Instruction

Suggest that students make a cluster diagram for the uses of ultrasound that are described in the lesson (echolocation, sonar, and ultrasonography).

Enrichment

Ask one or more students who play musical instruments to demonstrate their instruments to the class. They should explain and show how to make sounds with the instruments and how to control pitch and loudness. If possible, have students demonstrate an instrument in each of the three categories of musical instruments (percussion, wind, and string instruments).

Science Inquiry

The activity "Pitch" at the URL below uses a phenomenological approach to problem solving to demonstrate the process of science inquiry. Through the exploratory activity, students will observe that the pitch of a sound varies by the length of the vibrating medium. Then they will apply what they learn to musical instruments.

- http://mypages.iit.edu/~smile/ph9317.html

Health Connection

Discuss specific medical uses of ultrasound, including both diagnostic and treatment applications. You can find background information on the subject at the following URLs.

- http://www.nlm.nih.gov/medlineplus/ultrasound.html
- http://www.mayoclinic.com/health/ultrasound/MY00308

Answer to You Try It!

Problem: The sonar device on a ship sends an ultrasound wave to the bottom of the water at a speed of 1437 m/s. The wave is reflected back to the device in 4 seconds. How deep is the water?

Solution: It takes 2 seconds for the wave to reach the bottom of the water, so the distance is 1437 m/s $\times$ 2 s = 2874 m.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Describe ultrasound.
   - [Ultrasound is sound with frequencies greater than 20,000 hertz, which is above the range of frequencies that the human ear can detect.]
2. How does resonance occur? Give an example.
   - [Resonance occurs when an object vibrates in response to sound waves of a certain frequency. An example is the vibration of a guitar when a single string is plucked and starts vibrating.]
3. What does sonar stand for?
   - [Sonar stands for sound navigation and ranging.]
4. List two uses of sonar.
   - [Two uses of sonar are to find the location of underwater objects such as submarines and to determine the depth of the water.]
5. What is ultrasonography?
   - [Ultrasonography is the use of ultrasound to "see" inside the human body. Harmless ultrasound waves are sent inside the body, and the reflected waves are used to create an image on a screen.]
6. Create a sketch to show how a whale might use echolocation to locate a school of fish.
   - [Sketches may vary but should reflect a correct understanding of echolocation and how it is used.]
7. Compare and contrast echolocation, sonar, and ultrasonography.
   - [Echolocation, sonar, and ultrasonography are similar in their use of ultrasound to provide information about objects that cannot be viewed directly. They differ in the purpose for which they are used. Echolocation is the use of ultrasound by animals such as bats and whales to detect objects they cannot see, such as prey. Sonar is the use of ultrasound by people to detect underwater objects or depth of water. Ultrasonography is the use of ultrasound to "see" inside the human body for medical reasons.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 20.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you read about sound waves, which start with a disturbance of matter and travel through matter as longitudinal waves. In the next chapter, you'll read about electromagnetic waves, such as light and X rays, which can travel through empty space.

- How do you think electromagnetic waves might be different from waves that travel through matter?

Electromagnetic waves do not need a medium. They can travel through empty space.

- How do you think electromagnetic waves get started?

An electromagnetic wave begins when an electrically charged particle vibrates.

CHAPTER 21 TE Electromagnetic Radiation

Chapter Outline

21.1 Chapter 21: Electromagnetic Radiation

Chapter Overview

An electromagnetic wave consists of vibrating electric and magnetic fields. It begins when an electrically charged particle vibrates, and it travels as a transverse wave that does not need a medium. When electromagnetic waves strike matter, they may reflect, refract, or diffract; or they may be converted to other forms of energy. Electromagnetic radiation behaves like particles as well as waves, which led Einstein to develop the wave-particle theory of light. All electromagnetic waves travel at the same speed through space, called the speed of light, but they differ in wavelength and frequency. The electromagnetic spectrum is the full range of wavelengths and frequencies of electromagnetic radiation. From longest to shortest wavelengths, it includes radio waves, light, X rays, and gamma rays.

Online Resources

See the following Web sites for appropriate laboratory activities:

This experiment will help students understand that ultraviolet radiation is present in natural outdoor light and that the intensity of the light varies with season and time of day. It uses UV-sensitive Frisbees, which can be purchased from toy stores.

- http://www.ucar.edu/learn/1_6_2_27t.htm

The following URL provides a low-cost, easy-to-do experiment that allows students to discover infrared light for themselves. They will perform a version of Herschel's 1800 experiment in which he discovered infrared radiation.

- http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_experiment.html

These Web sites may also be helpful:

The following URL provides links to numerous resources on electromagnetic waves for middle school students. The resources include activities, labs, interactive Web sites, online quizzes, and games.

- http://www.science-class.net/Physics/waves.htm

The science object at the URL below ("Nature of Light: Light as Waves") is a two-hour learning experience designed for teachers to enhance their understanding of electromagnetic radiation.

- http://learningcenter.nsta.org/product_detail.aspx?id=10.2505/7/SCB-NOL.2.1

If you need a refresher on the wave-particle nature of light, the URL below is an excellent tutorial on the topic. It traces the early history of light refraction theory. Included are interactive simulations showing how particles and waves behave when refracted, diffracted, and reflected. The tutorial could also be used as enrichment for advanced students.

- http://micro.magnet.fsu.edu/primer/lightandcolor/particleorwave.html

The URL below is the index to a collection of excellent interactive physics applets. The applets under "Einstein's Legacy" are all about electromagnetic radiation.

- http://www.colorado.edu/physics/2000/index.pl?Type=TOC

Pacing the Lessons

TABLE 21.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
21.1 Electromagnetic Waves	1.0
21.2 Properties of Electromagnetic Waves	1.0
21.3 The Electromagnetic Spectrum	3.0

21.2 Lesson 21.1 Electromagnetic Waves

Key Concepts

An electromagnetic wave consists of vibrating electric and magnetic fields, and it begins when an electrically charged particle vibrates. It is a transverse wave that can travel across space without a medium. When electromagnetic waves strike matter, they may reflect, refract, or diffract; or they may be converted to other forms of energy. Electromagnetic radiation behaves like particles as well as waves, which led Einstein to develop the wave-particle theory of light. Electromagnetic radiation from the sun provides virtually all the energy that supports life on Earth. Other sources of electromagnetic radiation depend on technology and are used for a variety of purposes.

Standards

- MCR.6-8.SCI.9.4, 8
- NSES.5-8.B.3.1, 3, 6; NSES.5-8.D.3.4
- AAAS.6-8.4.E.2, 3, 5; AAAS.6-8.4.F.7; AAAS.6-8.12.D.4, 9

Lesson Objectives

- Describe electromagnetic waves.
- Explain how electromagnetic waves begin.
- State how electromagnetic waves travel.
- Summarize the wave-particle theory of light.
- Identify sources of electromagnetic waves.

Lesson Vocabulary

- **electromagnetic radiation:** transfer of energy by electromagnetic waves across space or through matter
- **electromagnetic wave:** transverse wave consisting of vibrating electric and magnetic fields that can travel across space
- **photon:** tiny "packet" of electromagnetic radiation that is released when an electron returns to a lower energy level or a nucleus gives off energy in gamma decay

Teaching Strategies

Introducing the Lesson

Help students recall what they already know about waves as an introduction to electromagnetic waves. You can use questions such as:

Question: What is a wave?
Answer: A wave is a disturbance that transfers energy from place to place.
Question: What is a transverse wave?
Answer: A transverse wave is a wave in which vibrations occur at right angles to the direction of the wave.
Question: Mechanical transverse waves need a medium. An example is a wave traveling through a rope. Do all waves need matter in order to travel?
Answer: No; electromagnetic waves can travel through empty space.
Question: What are examples of electromagnetic waves?
Answer: Examples include radio waves, light, and X rays.

Tell students they will learn about these and other electromagnetic waves in this chapter.

Activity

With the excellent interactive tutorial at the following URL, students can find a clear yet detailed answer to the question, "What are Electromagnetic Waves?" The tutorial is written in a conversational style and includes helpful visuals and animations.

- http://www.colorado.edu/physics/2000/waves_particles/index.html

Differentiated Instruction

The animation at the URL below may help students understand the difficult concept of electromagnetic waves as vibrating electric and magnetic fields. The animation may be especially beneficial to visual learners, less proficient readers, and English language learners.

- http://www.phys.hawaii.edu/~teb/java/ntnujava/emWave/emWave.html

Enrichment

Students interested in space travel can learn about the radiation dangers associated with space travel with the set of activities titled "Space Faring: the Radiation Challenge," available at the following URL. The Web site includes videos and a teacher's guide.

- http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/SF_Radiation_Challenge_MS_video1.html

Science Inquiry

Assign the interactive applet at the URL below. It explains how microwaves in an oven cook food by energizing water molecules in the food. Have students use the question-and-answer format of the applet to challenge their predictive and explanatory skills. For each question, they should try to answer the question before reading the answer.

- http://www.colorado.edu/physics/2000/microwaves/index.html

Astronomy

Explain how scientists learn about the sun and other stars by analyzing their electromagnetic radiation with spectroscopy. The video at the first URL below provides a good introduction for students. For more in-depth information, see the other two URLs below.

- http://video.pbs.org/video/2219781967/
- http://www.ipac.caltech.edu/outreach/Edu/Spectra/spec.html
- http://www.enchantedlearning.com/subjects/astronomy/glossary/spectroscopy.shtml

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define electromagnetic radiation.
   - [Electromagnetic radiation is the transfer of energy by waves that are emitted from vibrating charged particles and that travel though matter or across empty space.]
2. What is an electromagnetic wave?
   - [An electromagnetic wave is a transverse wave that consists of vibrating electric and magnetic fields.]
3. How do electromagnetic waves interact with matter?
   - [Electromagnetic waves interact with matter by reflecting (bouncing back), refracting (bending while traveling through different materials), or diffracting (spreading out around obstacles).]
4. What is a photon?
   - [A photon is a tiny "packet" of electromagnetic energy that an electron gives off when it returns to a lower energy level.]
5. Identify sources of electromagnetic waves.
   - [Sources of electromagnetic waves include the sun and other stars and also devices such as radio towers and microwave ovens.]
6. Create a diagram to represent an electromagnetic wave. Explain your diagram to another student who has no prior knowledge of electromagnetic waves.
   - [Diagrams of electromagnetic waves should show they are transverse waves that consist of vibrating electrical and magnetic fields. Encourage students to explain their diagrams to other students.]
7. Explain how an electromagnetic wave begins.

- [An electromagnetic wave begins with a vibrating charged particle. The vibrating particle generates a vibrating electrical field, which in turn creates a vibrating magnetic field. Both fields together make up the electromagnetic wave.]

8. Compare and contrast mechanical transverse waves and electromagnetic transverse waves.
    - [Both types of transverse waves involve vibrations at right angles to the direction in which the wave travels. However, mechanical waves can travel only through a medium, whereas electromagnetic waves can travel across space as well as through a medium.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you learned that electromagnetic waves are transverse waves. Like other transverse waves, electromagnetic waves have certain properties.

- Based on your knowledge of other transverse waves, such as waves in a rope, what is the wavelength of an electromagnetic wave? How is it measured?

The wavelength of an electromagnetic wave is the distance between corresponding points of adjacent waves. It may be

- How do you think the wavelengths of electromagnetic waves are related to their frequencies? (*Hint*: How is the speed of waves calculated?)

The wavelengths of electromagnetic waves are inversely related to their frequencies.

21.3 Lesson 21.2 Properties of Electromagnetic Waves

Key Concept

All electromagnetic waves travel at the same speed through space, called the speed of light, which equals 3.0×10^8 meters per second. However, electromagnetic waves travel more slowly through a medium. Electromagnetic waves differ in their wavelengths and frequencies. The higher the frequency of an electromagnetic wave, the greater its energy. The speed of an electromagnetic wave is the product of its wavelength and frequency, so a wave with a shorter wavelength has a higher frequency, and vice versa.

Standards

- SCI.CA.8.IE.9.f
- NSES.5-8.B.3.6
- AAAS.6-8.4.A.3; AAAS.6-8.4.E.4; AAAS.6-8.4.F.8; AAAS.6-8.11.D.3; AAAS.6-8.12.D.4

Lesson Objectives

- Describe the speed of electromagnetic waves.
- Relate wavelength and frequency of electromagnetic waves.

Lesson Vocabulary

- **speed of light:** speed at which all electromagnetic waves travel through space, which is 3.0×10^8 m/s

Teaching Strategies

Introducing the Lesson

Most students will know that a lightning strike is seen before the accompanying thunder is heard. Ask them to explain why in order to elicit the information that light travels at a faster speed than sound. Tell students that the speed of light through space is faster than any other known speed in the universe and that they will learn in this lesson just how quickly light travels.

Activity

Have students explore the interactive animation at the URL below to see the relationships among speed, wavelength, and frequency of electromagnetic waves.

- http://www.colorado.edu/physics/2000/waves_particles/lightspeed-1.html

Building Science Skills

Give students additional practice finding the wavelength or frequency of electromagnetic waves when the other property is known. Here are two sample problems:

Problem: What is the frequency of an electromagnetic wave that has a wavelength of 1.5 meters?
Solution: Frequency $= \frac{3.0 \times 10^8 \text{ m/s}}{1.5 \text{ m}} = 2.0 \times 10^8$ waves/s, or 2.0×10^8 Hz
Problem: What is the wavelength of an electromagnetic wave with a frequency of 6.0×10^8 hertz?
Solution: Wavelength $= \frac{3.0 \times 10^8 \text{ m/s}}{6.0 \times 10^8 \text{ waves/s}} = 0.5$ m

Differentiated Instruction

Pair students who need extra help with students who are doing well in the class, and have partners make a main ideas/details chart for this lesson. Tell them to divide a sheet of paper down the middle and list the following main ideas on the left side of the paper, leaving room to add details about the main ideas on the right side of the paper:

- Speed of electromagnetic waves
- Wavelength of electromagnetic waves
- Frequency of electromagnetic waves
- Relationships among speed, wavelength and frequency of electromagnetic waves

Enrichment

Challenge interested students to explore the quantitative relationship between frequency and energy of electromagnetic waves. They can start with the URLs below. Ask them to share what they learn with the class.

- http://science.hq.nasa.gov/kids/imagers/ems/waves4.html
- http://csep10.phys.utk.edu/astr162/lect/light/spectrum.html

Science Inquiry

The hands-on guided inquiry activity at the following URL will allow students to discover and verify the relationship between wavelength and frequency of electromagnetic waves. In the activity, students will construct a simple model of light waves and gather data on wavelength and frequency.

- http://imagine.gsfc.nasa.gov/docs/teachers/lessons/roygbiv/roygbiv.html

Common Misconceptions

Students may think that light travels at the same speed in all media, as well as in space, because they have learned that the speed of light is constant, as it is, for example, in Einstein's equation $E = mc^2$. Explain to the class that the speed of light, and of electromagnetic waves in general, is constant when the waves travel across space. However, the waves travel at a slower speed through a medium, and this speed varies depending on the medium.

Answer to You Try It!

Problem: What is the wavelength of an electromagnetic wave that has a frequency of 3.0×10^8 hertz?

Solution: Wavelength $= \frac{\text{Speed}}{\text{Frequency}} = \frac{3.0 \times 10^8 \text{ m/s}}{3.0 \times 10^8 \text{ waves/s}} = 1.0$ m

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is the speed of light?
   - [The speed of light is the speed at which all electromagnetic waves travel through empty space. It is equal to 3.0×10^8 m/s.]
2. What is the wavelength of an electromagnetic wave?
   - [The wavelength of an electromagnetic wave is the distance between two corresponding parts of adjacent waves, such as the distance between two adjacent crests.]
3. Describe the range of frequencies of electromagnetic waves.
   - [Electromagnetic waves range in frequency from thousands of waves per second to trillions of waves per second.]
4. If an electromagnetic wave has a wavelength of 1 meter, what is it frequency?
   - [The frequency of the wave is the speed of light divided by the wavelength: Frequency $= \frac{3.0 \times 10^8 \text{ m/s}}{1 \text{ m}} = 3.0 \times 10^8$ waves/s, or 3.0×10^8 Hz]
5. Explain why light waves bend when they pass from air to water at an angle.
   - [Light waves travel more slowly through water than through air. Therefore, when they pass from air to water at an angle, they slow down and appear to bend.]
6. Explain the relationship between frequency and wavelength of electromagnetic waves.
   - [Higher frequency waves are generated by particles that are vibrating at a faster speed. This takes more energy than vibrating more slowly. Therefore, higher frequency waves have more energy than lower frequency waves.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you learned that electromagnetic waves vary in their wavelength and frequency. The complete range of wavelengths and frequencies of electromagnetic waves is outlined in the next lesson, "The Electromagnetic Spectrum."

- What do you think are the longest-wavelength electromagnetic waves?

Radio waves are the longest-wavelength electromagnetic waves.

- What might be the electromagnetic waves with the highest frequencies?

Gamma rays are the electromagnetic waves with the highest frequencies.

21.4 Lesson 21.3 The Electromagnetic Spectrum

Key Concept

The electromagnetic spectrum is the full range of wavelengths and frequencies of electromagnetic radiation. Radio waves are the broad range of electromagnetic waves with the longest wavelengths and lowest frequencies. They include microwaves. Mid-wavelength electromagnetic waves are called light, which consists of infrared, visible, and ultraviolet light. X rays and gamma rays are the electromagnetic waves with the shortest wavelengths and highest frequencies. They are used in medicine and for other purposes.

Standards

- MCR.6-8.SCI.9.4, 9
- NSES.5-8.B.3.6
- AAAS.6-8.4.E.5; AAAS.6-8.4.F.1, 2, 6, 9; AAAS.6-8.8.D.2; AAAS.6-8.12.D.4

Lesson Objectives

- Define the electromagnetic spectrum.
- Describe radio waves and their uses.
- Identify three forms of light.
- Describe X rays and gamma rays.

Lesson Vocabulary

- **electromagnetic spectrum:** full range of wavelengths of electromagnetic waves, from radio waves to gamma waves
- **gamma ray:** type of wave in the electromagnetic spectrum that has the shortest wavelength and greatest amount of energy
- **infrared light:** part of the electromagnetic spectrum in which waves have a wavelength between those of radio waves and visible light
- **microwave:** wave in the electromagnetic spectrum that falls at the upper range of radio waves
- **radar:** radio detection and ranging; use of reflected radio waves to track the position of objects
- **radio wave:** any wave in the electromagnetic spectrum that has a wavelength longer than infrared light
- **ultraviolet light:** electromagnetic radiation with a wavelength falling between the wavelengths of visible light and X rays
- **visible light:** range of wavelengths of electromagnetic waves that the human eye can detect
- **X ray:** wave in the electromagnetic spectrum with a wavelength between the wavelengths of ultraviolet light and gamma rays

Teaching Strategies

Introducing the Lesson

Write the names of the different wavelengths of electromagnetic radiation on the board in alphabetical order (gamma rays, infrared light, microwaves, radio waves, ultraviolet light, visible light, X rays). Then ask students to put the types of radiation in order based on wavelength, from longest wavelength (radio waves) to shortest wavelength (gamma rays). Students may not know the correct order at this point, so conclude by telling them they will learn the correct order—and why it matters—when they read this lesson.

Activity

Have students work as a class to make an electromagnetic spectrum chart that runs the length of a classroom wall. You can provide them with a roll of butcher or craft paper for the chart (available at office supply stores). Students should draw a horizontal axis and label it with the different types of radiation and their corresponding range of wavelengths and frequencies. The bandwidths of the different types of waves should be approximately proportional to the bandwidths of the actual waves. You might also have students add the range of energies associated with each wavelength and pictures of common sources of electromagnetic radiation for each region of the spectrum.

Discussion

Students can learn how different wavelengths in the electromagnetic spectrum are used in the U.S. by exploring the interactive chart at the first URL below. They are likely to be impressed by the number of different ways electromagnetic waves are used. After students have explored the chart, discuss with the class why the government regulates use of the electromagnetic spectrum. More information about the issue is available at the second URL below.

- http://reboot.fcc.gov/spectrumdashboard/searchSpectrum.seam
- http://www.eolss.net/EolssSampleChapters/C04/E6-31-02-09/E6-31-02-09-TXT-02.aspx

Differentiated Instruction

Suggest that students take the self-guided tour of the electromagnetic spectrum at the following URL. It is a self-paced tutorial for beginners, and covers all seven sections of the spectrum, from radio waves through gamma rays. Each segment of the tutorial contains specific examples, photos, and naturally occurring sources of the waves. Students can learn more when they are ready by rolling the cursor over the examples.

- http://www.pbs.org/wgbh/nova/assets/swf/1/electromagnetic-spectrum/electromagnetic-spectrum.swf

Enrichment

Ask a few students to create a song or rap about the electromagnetic spectrum that conveys basic information about the different wavelengths of radiation. If they need inspiration, suggest they listen to the teacher-created song at the following URL.

- http://www.youtube.com/watch?v=P_PVz8HrrCI

Science Inquiry

Some students may be interested in how X rays and CAT scans make images of structures inside the body. Direct them to the excellent tutorial at the URL below.

- http://www.colorado.edu/physics/2000/xray/index.html

Science Inquiry

The URL below provides a self-directed interactive inquiry activity consisting of four modules. Students may work independently or in small groups to complete each module. They will investigate different concepts related to the electromagnetic spectrum by examining relationships among wavelength, color, and temperature. Then they will determine the temperature of a variety of stars found in images from the Hubble Space Telescope and other sources.

- http://amazing-space.stsci.edu/resources/explorations/light/

Real-World Connection

Have students explore how their lives are affected by electromagnetic radiation by keeping an "electromagnetic journal" for a week. Ask them to record each time they observe or come in contact with any type of electromagnetic radiation. Examples might include listening to the radio, watching TV, making popcorn in a microwave oven, talking on their cell phone, or going through security at an airport. Students should record the date, time, and a one-sentence explanation of the incident, including which type of electromagnetic radiation was involved. At the end of the week, have students share their encounters with electromagnetic radiation and create a class tally to find out the most common activity involving exposure to electromagnetic radiation.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is the electromagnetic spectrum?
    - [The electromagnetic spectrum is the full range of wavelengths and frequencies of electromagnetic radiation, from radio waves to gamma rays.]
2. Describe how wave frequency changes across the electromagnetic spectrum, from radio waves to gamma rays.
    - [Radio waves are the longest-wavelength, lowest-frequency electromagnetic waves. Gamma rays are the shortest-wavelength, highest-frequency electromagnetic waves. Other electromagnetic waves vary continuously between these two extremes.]
3. List three uses of radio waves.

- [Answers may vary. *Sample answer*: Three uses of radio waves are radio and television broadcasts, cell phone transmissions, and radar.]

4. How are X rays and gamma rays used in medicine?
    - [X rays are used in medicine to make images of bones inside the body. Gamma rays are used in medicine to kill cancer cells.]
5. Create a public service video warning people of the dangers of ultraviolet light. Include tips for protecting the skin from ultraviolet light.
    - [Public service videos will vary but should clearly state the health dangers of ultraviolet light and how to protect the skin from ultraviolet light.]
6. Explain two ways that sounds can be encoded in electromagnetic waves.
    - [Sounds can be encoded in electromagnetic waves by variations in either the amplitude or the frequency of the waves.]
7. Explain how radar works.
    - [Radar works by sending radio waves toward an object and then detecting the reflected waves. If the object is moving toward or away from the radar device, the reflected waves can be used to determine its speed.]
8. Compare and contrast infrared, visible, and ultraviolet light.
    - [All three forms of light are in the mid-wavelength, mid-frequency range of the electromagnetic spectrum, between radio waves on one side and X rays and gamma rays on the other side. Visible light is in the middle of the light range. It is a very narrow range of wavelengths that the human eye can detect. Infrared light has wavelengths longer than red light in the visible range. It is low-energy light that can be felt as warmth. Ultraviolet light has wavelengths shorter than violet light in the visible range. Ultraviolet light is high-energy light that can damage the skin.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 21.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

This chapter introduces visible light. The next chapter, "Visible Light," discusses visible light in greater detail.

- In this lesson, you read that visible light consists of light of different colors. Do you know how visible light can be separated into its different colors? (*Hint*: How does a rainbow form?)

Visible light can be separated into its spectrum of colors by refraction. This may occur when light passes through rain

- In the next chapter, you'll read that visible light interacts with matter in certain characteristic ways. Based on your own experiences with visible light, how does it interact with matter? (*Hint*: What happens to visible light when it strikes a wall, window, or mirror?)

Visible light may be absorbed, refracted, reflected, or transmitted by matter.

CHAPTER 22 TE Visible Light

Chapter Outline

22.1 Chapter 22: Visible Light

Chapter Overview

Visible light can be produced by incandescence or luminescence. Light may interact with matter by reflection, refraction, transmission, or absorption. In terms of light, matter may be transparent, translucent, or opaque. The wavelength of visible light determines the color that the light appears to the human eye. Mirrors form images by reflecting light, and lenses form images by refracting light. Mirrors and lenses are used in optical instruments such as microscopes and telescopes. The structures of the human eye collect and focus light and send electrical signals to the brain, which interprets the signals. Common vision problems can be corrected with lenses, which help to focus images on the retina.

Online Resources

See the following Web sites for appropriate laboratory activities:

At the following URL, you can access more than 50 hands-on experiments designed to introduce middle school (and high school) students to optics based on the ray model of light. Topics include reflection, refraction, pinhole cameras, the human eye, color and the visible spectrum, and optical devices. Each lab has background information, safety guidelines, and tips for use in the classroom.

- http://www.nuffieldfoundation.org/practical-physics/optics

In this class experiment, students build a simple spectroscope, using inexpensive materials, to separate visible light into its component colors. Students will also use their spectroscope to analyze light from different sources.

- http://www.exploratorium.edu/spectroscope/

These Web sites may also be helpful:

The resource at the URL below contains a set of six activities on the properties of light, designed to be used as learning centers in middle school physical science classrooms. The stations include lessons on diffraction, transparency and translucence, rainbows, spinning disks, refraction, and the relationship between light and heat. The activities were designed to be economical and simple to set up, using common objects such as thermometers, Styrofoam cups, flashlights, and aluminum foil. Students rotate from one station to the next to observe and analyze each unique property.

- http://micro.magnet.fsu.edu/optics/activities/teachers/properties.html

This Web site offers a collection of resources on the topic of optics, including simulations, activities, and reference materials. There are sections dedicated to teachers and aspiring scientists, so the resources range in scope from simple to complex.

- http://www.optics4kids.org/home/tutorials.aspx

This is a guide for an introductory workshop on light for teachers. The workshop has been discontinued, but teachers may freely download all the materials. After completing the workshop materials, you may be better prepared to teach your classes about light, and you can adapt most of the experiments for use in the classroom.

- http://www.thephysicsfront.org/items/detail.cfm?ID=2508

The site below is a large collection of high school and middle school curricular materials on optics and microscopy. Users can link to comprehensive tutorials on basic microscopy, digital imaging, optical microscopy, and related topics. Text is supplemented with innovative virtual microscopes that allow users to explore focus and magnification.

- http://micro.magnet.fsu.edu/optics/

Pacing the Lessons

TABLE 22.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
22.1 The Light We See	2.5
22.2 Optics	3.0
22.3 Vision	1.0

22.2 Lesson 22.1 The Light We See

Key Concept

Visible light can be produced by incandescence or luminescence. Incandescence is the production of light by an object that is so hot it glows. Luminescence is the production of light by other means, such as chemical reactions. Light may interact with matter in several ways, including reflection, refraction, transmission, and absorption. Matter can be classified on the basis of how light interacts with it as transparent, translucent, or opaque. The wavelength of visible light determines the color that the light appears to the human eye. The primary colors of light are red, green, and blue. All other colors of light can be created by combining these primary colors.

Standards

- MCR.6-8.SCI.9.8, 9
- NSES.5-8.B.3.3
- AAAS.6-8.4.D.15; AAAS.6-8.4.E.5; AAAS.6-8.4.F.1, 6, 7, 8

Lesson Objectives

- Identify common sources of visible light.
- Explain how light interacts with matter.
- Describes the colors of visible light.

Lesson Vocabulary

- **absorption:** interaction of light with matter in which the particles of matter absorb light energy so light neither reflects from nor passes through matter
- **incandescence:** production of visible light by an object that is so hot it glows
- **luminescence:** production of visible light that does not involve high temperatures but instead occurs through chemical reactions or other means
- **opaque:** referring to matter that does not allow visible light to pass through it because it reflects or absorbs all of the light
- **pigment:** substance that colors materials by reflecting light of certain wavelengths and absorbing light of all other wavelengths
- **primary color:** one of three colors (red, green, or blue) that can be combined to produce all other colors of light
- **scattering:** process in which transmitted light is spread out in all directions by particles of matter
- **translucent:** referring to matter that transmits but scatters visible light
- **transmission:** process in which light passes through matter

- **transparent:** referring to matter that allows all visible light to pass through

Teaching Strategies

Introducing the Lesson

Use a prism to make a rainbow on a sheet of white paper or overhead projector. Ask students to identify and explain what they are seeing. Accept all reasonable answers at this point, and tell students they can find the correct answers when they read this lesson.

Activity

You may want to use the online lesson at the following URL to teach the topics in the FlexBook® lesson. The online lesson focuses on the idea that we can see objects because they either emit or reflect light. It discusses the way light is reflected, absorbed, and scattered to allow certain wavelengths to reach the eye, leading to the perception of different colors. Materials include a student worksheet, slideshow, and hands-on activity in which students examine different materials and describe how they interact with light.

- http://sciencenetlinks.com/lessons/light-2-the-lighter-side-of-color/

Building Science Blocks

You can use the NASA-created lesson plan at the URL below to introduce students to the basics of the primary additive colors. They will learn about the primary colors and color addition through a hands-on experiment with flashlights and colored filters. The Web site includes printable worksheets with answer keys.

- http://science.hq.nasa.gov/kids/imagers/teachersite/UL1.htm

Differentiated Instruction

Pair students of differing abilities, and ask partners to make flashcards of the lesson vocabulary terms. Tell them to write each term on one side of an index card and a definition and example on the other side of the card. Have pairs exchange flashcards and then use them to quiz their partner on the terms.

Enrichment

Students with an interest in life science may enjoy learning more about bioluminescence. Suggest that they identify at least two or three additional organisms (besides jellyfish and fireflies) that are bioluminescent and find out how they make use of their ability to produce light (some examples are described at the URLs below). Ask the students to prepare a PowerPoint presentation on the organisms to share the information with the class. Tell them to include photos of the organisms in their presentation.

- http://animals.nationalgeographic.com/animals/fish/anglerfish/
- http://www.seasky.org/deep-sea/lanternfish.html
- http://www.scientificamerican.com/article.cfm?id=bioluminescent-avatar
- http://www.scientificamerican.com/slideshow.cfm?id=bioluminescent-avatar

Science Inquiry

In the inquiry activity at the URL below, students work cooperatively to learn how light refracts through a prism. An accompanying Java simulation allows them to explore the refraction of light as it moves from a vacuum to different media, including air, water, and glass. Also included are details about Isaac Newton's early work with prisms.

- http://micro.magnet.fsu.edu/optics/activities/teachers/prisms.html

Use the worksheet/assessment at the first URL below with the PhET simulation "Color Vision" at the second URL. The worksheet gives step-by-step directions to focus students on the fundamentals of color addition and subtraction, with opportunities to construct hypotheses as they go.

- http://phet.colorado.edu/en/contributions/view/3050
- http://phet.colorado.edu/en/simulation/color-vision

Common Misconceptions

Electromagnetic radiation is sometimes referred to simply as "light." For example, the speed of all electromagnetic waves is often called simply the "speed of light." However, as discussed in this chapter, light refers specifically to visible light, which is just a tiny part of the electromagnetic spectrum. These dual uses of the term light may lead to confusion. Students may also confuse the spectrum of colors of visible light with the electromagnetic spectrum. Discuss these possible areas of confusion with the class to avoid misconceptions.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is incandescence?
   - [Incandescence is the production of visible light by an object that is so hot it glows.]
2. Define luminescence.
   - [Luminescence is the production of visible light that does not involve high temperatures but instead occurs through chemical reactions or other means.]
3. Identify two types of light bulbs and describe how they produce visible light.
   - [Answers may vary. Students should choose any two types of light bulbs that are described in the lesson and explain how they produce light. *Sample answer*: An incandescent light bulb produces visible light by incandescence. The bulb contains a very thin wire that becomes so hot that it glows when electricity passes through it. A fluorescent light bulb produces visible light by fluorescence. The bulb contains mercury gas that gives off ultraviolet light when electricity passes through it. The ultraviolet light is absorbed by a substance called phosphor, which coats the inside of the bulb, and the phosphor gives off most of the energy as visible light.]

4. What determines the color of visible light?
    - [The color of visible light is determined by its wavelength.]
5. List four ways that light interacts with matter.
    - [Four ways that light interacts with matter are reflection, refraction, transmission (with or without scattering), and absorption.]
6. If only blue light were to strike the bottle in the **Figure** 22.6, what color would the bottle appear?
    - [If only blue light were to strike the bottle in the figure, the bottle would still appear blue. It would transmit all of the blue light that strikes it.]
7. Compare and contrast transparent, translucent, and opaque matter.
    - [Matter can be classified as transparent, translucent, or opaque depending on how visible light interacts with it. Transparent matter, such as clear glass, transmits all of the light that strikes it. You can see clearly through transparent matter. Translucent matter, such as frosted glass, transmits but scatters the light that strikes it. You can see, at best, only blurry images or shapes through translucent matter. Opaque matter does not allow light to pass through it. Instead, it reflects and/or absorbs all of the light that strikes it. You cannot see anything through opaque matter.]
8. Explain why snow appears white to the human eye.
    - [Snow appears white to the human eye because it reflects all of the light that strikes it and all of the colors of visible light combined create white light.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you were introduced to the reflection and refraction of light. The next lesson "Optics" describes how mirrors reflect light and how lenses refract light.

- Based on your own experiences with mirrors, how do you think a mirror forms an image of the person in front of it?

***Sample answer*: I think it forms an image by reflecting light back to my eyes.**

- An example of a lens is a hand lens, also called a magnifying glass. This type of lens makes objects look bigger than they really are. How do you think this happens?

***Sample answer*: I think it makes objects look bigger by making an enlarged image of them.**

22.3 Lesson 22.2 Optics

Key Concept

Objects that reflect or refract light may form images. An image is a copy of an object that is formed by reflected or refracted light. According to the law of reflection, light is reflected at the same angle that it strikes a reflective surface. Mirrors reflect all of the light that strikes them and form images. Mirrors include plane (flat), concave, and convex mirrors. Each type of mirror forms images differently. Refraction of light occurs when light passes from one medium to another at an angle other than 90° and the speed of light changes in the new medium. Lenses refract light and form images. Lenses may be concave or convex, and the two types form images differently. Mirrors and lenses are used in optical instruments such as microscopes and telescopes to reflect or refract light and form images.

Standards

- MCR.6-8.SCI.9.8; MCR.6-8.TECH.6
- NSES.5-8.B.3.3
- AAAS.6-8.4.F.7; AAAS.6-8.8.D.2; AAAS.6-8.12.D.4

Lesson Objectives

- Outline how light is reflected.
- Describe how mirrors reflect light and form images.
- Explain the refraction of light.
- Describe how lenses refract light and form images.
- Explain how mirrors and lenses are used in optical instruments.

Lesson Vocabulary

- **concave:** curving inward like the inside of a bowl
- **convex:** curving outward like the outside of a bowl
- **image:** copy of an object that is formed by reflected or refracted light
- **laser:** device that produces a very focused beam of light of just one wavelength and color
- **law of reflection:** law stating that the angle at which reflected rays of light bounce off a surface is equal to the angle at which the incident rays strike the surface
- **lens:** transparent object with one or two curved surfaces that forms images by refracting light
- **optics:** study of visible light and the ways it can be used to extend human vision and do other tasks

Teaching Strategies

Introducing the Lesson

Show students common examples of concave mirrors (such as a makeup mirror and a dental mirror) and convex lenses (such as a hand lens and reading glasses). Pass the items around the room so students have a chance to observe how they affect the appearance of objects. Tell students they will learn in this lesson how mirrors and lenses such as these focus light and extend human vision.

Building Science Skills

Have students do the activity at the URL below. In the activity, they will explore different types of lenses. For each type, they will observe how objects look through the lenses and what happens to light that shines through the lenses. From their observations, they will develop descriptive statements and questions about lenses.

- http://micro.magnet.fsu.edu/optics/activities/students/exploringlenses.html

The module at the first URL below was created specifically for use with the PhET simulation "Geometric Optics" (second URL below), and it teaches students about convex lenses. The module includes a lesson plan for teachers, step-by-step directions for students, and a set of Power Point questions for use as warm-up questions or informal assessment.

- http://phet.colorado.edu/en/contributions/view/2852
- http://phet.colorado.edu/en/simulation/geometric-optics

Activity

Assign the two quick, interactive animations below. The first animation shows how the image created by a convex lens is affected by the distance between the object and lens. The second animation shows how various objects look when viewed under a microscope at different magnifications.

- http://micro.magnet.fsu.edu/primer/java/scienceopticsu/magnify/index.html
- http://micro.magnet.fsu.edu/primer/java/scienceopticsu/virtual/magnifying/index.html

Differentiated Instruction

Make sure students have a chance to handle and use different types of mirrors and lenses so they can observe the images they create and how the distance of objects from the mirrors or lenses affects the images. It may also be helpful for students to create a compare/contrast table for concave and convex mirrors and lenses to help them sort out their similarities and differences.

Enrichment

A fun extension project is to explore funhouse mirrors, which consist of a combination of concave and convex surfaces. Direct students to the activity at the following URL to apply their knowledge of concave and convex mirrors to funhouse mirrors. Urge them to share what they learn with the class.

- http://www.learner.org/teacherslab/science/light/lawslight/funhouse/index.html

Science Inquiry

Use the inquiry activity at the following URL to help students understand the law of reflection. The only materials required are a mirror, paper, and masking tape. The Web page also includes a Java simulation on angles of reflection.

- http://micro.magnet.fsu.edu/optics/activities/teachers/mirror.html

Common Misconceptions

Make sure students understand that plane mirrors only appear to reverse left and right. It is our brain that interprets the image that way. For a detailed explanation and ways to discourage the misconception that mirrors actually reverse left and right, read the article at this URL: http://scienceinquirer.wikispaces.com/file/view/MirrorReverses.pdf .

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define optics.
   - [Optics is the study of visible light and the ways it can be used to extend human vision and do other tasks.]
2. State the law of reflection.
   - [The law of reflection states that the angle at which reflected rays of light bounce off a surface is equal to the angle at which the incident rays strike the surface.]
3. What type of image does a convex mirror form?
   - [A convex mirror forms only virtual, right-side up, reduced images.]
4. What type of image does a concave lens form?
   - [A concave lens forms only virtual, right-side up, reduced images.]
5. Choose an optical instrument described in this lesson and state how it uses lenses and/or mirrors to focus visible light.
   - [Answers may vary. Students should choose one type of optical instrument described in the lesson and state how it uses lenses and/or mirrors to change visible light. *Sample answer*: A light microscope uses convex lenses to make enlarged images of tiny objects.]
6. Assume that a light shines upward through the water of a swimming pool. Create a diagram to show what happens to the light when it passes from the water to the air above the water's surface. (The light should enter the air from the water at an angle other than 90°.) Explain your diagram to another student.
   - [Diagrams may vary but should show that rays of light refract when they pass from water to air at an angle other than 90°.]

7. Compare and contrast regular and diffuse reflection.
   - [Both regular and diffuse reflection occur when rays of light bounce off a reflective surface. In both cases, the angles of the reflected rays are the same as the angles of the incident rays. However, in regular reflection all of the reflected rays are parallel because the surface is smooth, whereas in diffuse reflection the reflected rays go in different directions because the surface is not smooth. As a result, regular reflection produces a clear image, and a diffuse reflection produces either no image or a blurry image.]
8. Explain how concave mirrors form real and virtual images.
   - [The image formed by a concave mirror depends on how far the object is from the mirror. If the object is farther from the mirror than the focal point is, then the image is real, upside down, and reduced in size. If the object is closer to the mirror than the focal point is, then the image is virtual, right-side up, and enlarged in size.]
9. Relate focus and position of an object to the image formed by a convex lens.
   - [If the object is closer to the lens than the focus is, a virtual image forms on the same side of the lens as the object. The image is right-side up and enlarged. If the object is farther from the lens than the focus is, a real image forms on the side of the lens opposite the object, and the image is upside down. The image may be smaller, larger, or the same size as the object depending on the object's distance from the lens. The farther away the object is, the more reduced the image is.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read how convex and concave lenses refract light. The human eye, which you can read about in the next lesson "Vision," also contains a lens.

- How do you think the lens in the eye works? What is its role in vision?

The role of the lens in vision is to help focus light and form an image on the retina at the back of the eye.

- Do you think the lens in the eye is a concave lens or a convex lens?

It is a convex lens that forms reduced upside-down images.

22.4 Lesson 22.3 Vision

Key Concept

The structures of the human eye collect and focus light, forming an image on the retina at the back of the eye. The image is converted to electrical signals that travel to the brain, which interprets the signals and "tells" us what we are seeing. Common vision problems include nearsightedness (myopia), which can be corrected with concave lenses, and farsightedness (hyperopia), which can be corrected with convex lenses.

Standards

- NSES.5-8.B.3.3
- AAAS.6-8.4.F.2, 6; AAAS.6-8.12.D.4

Lesson Objectives

- Describe the structure and function of the eye.
- Explain how the eyes and brain work together to enable vision.
- Identify common vision problems and how they can be corrected.

Teaching Strategies

Introducing the Lesson

Introduce the eye and the upside-down images it forms by asking students to imagine what it would be like if everything they saw was upside down. Give students a chance to experience this by holding a plane mirror in front of them so that it reflects the ceiling. Tell them to take a few steps while holding the mirror in this way (make sure they do this where there are no objects on the floor to trip them). They will know they are walking on the floor but will have the odd sensation of walking on the ceiling. Explain that the eye actually does form upside-down images, yet everything we see appears to be right-side up as it really is. Tell students they will learn how this happens when they read this lesson.

Activity

To introduce the roles of the eye and brain in the perception of objects, including their color, use the activity at the URL below. The Web site includes a student worksheet and slideshow. Also provided are discussion questions, ideas for assessment, and extensions.

- http://sciencenetlinks.com/lessons/light-3-all-those-seeing-color-say-eye/

Demonstration

The interesting demonstration at the following URL will help students understand eye anatomy by finding the blind spot in their own retinas. Explain that the blind spot is an area on the retina without light receptors, so an image that falls on this area cannot be detected. It is in this area that the optic nerve exits the eye on its way to the brain.

- http://faculty.washington.edu/chudler/chvision.html

Activity

The video-based interactive activity at the URL below gives students a close-up view of the anatomy of a real cow's eye as it is dissected by a teenaged narrator. The Flash movies are divided into 12 segments which may be stopped and restarted interactively. Each segment contains text information with vocabulary definitions in a "hover-over" format. The resource also provides a diagram of the eye and detailed illustrations that show how the eye refracts light and sends messages to the optic nerve.

- http://www.teachersdomain.org/asset/lsps07_int_coweye/

Differentiated Instruction

Suggest that students make a simple flow chart to summarize how light passes through the eye and how the light is affected by each structure it passes through.

Enrichment

Ask a few interested students to explore the topic of optical illusions to show the importance of the brain in vision. Have them find several online examples of optical illusions to share with and explain to the class. The following URLs are good places to start.

- http://kids.niehs.nih.gov/games/illusions/index.htm
- http://www.illusions.org/

Science Inquiry

Challenge small groups of students to make cross-sectional models of the human eye, following the guidelines at this URL: http://mesa.ucop.edu/mesa_day_rules/Model_Science_The_Human_Eye_2012-2013.pdf .

Common Misconceptions

Common misconceptions about the human eye include the following:

- The pupil of the eye is a black spot on the surface of the eye.
- The eye perceives upright images.
- The lens forms a picture on the retina, and the brain "looks" at this picture

Address these misconceptions and explain why they are incorrect. For example, for the third misconception, explain that images on the retina are converted to electrical signals that travel to the brain through the optic nerve and that the brain then interprets the electrical signals as images.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. How are the pupil and iris related?
   - [The pupil is an opening in the eye that lets light enter the eye. The pupil gets bigger or smaller to allow more or less light in as needed. The iris, which is the colored part of the eye, controls the size of the pupil.]
2. Which parts of the eye focus light?
   - [The cornea and lens focus light.]
3. Describe the retina.
   - [The retina is a membrane lining the back of the eye where images are focused. It contains nerve cells that change the images to electrical signals.]
4. What is the function of the optic nerve?
   - [The optic nerve carries electrical signals from the rods and cones in the retina to the brain.]
5. In an eye with normal vision, where are images focused?
   - [In an eye with normal vision, images are focused on the retina.]
6. Create a lesson for younger students to teach them how the eye works. With your teacher's approval, present your lesson to a class in a lower grade.
   - [Lessons will vary, but they should reflect a correct understanding of how the structures of the eye work together to gather and focus light and form an image. The lesson should be appropriate for younger students. If possible, arrange for students to present their approved lessons to classes in a lower grade.]
7. Compare and contrast rods and cones.
   - [Both rods and cones are light-sensing cells in the retina of the eye. They change light images to electrical signals. Rods can sense dim light but not colors of light, whereas cones can sense colors but not in dim light.]
8. Why is the brain needed for vision?
   - [The eyes only form images and convert them to electrical signals. The brain is needed to interpret the signals as images and "tell" us what we are seeing.]
9. Identify a common vision problem and explain how lenses can be used to correct it.
   - [Answers may vary. Students are likely to describe either myopia or hyperopia and how it can be corrected with lenses. *Sample answer*: A common vision problem is myopia, or nearsightedness, in which near vision is clear but distant vision is blurry. It occurs when the eyeball is longer than normal, causing images to be focused in front of the retina. Myopia can be corrected with concave lenses. The lenses focus images farther back in the eye, so they are on the retina instead of in front of it.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 22.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

This chapter focuses on energy in the form of visible light. Another common form of energy, electrical energy, is the focus of the chapter "Electricity."

- What are some ways you use electrical energy?

Ways might include running appliances, computers, and lights.

- Where does the electrical energy you use come from?

Sources may vary. For example, the electrical energy might come from a coal-burning power plant or a hydroelectric p

CHAPTER 23 TE Electricity

Chapter Outline

23.1 Chapter 23: Electricity

Chapter Overview

Electric charge is a physical property of particles or objects that attract or repel each other because they are surrounded by an electric field that exerts electric force. Objects become charged when they transfer electrons, and a buildup of charges is called static electricity. Electric current is a continuous flow of electric charges through matter that occurs whenever there is a difference in voltage. Ohm's law states that current increases when voltage increases or resistance of matter to the current decreases. An electric circuit is a closed loop through which electric current can flow. Electric power is the rate at which an electric device changes electric current to another form of energy. Electronics is the use of electric current to encode information. Electronic components such as transistors and microchips are made of semiconductors and are found in electronic devices such as computers and TV remotes.

Online Resources

See the following Web sites for appropriate laboratory activities:

This set of eight classroom experiments was designed to help students gain a conceptual understanding of voltage, current, resistance, and Ohm's law by exploring simple circuits, diagnosing faulty circuits, and using voltmeters and ammeters. Each experiment features detailed diagrams and/or photos, plus questions to elicit critical thinking. Additional links provide instructional support for how to introduce current, how to work safely with electrical components, and a history of the field of electricity.

- http://www.nuffieldfoundation.org/practical-physics/simple-electric-circuits

At the following URL, you can access a set of experiments for teaching the basics of electricity, electromagnetism, and electronics using hands-on activities with circuits and batteries.

- http://www.energizer.com/learning-center/science-center/Pages/battery-powered-science-projects.aspx

These Web sites may also be helpful:

If you want to brush up on electricity before teaching the lessons in this chapter, the URL below provides an excellent free resource that is highly recommended. It presents key ideas in the language of a non-physicist. Topics include electrostatics, conductors and insulators, simple and parallel circuits, resistance, voltage, and current.

- http://www.allaboutcircuits.com/vol_1/index.html

This URL has many interesting middle school activities relating to electricity and electronics. The activities can be used for classroom or science fair projects.

- http://www.sciencebuddies.org/science-fair-projects/recommender_interest_area.php?ia=Elec&d=intermediate&p=1

Pacing the Lessons

TABLE 23.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
23.1 Electric Charge	2.0
23.2 Electric Current	2.0
23.3 Electric Circuits	2.5
23.4 Electronics	1.5

23.2 Lesson 23.1 Electric Charge

Key Concept

Electric charge is a physical property that causes particles or objects to attract or repel each other because they are surrounded by an electric field that exerts electric force. Objects become charged when they transfer electrons, which can occur through friction, conduction, or polarization. A buildup of charges on an object is known as static electricity. Static discharge occurs when the built-up charges suddenly flow from the object.

Standards

- MCR.6-8.SCI.9.1
- NSES.5-8.B.3.1
- AAAS.6-8.4.G.5; AAAS.6-8.12.D.4

Lesson Objectives

- Define electric charge and electric force.
- Describe electric fields.
- Identify ways that electric charge is transferred.

Lesson Vocabulary

- **electric charge:** physical property of particles or objects that causes them to attract or repel each other without touching; may be positive or negative
- **electric field:** space around a charged particle where the particle exerts electric force on other particles
- **electric force:** force of attraction or repulsion between charged particles
- **law of conservation of charge:** law stating that charges are not destroyed when they are transferred between two materials or within a material, so the total charge remains the same
- **static discharge:** sudden flow of electrons from an object that has a buildup of charges
- **static electricity:** buildup of charges on an object that occurs through polarization

Teaching Strategies

Introducing the Lesson

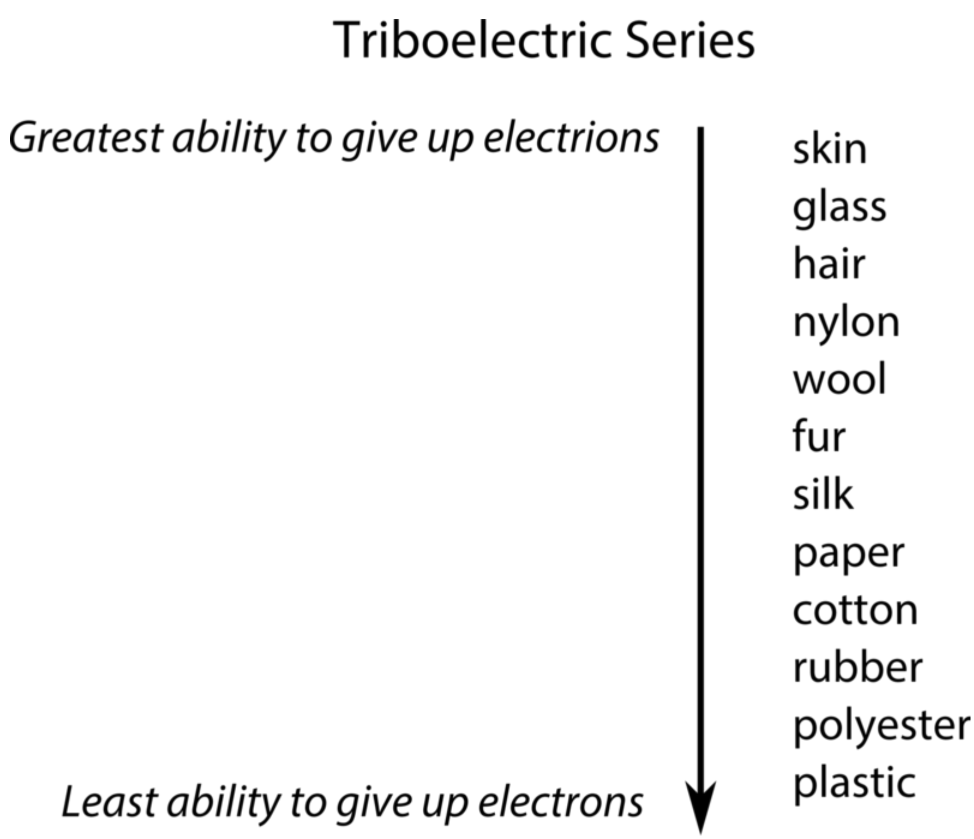
Blow up a latex balloon and ask a volunteer to let you rub the balloon on his or her hair. Students will observe that this causes the balloon and hair to attract each other. Tell the class they will learn in this lesson why this interesting phenomenon occurs.

Building Science Skills

Students can detect electric fields by building and using an electric field detector. The activity "Detecting Electric Fields" at the following URL explains how. http://www.ehow.com/info_8006745_middle-school-electronic-projects.html

Activity

Explain to students that scientists have ranked materials in order of their ability to give up or hold onto electrons. This ranking is called a triboelectric series (see the list below). If two materials are rubbed together, the one higher on the list should give up electrons and become positively charged and the one lower on the list should accept electrons and become negatively charged. Provide the class with several of the materials on the list, and give students a chance to select pairs of the materials to rub together and observe whether they become oppositely charged (by attracting each other).



Differentiated Instruction

Before students read the lesson, have them make a three-column KWL chart about electricity. Tell students to fill in the K (Know) and W (Want to Know) columns of the chart before they read the lesson. This should be relatively easy to do even for low-science-information students because of their daily use of electricity. The items they enter in the K column may reveal misconceptions that students hold about electricity, so be sure to correct these erroneous ideas. After students read the lesson, they should fill in the L (Learned) column of their chart. Ask them if any of their Want-to-Know questions remain unanswered. If questions still remain, call on volunteers to answer them or address them yourself.

Enrichment

Assign a small group of students to do the activity "The Day the Lights Went Out" at the following URL. They will brainstorm what life would be like if they suddenly had no electricity for devices such as appliances and lights. Then they will create a short skit to demonstrate their ideas about a life without electricity. Give the students a chance to present their skit to the class.

- http://www.thetech.org/exhibits/online/topics/11o.html

Science Inquiry

Divide the class into groups, and have each group do one of the static electricity inquiry activities at the URLs below. Provide the groups with the procedure and materials, but do not provide them with the explanations. Instead, challenge them to explain what happened in their experiment.

- http://www.miamisci.org/af/sln/frankenstein/static.html
- http://www.exploratorium.edu/science_explorer/sparker.html

Real-World Connection

Have pairs or small groups of students do the activity "Making Use of Electricity" at the following URL. They will identify many electrical devices in their home or school and analyze how the devices use electricity. They will also discover the ways electrical devices change current to other forms of energy, including heat, light, and motion.

- http://www.thetech.org/exhibits/online/topics/11g.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define electric charge.
   - [Electric charge is a physical property of particles or objects that causes them to attract or repel each other without touching.]
2. Describe the forces between charged particles.
   - [Forces between charged particles are forces of attraction or repulsion. Opposite charges attract each other, whereas like charges repel each other.]
3. What is an electric field?
   - [An electric field is a space around a charged particle where the particle exerts electric force on other particles.]
4. State the law of conservation of charge.
   - [The law of conservation of charge states that when electrons are transferred between two atoms or objects or within an object, the total charge remains the same. Electrons move, but they aren't destroyed.]
5. Outline how lightning occurs.
   - [Lightning occurs when a cloud builds up regions of positive and negative charges. The negative charges are concentrated at the bottom of the cloud and the positive charges are concentrated at the top. Through polarization, the ground below the cloud becomes positively charged. As charges keep building up, eventually a channel of charged particles starts to form in the air between the cloud and the ground. When the channel of charges is complete, electricity is suddenly discharged as a bolt of lightning.]
6. If you rub a piece of tissue paper on a plastic comb, the paper and comb stick together. Based on lesson concepts, explain why this happens.
   - [If you rub a piece of tissue paper on a plastic comb, the paper becomes positively charged and the comb becomes negatively charged due to friction between the two materials and their different abilities to attract electrons. The paper and comb then stick together because opposite charges attract each other.]
7. Compare and contrast the ways that friction, conduction, and polarization transfer electric charge.
   - [Friction, conduction, and polarization are different ways in which electric charge may be transferred. Friction and conduction occur when two materials have direct contact and one of them attracts electrons more strongly than the other. In friction, the two materials rub together. In conduction, the two materials just have direct contact with each other. Polarization occurs without direct contact between materials when a charged object comes close to a neutral object. The neutral object develops areas of positive and negative charges because of the force of attraction or repulsion between the electric field of the charged object and the electrons in the neutral object.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

You read in this lesson that lightning is a flow of electric charges. The electric current that flows through wires in your home is also a flow of electric charges. You'll read about electric current in the next lesson, "Electric Current."

- How might the electric current in a wire inside the walls of a house differ from a bolt of lightning?

A bolt of lightning is the sudden transfer of a great deal of electric charge. Electric current in a wire is a relatively sma

- Lightning strikes may injure people or start fires. How do you think current can be used safely inside the walls of buildings?

Current can be used safely inside walls because it is carried by wires that are wrapped in an insulating material such a

23.3 Lesson 23.2 Electric Current

Key Concept

Electric current is a continuous flow of electric charges through matter that occurs whenever there is a difference in voltage, or electric potential energy. Sources of voltage include electric generators and chemical or solar cells. Materials with low resistance to the flow of current are called electric conductors, and materials with high resistance are called electric insulators. According to Ohm's law, current increases when voltage increases or resistance decreases. Current can be calculated as voltage divided by resistance.

Standards

- SCI.CA.8.IE.9.f; SCI.CA.8.PS.7.C
- AAAS.6-8.4.D.15; AAAS.6-8.4.E.4; AAAS.6-8.8.C.4; AAAS.6-8.11.C.3; AAAS.6-8.12.D.4, 11

Lesson Objectives

- Define electric current.
- Explain how voltage is related to electric current.
- Identify sources of voltage
- Relate electric current to materials.
- State Ohm's law.

Lesson Vocabulary

- **alternating current (AC):** electric current that keeps reversing the direction in which the current flows
- **direct current (DC):** electric current that flows in only one direction
- **electric conductor:** material that has low resistance to the flow of electric current
- **electric current:** continuous flow of electric charges due to a difference in electric potential energy, or voltage
- **electric insulator:** material that has high resistance to the flow of electric current
- **Ohm's law:** law stating that current increases as voltage increases or resistance decreases
- **resistance:** opposition to the flow of electric charges that occurs when electric current travels through matter
- **voltage:** difference in electric potential energy between two positions; also called potential difference

Teaching Strategies

Introducing the Lesson

Bring a variety of small chemical batteries to class, including 1.5-volt (AAA, AA, and D) and 9-volt batteries. Pass the batteries around and ask students to identify the number of volts for each battery (in fine print on the side of the battery). Ask students if they know what volts measure. Point out the two terminals on each battery, and ask students if they know why each battery has a positive and negative terminal. Tell students to record their answers to the questions in their science notebook and then revisit the answers after they read the lesson to see if they were correct.

Activity

When you teach students about batteries and other sources of voltage, place the content in historical context by assigning the tutorial at the first URL below. The tutorial explains how Volta invented the first battery, called the voltaic pile, in 1800. It also describes how the invention soon led to new scientific discoveries. You can have students replicate Volta's voltaic pile device with the lesson plan at the second URL below.

- http://www.magnet.fsu.edu/education/tutorials/java/voltaicpile1/index.html
- http://www.chymist.com/batteries.pdf

Building Science Skills

Students can observe Ohm's law in action and also use the equation for Ohm's law by doing at the activity "Currents and LED brightness" at the following URL.

- http://www.ehow.com/info_8006745_middle-school-electronic-projects.html

Differentiated Instruction

Pair less proficient readers and English language learners with students who are doing well in the class, and ask partners to make a cluster diagram for electric current. The should label a small center circle "Electric Current" and add several larger circles around it for concepts pertaining to electric current. For example, they might have circles for the following concepts: definition of current, direct and alternating current, voltage and voltage sources, resistance, electric conductors and insulators, and Ohm's law. They should fill in the circles with important details about the topics. Suggest to students that they save their cluster diagrams for lesson review.

Enrichment

Have a few students make and demonstrate a simple electric motor with the activity "Electrical Motor" at the following URL. The device will show students how electric current can change to kinetic energy.

- http://www.ehow.com/info_8006745_middle-school-electronic-projects.html

Science Inquiry

Have students make their own batteries with citrus fruit and metal screws by following the procedure at the URL below. They will test their battery with a light bulb and then investigate whether the juice of other fruits and vegetables can be used to make electricity. They will also measure the pH of each "battery" and see if there is a relationship between the pH of the juice and the amount of light that is produced.

- http://www.miamisci.org/af/sln/frankenstein/fruity.html

Common Misconceptions

Several common misconceptions about electric charge, current, and circuits are listed below. All of them are logical extensions of the first misconception on the list, which is a basic misunderstanding of electric charge. Discuss the misconceptions with the class and explain why they are erroneous. You can find detailed explanations at this URL: http://www.physicsclassroom.com/class/circuits/u9l2e.cfm .

Misconceptions:

- When a chemical cell no longer works, it is out of charge and must be recharged before it can be used again.
- A chemical cell can be a source of charge in a circuit, and the charge that flows through the circuit originates in the cell.
- Charge becomes used up as it flows through a circuit. For example the amount of charge that leaves a light bulb is less than the amount that enters the light bulb.
- Charge flows through a circuit at a very high speed. This explains why a light bulb lights up immediately after the wall switch is turned on.

Answer to You Try It!

Problem: A 120-volt voltage source is connected to a wire with 20 ohms of resistance. How much current flows through the wire?

Solution: Current $= \frac{120 \text{ volts}}{20 \text{ ohms}} = 6$ amps

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is electric current?
   - [Electric current is a continuous flow of electric charges.]
2. What is the difference between direct and alternating current?
   - [Direct current flows in just one direction. Alternating current keeps reversing direction.]
3. Define voltage.

- [Voltage is a difference in electric potential energy between two positions.]

4. List three sources of voltage.
   - [Three sources of voltage are electric generators, chemical cells, and solar cells.]
5. Identify three properties that affect the resistance of a given material.
   - [Three properties that affect the resistance of a given material are the materials length, width, and temperature.]
6. A 12-volt battery is connected to a light bulb by wires. The wires and light bulb together have 6 ohms of resistance. How many amps of current are flowing through the wires?
   - [The amps of current flowing through the wires are: Current $= \frac{12 \text{ volts}}{6 \text{ ohms}} = 2$ amps.]
7. Explain how voltage is related to electric current.
   - [Voltage is a difference in electric potential energy between two positions. For an electric current to flow from one position to another, there must be a difference in voltage between the two positions.]
8. Compare and contrast electric conductors and electric insulators. Give an example of each.
   - [Some materials resist the flow of electric current more or less than other materials do. Electric conductors are materials that have low resistance to electric current. An example is copper. Electric resistors are materials that have high resistance to electric current. An example is wood.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you learned about electric current. The next lesson, "Electric Circuits," focuses on the path that electric current travels. Think about a ceiling light with a wall switch. You probably have several in your home.

- What path does current travel to get from the switch on the wall to the light on the ceiling?

The current travels through wires inside the wall and ceiling.

- How do you think the switch controls the flow of current to the light?

The switch opens and closes the circuit to turn the flow of current off and on.

23.4 Lesson 23.3 Electric Circuits

Key Concept

An electric circuit is a closed loop through which electric current can flow. It must include a source of voltage and conductors such as wires, which may be arranged in series or parallel. Electric power is the rate at which an electric device changes electric current to another form of energy. Electric safety features include three-prong plugs, circuit breakers, and GFCI outlets.

Standards

- SCI.CA.8.IE.9.f
- MCR.6-8.SCI.9.5, 10
- NSES.5-8.B.3.4
- AAAS.6-8.4.E.2; AAAS.6-8.4.E.4; AAAS.6-8.4.G.4; AAAS.6-8.8.C.4; AAAS.6-8.11.C.3; AAAS.6-8.12.D.4, 11

Lesson Objectives

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

Lesson Vocabulary

- **electric circuit:** closed loop through which current can flow
- **electric power:** rate at which a device changes electric current to another form of energy
- **parallel circuit:** electric circuit that has two loops through which current can flow
- **series circuit:** electric circuit that has only one loop through which current can flow

Teaching Strategies

Introducing the Lesson

Create a very simple electric circuit modeled on the circuit pictured on the first page of the lesson. It should include a battery, two wires, and a small light. Leave one of the wires disconnected from the positive terminal of the battery but connected to the light, as in the picture. Call on students to explain what is wrong with the circuit. Some students are likely to recognize the problem. Connect the wire to show them that the light comes on when the circuit is complete. Tell the class they will learn about circuits, beginning with simple circuits like this one, when they read this lesson.

Activity

A fun way for students to learn about circuits is with the "Squishy Circuits Project" at the following URL. Students can make circuits using two homemade PlayDoh-like materials, one of which is a conductor and one of which is an insulator. Other parts of the circuit include an LED light and a battery pack. More advanced projects are also provided by the Web site, including building parallel circuits, motor circuits, and buzzer circuits. All needed materials are inexpensive and readily available, or a kit can be purchased from the Web site for about $20. Videos and a teacher's guide can also be accessed at the URL.

- http://courseweb.stthomas.edu/apthomas/SquishyCircuits/index.htm

Building Science Skills

With the high-quality interactive simulation at the URL below, students can build virtual models of a DC circuit, using "click and drag" to attach wires, batteries, switches, and resistors. The simulation allows them to experiment with a wide variety of circuit configurations and to vary voltage and resistance.

- http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

Activity

Students can get hands-on experience with circuits by building and testing a simple circuit, using the activity "Build a Simple Circuit" at the following URL. Be sure to have students answer the questions at the end of the activity.

- http://www.thetech.org/exhibits/online/topics/12e.html

Differentiated Instruction

The fine tutorial at the URL below is recommended for students who are visual learners or need extra help understanding electric current and circuits. The tutorial uses water flowing through a closed system as a more accessible model for electricity flowing through a circuit. It includes interactive animations and an engaging question-and-answer format.

Enrichment

Ask one or more students to interview an expert on electric circuits. The expert might be an electrician, electrical contractor, or electrical engineer. Students should use the interview opportunity to find out about the career as well as learn more about electric circuits. Advise students to prepare for the interview by drawing up a set of questions they would like to have answered. Invite the students to share what they learn with the class in an informal oral presentation.

Science Inquiry

Have groups of students do the activity "Build a Series Circuit" at the first URL below. They will make a simple series circuit and answer some critical thinking questions about series circuits. Then they will be challenged to think of a way to convert their series circuit to a parallel circuit. They can find out how by completing the activity "Build a Parallel Circuit" at the second URL.

- http://www.thetech.org/exhibits/online/topics/12k.html (series circuit)
- http://www.thetech.org/exhibits/online/topics/12o.html (parallel circuit)

Common Misconceptions

The PDF document below identifies several common student misconceptions about electric circuits and electricity in general. For example, many students think that devices such as lights in a circuit actually use up current. Many also confuse the concepts of voltage and current in a circuit. For instructional ideas to overcome these and other misconceptions, see pages 6–8 of the document.

- http://www.epcae.org/uploads/documents/Electricity_pck_Sept%2018.pdf

Answers to You Try It!

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

Solution: Power = 120 volts $\times$ 12 amps = 1440 watts, or 1.44 kilowatts

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

Solution: Electrical Energy = 0.12 kilowatts $\times$ 2 hours = 0.24 kilowatt-hours

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Identify the parts of an electric circuit.
   - [An electric circuit must include a source of voltage, such as a battery, and a closed loop of a conductor, such as a wire. It may also include electric devices that convert some of the electrical energy to other forms of energy, and a switch, which turns the current off or on by opening or closing the circuit.]
2. What is electric power?

- [Electric power is the rate at which a device changes electric current to another form of energy. It is equal to current multiplied by voltage.]

3. What variables determine the amount of electrical energy an appliance uses?
   - [Variables that determine the amount of electrical energy an appliance uses are the power of the appliance and how long it is used.]
4. Identify an electric safety feature and describe how it works.
   - [Answers may vary. *Sample answer*: An electric safety feature is a circuit breaker. It is a switch that automatically opens a circuit if too much current flows through it. Once the problem is resolved, the circuit breaker can be switched back on to close the circuit again.]
5. List three tips to reduce the risk of injury or fire from electricity.
   - [Answers may vary. *Sample answer*: Three tips to reduce the risk of injury or fire from electricity are: never mix electricity and water, never overload circuits, and never use devices with damaged cords or plugs.]
6. Draw a simple electric circuit that includes a battery, light bulb, and switch. Use arrows to show the flow of electrons through the circuit.
   - [Drawings may vary but should show a complete circuit that includes a battery, wires attached to the two terminals of the battery, a light bulb, and a switch. Arrows should show that electrons flow through the circuit from the negative to positive terminals of the battery when the switch is turned to the "on" position.]
7. What is the power of an electric device that is connected to a 12-volt battery if the circuit is carrying 3 amps of current?
   - [The power of the device is: Power = 3 amps $\times$ 12 volts = 36 watts.]
8. Compare and contrast series and parallel circuits.
   - [Both series and parallel circuits consist of closed loops that carry electric current. However, a series circuit has only one loop, whereas a parallel circuit has two (or more) loops. As a result, if a series circuit is interrupted at any point, no current can flow through the circuit. In contrast, if a parallel circuit is interrupted in one loop, current can still flow through the other loop.]
9. Explain how a short circuit occurs.
   - [A short circuit occurs when electric current follows a shorter path than the intended loop of the circuit. For example, if two wires in a damaged appliance cord come into contact with each other, current can flow from one wire to the other and bypass the appliance.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.3 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you read that electric devices convert electrical energy to other forms of energy. For example, a microwave oven converts electrical energy to electromagnetic energy in the form of microwaves. A blender converts electrical energy to sound energy and the kinetic energy of the whirring blades.

- Do you think all electric devices convert electrical energy to other forms of energy?

No; electronic devices use electrical energy to encode information.

- Computers are familiar electric devices. Do you know how they use electric current?

Computers are electronic devices. They use electric current to encode, analyze, and transmit information.

23.5 Lesson 23.4 Electronics

Key Concept

Electronics is the use of electric current to encode information in either digital or analog signals, both of which change the voltage of the current but in different ways. Electronic components, such as transistors and microchips, are made of p-type and n-type semiconductors. Electronic devices include computers, mobile phones, and TV remotes, all of which contain many electronic components.

Standards

- MCR.6-8.TECH.1
- AAAS.6-8.1.C.7; AAAS.6-8.8.D.2; AAAS.6-8.8.E.1; AAAS.6-8.9.A.7; AAAS.6-8.12.D.4

Lesson Objectives

- Describe electronic signals.
- Identify types of electronic components.
- Explain how computers use electronics.

Lesson Vocabulary

- **electronics:** use of electric current to encode information
- **semiconductor:** solid crystal—usually consisting mainly of silicon—that can conduct current better than an electric insulator but not as well as an electric conductor; found in electronic components

Teaching Strategies

Introducing the Lesson

Ask students to name electronic devices they own or commonly use. (Answers might include cell phones, computers, and televisions.) Tell the class that electronic devices such as these use electricity differently than other electric devices such as toasters and microwaves. Ask if they can guess how, and then tell them they will learn how in this lesson.

Building Science Skills

Students will have a better understanding of analog and digital electronic signals if they think of ways they could model the two types of signals. They should think of common events or situations that are analogous to the signals. For example, flipping a light switch off and on models a digital signal and continuously turning a dimmer switch on a light models an analog signal.

Demonstration

Take apart an old computer to show students the motherboard and other computer components described in the lesson. Ask students to identify and describe the function of the different components.

Differentiated Instruction

Give students a list of cloze prompts to complete as they read the lesson. A few sample cloze prompts for the lesson are provided below [sample answers are given in brackets]. Tell students that each blank requires at least a few words in order to correctly complete the statement.

- An electronic signal encodes a message by __________. [repeatedly changing the voltage of current]
- An analog signal consists of __________. [continuously changing voltage in a circuit]
- A digital signal consists of __________. [pulses of voltage, created by repeatedly switching the current off and on]

Enrichment

Students who excel in science may be interested in learning more about electronic components. At the URL below, they can learn about the history of the transistor and how integrated circuits were first developed.

- http://www.pbs.org/transistor/index.html

Science Inquiry

Challenge groups of students to create physical models of p-type and n-type semiconductors that represent their basic structure and function. The models should show that a semiconductor consists of a doped silicon crystal that has either extra electrons (n-type) or holes for missing electrons (p-type). Models should also allow the extra electrons to be moved from the n-type to the p-type semiconductor. Students might use toothpicks and marshmallows or craft sticks and modeling clay to represent atoms and electrons in the crystals. Encourage them to be creative. One student in each group should demonstrate the group's model to the rest of the class. You may also want to display their completed models in the classroom.

Real-World Connection

Use the article and activity at the following URL to demonstrate the unintended real-world consequences of the burgeoning growth of consumer electronics, including TVs, iPods, computers, and cell phones. Students will examine statistics on energy consumption and environmental pollution resulting from the massive increase in electronic devices. They will also test the energy consumption of actual devices. Then they will brainstorm ways the problems associated with consumer electronics might be addressed, both by consumers and by manufacturers.

- http://msms.ehe.osu.edu/tag/consumer-electronics/

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is an electronic signal?
   - [An electronic signal is a message that is encoded using an electric current. This is done by rapidly and repeatedly changing the voltage of the current.]
2. Name two types of electronic signals. How do they differ?
   - [Two types of electronic signals are analog signals and digital signals. Analog signals consist of continuously changing voltage in a circuit. Digital signals consist of pulses of voltage, created by repeatedly switching the current off and on.]
3. Describe a semiconductor.
   - [A semiconductor is a solid crystal—usually consisting mainly of silicon—that can conduct current better than an electric insulator but not as well as an electric conductor. Very small amounts of other elements, such as boron or phosphorus, are added to the silicon to help it conduct current. These other elements have more or less valence electrons than silicon, so they create excess electrons or positive holes with missing electrons in the silicon crystal.]
4. Identify one type of electronic component and state how it works.
   - [Answers may vary but should describe one type of electronic component and explain how it works. *Sample answer*: One type of electronic component is a diode. It consists of a p-type and an n-type semiconductor placed side by side. When a diode is connected to a voltage source, electrons flow from the n-type to the p-type semiconductor. This is the only direction that electrons can flow in a diode. This makes a diode useful for changing alternating current to direct current.]
5. Create an original binary code using the digits 0 and 1, and use it to encode a short message. Explain how your code is like the digital electronic code used in a computer.
   - [Codes may vary but should consist only of the digits 0 and 1. For example, letters of the alphabet might be represented by combinations of the two digits, such as a = 0, b = 1, c = 01, d = 10, and so on. Students should use their code to encode a short message. The code is like the digital electronic code used in a computer because a digital code also consists only of the digits 0 and 1.]
6. Compare and contrast n-type and p-type semiconductors. Explain why both types of semiconductors must be used together in electronic components.
   - [Both types of semiconductors consist of silicon crystals with added elements that give the crystal either more or less valence electrons. An n-type semiconductor has an added element such as phosphorus, which has one more valence electron than silicon. A p-type semiconductor has an added element such as boron, which has one less valence electron than silicon. Both types of semiconductors must be used together in electronic components in order for the components to carry current. Electrons flow from an n-type semiconductor, which has extra electrons, to a p-type semiconductor, which has missing electrons.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 23.4 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you learned that electric charge is a physical property of some types of matter. In the chapter "Magnetism," you will read about another physical property of some types of matter—magnetism.

- If you've ever used a magnet, you already know something about magnetism. How would you define magnetism or explain it to someone who has no experience with magnets?

Magnetism is the ability of a material to respond to and exert magnetic force, which is a force of attraction or repulsio

- Earth is considered to be a giant magnet. Do you know why?

(Earth is considered to be a giant magnet because it has north and south magnetic poles that generate a magnetic field around Earth.)

CHAPTER 24 TE Magnetism

Chapter Outline

24.1 Chapter 24: Magnetism

Chapter Overview

A magnet is an object that attracts certain materials and has two magnetic poles and a magnetic field. Only ferromagnetic materials—including iron, cobalt, and nickel—have the property of magnetism, or the ability to be attracted by a magnet and to act as a magnet. Earth has north and south magnetic poles and a magnetic field called the magnetosphere, caused by the movement of charged particles through molten metals in the outer core. Earth's magnetic field helps protect Earth's surface and its organisms from harmful solar radiation and is also used for navigation by humans and other animals.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this "Fun with Magnets" lab, students will use a magnet to separate iron from an iron-fortified breakfast cereal.

- http://www.magnet.fsu.edu/education/teachers/resources/documents/worksheets/Iron-in-your-cereal.pdf

Another "Fun with Magnets" lab can be found at the URL below. In this lab, students will make and experiment with a ferrofluid. They will observe the fluid form a solid in the presence of a magnetic field.

- http://www.magnet.fsu.edu/education/teachers/resources/documents/worksheets/Making-Ferrofluid.pdf

In this award-winning lab, students will build a simple magnetometer using a soda bottle and a bar magnet. Then they will use their magnetometer to monitor changes in Earth's magnetic field and investigate magnetic storms. In the lab, students will make measurements and perform simple statistical analysis

- http://image.gsfc.nasa.gov/poetry/workbook/magnet.html

These Web sites may also be helpful:

You can find several videos for middle school students pertaining to the topic of magnetism at this URL: http://www.neok12.com/Magnetism.htm .

For background reading on Earth's magnetic field, see the article at the following URL.

- http://image.gsfc.nasa.gov/poetry/magnetism/magnetism.html

Pacing the Lessons

TABLE 24.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
24.1 Magnets and Magnetism	2.5
24.2 Earth as a Magnet	2.0

24.2 Lesson 24.1 Magnets and Magnetism

Key Concept

A magnet is an object that attracts certain materials such as iron. All magnets have two magnetic poles and a magnetic field over which they exert force. Opposite magnetic poles attract each other, and like magnetic poles repel each other. Magnetism is the ability to be attracted by a magnet and to act as a magnet. Only ferromagnetic materials, which include iron, cobalt, and nickel, have this property. When these materials are magnetized, they become temporary or permanent magnets. The mineral magnetite is a naturally occurring permanent magnet.

Standards

- AAAS.6-8.4.D.15; AAAS.6-8.4.G.3

Lesson Objectives

- Identify properties of magnets.
- Explain why some materials are magnetic.

Lesson Vocabulary

- **ferromagnetic material:** material that can be magnetized (iron, nickel, or cobalt)
- **magnet:** object that attracts ferromagnetic materials such as iron
- **magnetic domain:** area of a ferromagnetic material where the north and south poles of atoms are all lined up in the same direction
- **magnetic field:** area around a magnet where it exerts magnetic force
- **magnetic force:** force of attraction or repulsion exerted by a magnet
- **magnetic pole:** north or south end of a magnet where the magnet exerts the most force
- **magnetism:** ability of a material to respond to and exert magnetic force

Teaching Strategies

Introducing the Lesson

Engage students' interest in magnetism by performing one or more of the eight magnetic "tricks" at the URL below. Challenge students to try to explain the tricks, and then tell them they will learn the correct explanations when they read this lesson.

- http://mypages.iit.edu/~smile/ph9115.html

Activity

The lesson plan at the following URL offers a hands-on way for students to learn about magnetism. In the activity part of the lesson, students will use a strong magnet to test various common materials and observe whether they are attracted by the magnet. The lesson plan includes the procedure for the activity, adaptations, and discussion questions.

- http://www.discoveryeducation.com/teachers/free-lesson-plans/magnetism.cfm

Building Science Skills

The activity described at the URL below involves four classroom stations where students can investigate different aspects of magnetism. Divide the class into groups and have the groups rotate from one station to the next until they have completed all four activities. Students will identify magnetic materials, assess the strength of magnets, map the magnetic field of a bar magnet, and make a magnet with an iron nail.

- http://mypages.iit.edu/~smile/mp0398.htm

Differentiated Instruction

Assign each of seven pairs of students one of the lesson vocabulary terms, and have partners add their term to the word wall. They should include a definition of the term and also an example or sketch to represent it.

Enrichment

Students who are interested in technology might want to make a magnetic crane and use it to further investigate magnetism. Complete instructions are provided at this URL: http://mypages.iit.edu/~smile/ph8806.html .

Science Inquiry

Divide the class into small groups and challenge each group to discuss, and develop a hypothesis about, the effect of temperature on the strength of a magnet. Then tell each group to develop a research plan to test its hypothesis. (You can see a sample research plan at the following URL.) Students must identify independent and dependent variables as well as controls. They must also describe how the variables will be measured. Have each group present its hypothesis and research plan to the class. Lead the class in discussing whether each hypothesis is testable and whether the research plan provides a good test of the hypothesis. If time permits, give groups a chance to carry out their research.

- http://www.education.com/science-fair/article/magnets-temperature/

Common Misconceptions

There are many common student misconceptions about magnets. Just a few are listed below. At the following URL, you can find these and other misconceptions, followed by background information and an activity that will help students overcome the misconceptions.

- https://sites.google.com/site/scienceinanutshell/common-misconceptions-about-magnetism

Misconceptions:

- All metals are attracted to a magnet.
- All magnets are made of iron.
- Larger magnets are stronger than smaller magnets.
- A magnet's magnetic field lines exist only outside the magnet.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a magnet?
   - [A magnet is an object that attracts certain materials such as iron. It has north and south poles and a magnetic field.]
2. Define magnetic force
   - [Magnetic force is a force of attraction that a magnet exerts on certain materials in its magnetic field.]
3. Give examples of objects that are attracted by magnets.
   - [Answers may vary. *Sample answer*: Examples of objects that are attracted by magnets include steel refrigerators and iron nails.]
4. Identify ferromagnetic materials.
   - [Iron, cobalt, and nickel are ferromagnetic materials.]
5. Draw magnetic field lines around the two bar magnets pictured below.

   - [The magnetic field lines around the two magnets should look like those in the top drawing of the figure above.]
6. Sasha dropped a magnet on the sidewalk. Now it no longer attracts paper clips. Apply lesson concepts to explain why.
   - [The magnet no longer attracts paper clips because its magnetic domains are no longer aligned after being dropped on the sidewalk.]
7. Explain how and why a ferromagnetic material can be magnetized.
   - [A ferromagnetic material can be magnetized by being placed in a magnetic field. This type of material has magnetic domains, which are areas where the north and south poles of atoms are all lined up in the same direction. Being placed in a magnetic field aligns all the magnetic domains, and the material becomes a magnet.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The northern lights that you saw in the opening photo of this chapter are caused by Earth's magnetic field. You will read about Earth's magnetic field in the next lesson, "Earth as a Magnet."

- If you could see Earth's magnetic field, what do you think it would look like? (*Hint*: Look at **Figure** 24.3.)

Earth's magnetic field would look like the magnetic field of a bar magnet.

- After reading this lesson, can you predict why the northern lights are most likely to be visible near Earth's poles?

The northern lights are most likely to be visible near Earth's poles because the magnetic field of a magnet—including

24.3 Lesson 24.2 Earth as a Magnet

Key Concept

Earth is a giant magnet with north and south magnetic poles and a magnetic field called the magnetosphere. Evidence shows that Earth's magnetic poles have repeatedly switched positions in the past. Scientists think that Earth's magnetic field is caused by the movement of charged particles through molten metals in the outer core. Earth's magnetic field helps protect Earth's surface and its organisms from harmful solar particles by pulling most of the particles toward the magnetic poles. Earth's magnetic field is also used for navigation by humans and many other animals.

Standards

- MCR.6-8.SCI.10.2
- NSES.5-8.D.1.1; NSES.5-8.E.2.3
- AAAS.6-8.1.A.4; AAAS.6-8.1.B.2; AAAS.6-8.3.A.2

Lesson Objectives

- Describe Earth as a magnet.
- State how Earth's magnetism benefits living things.

Lesson Vocabulary

- **magnetosphere:** region surrounding Earth that is affected by Earth's magnetic force; name for Earth's magnetic field

Teaching Strategies

Introducing the Lesson

Pass a compass around the class from student to student and point out how the needle of the compass always points north. Call on students to explain why. Accept all reasonable responses and then tell students they will learn why when they read this lesson.

Activity

Students can make a simple compass with the instructions at the following URL. Then they can use their compass to find Earth's north magnetic pole. Making their own compass will help reinforce concepts from the previous lesson, "Magnets and Magnetism," and using the compass will help them appreciate Earth's magnetic field.

- http://www.education.com/activity/article/hanging-compass/

Differentiated Instruction

Have pairs of students work together to create a concept map for the lesson. It should include the following concepts: Earth's magnetic poles, magnetosphere, magnetic field reversals, cause of Earth's magnetism, and benefits of Earth's magnetism.

Enrichment

Ask a few interested students to make a poster or PowerPoint presentation about the effect of solar wind on Earth's magnetosphere. A good reference to start with can be found at the URL below. Give students a chance to present their completed project to the class.

- http://helios.gsfc.nasa.gov/magnet.html

Science Inquiry

In the activity "Motion of the Magnetic Pole" at the URL below, students will plot the latitude and longitude of the north magnetic pole as it has moved over time. They can also predict the location of the north magnetic pole in a given year and justify their reasoning.

- http://image.gsfc.nasa.gov/poetry/activity/s8.pdf

Literature Connection

Have students do the activity "Magnetic Reversals: Fact and Fiction" at the following URL. This activity will help students discriminate between fictional and factual descriptions of a natural phenomenon (the shifting of Earth's magnetic field). In the activity, students will read and compare two fiction stories involving changes in Earth's magnetic field. They will also read a factual scientific summary of past reversals that includes graphical information.

- http://image.gsfc.nasa.gov/poetry/venus/Reversal.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is the magnetosphere?
   - [The magnetosphere is Earth's magnetic field.]
2. Identify evidence for magnetic reversals in Earth's past.
   - [Rocks from the ocean floor provide evidence for magnetic reversals. Magnetic domains are aligned in opposite directions in rocks that were formed at different times in the past.]
3. List two benefits to organisms of Earth's magnetic field.
   - [Two benefits to organisms of Earth's magnetic field are protection from solar particles and use of Earth's magnetism for navigation.]
4. Use a bar magnet, a globe or large ball, and any other props you need to demonstrate to another student how Earth is like a bar magnet.
   - [Give pairs of students a chance to use their props to explain to one another how Earth is like a bar magnet.]
5. What is the relationship between Earth's magnetic poles and Earth's geographic poles?
   - [Earth's magnetic poles are located near Earth's geographic poles, but they are not in exactly the same place. For example, the north geographic pole is located at 90° north latitude, whereas the magnetic north pole is located at about 80° north latitude.]
6. Explain why Earth is a magnet.
   - [Earth is a magnet because of the movement of charged particles through molten metals in Earth's outer core. The movement occurs as Earth spins on its axis. The current of particles gives Earth north and south magnetic poles and a magnetic field.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 24.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this chapter, you learned that Earth is a magnet because of moving charged particles in its outer core. In the chapter "Electricity," you learned that moving charged particles create electric current. The next chapter explains how electric current and magnetism are related.

- Based on what you now know about electricity and magnetism, can you predict how they are related?

Electric current produces a magnetic field.

- Do you think electric current could be used to create a magnet? How might this be done?

Electric current can be used to create a magnet by coiling wire around a bar of a ferromagnetic material such as iron a

CHAPTER 25 TE Electromagnetism

Chapter Outline

25.1 Chapter 25: Electromagnetism

Chapter Overview

Electromagnetism is magnetism produced by an electric current. More current creates a stronger magnetic field, and the direction of the current determines the direction of the magnetic field. A solenoid is a coil of wire with electric current flowing through it, making it a strong magnet similar to a bar magnet. An electromagnet is a solenoid wrapped around a bar of iron, which adds to the strength of the magnetic field. Many electric devices, such electric motors, contain electromagnets. A changing magnetic field produces an electric current by electromagnetic induction. An electric generator uses electromagnetic induction to change kinetic energy to electrical energy, and an electric transformer uses electromagnetic induction to change the voltage of electric current. Electric generators and transformers produce and regulate the electric current that flows through the power grid and electrifies homes.

Online Resources

See the following Web sites for appropriate laboratory activities:

You can use the lab at the following URL after students have read the first two lessons of the chapter. Students will find the direction of magnetic fields, see how current direction affects magnetic field direction, and learn how electromagnets are made and used.

- http://www.mrsec.org/sites/default/files/education/resources/wp-content/uploads/2009/02/electromagnetism_-numrsec.pdf

You can find many middle school experiments on electromagnetism and electromagnetic induction at the URLs below. The experiments are suitable for classroom use as well as for science fair projects.

- http://www.juliantrubin.com/fairprojects/electricity/electromagnetism.html
- http://www.juliantrubin.com/fairprojects/electricity/electric_motor.html

These Web sites may also be helpful:

The URL below provides many resources relating to chapter concepts, including games, puzzles, and videos: http://www.education.com/science-fair/magnet/#grade:middle-school|q:magnet .

This resource has several middle school activities on electromagnetism. Student worksheets and assessment rubrics are included.

- http://cse.ssl.berkeley.edu/segwayed/lessons/exploring_magnetism/Exploring_Magnetism/index.html

Pacing the Lessons

TABLE 25.1: Pacing the Lessons

Lesson	Class Period(s) (60 min)
25.1 Electricity and Magnetism	1.0
25.2 Using Electromagnetism	2.0
25.3 Generating and Using Electricity	2.0

25.2 Lesson 25.1 Electricity and Magnetism

Key Concept

Electromagnetism is magnetism produced by an electric current. Electromagnetism was discovered by Oersted in 1820. The magnetic field produced by current in a wire moves around the wire in concentric circles. More current creates a stronger magnetic field, and the direction of the current determines the direction of the magnetic field.

Standards

- MCR.6-8.SCI.10.2
- AAAS.6-8.4.G.3

Lesson Objectives

- Outline how electromagnetism was discovered.
- Describe the magnetic field created by an electric current.

Lesson Vocabulary

- **electromagnetism:** magnetism produced by an electric current

Teaching Strategies

Introducing the Lesson

Introduce electromagnetism by reviewing both electric currents and magnetic fields from previous chapters. Call on students to define or describe each phenomenon. Then challenge students to identify how the two phenomena might be related. Tell students they will learn how in this lesson.

Building Science Skills

Before students read the lesson, set up Oersted's original demonstration as described in the lesson, using a battery, electric wire, and compass. Connect the wire to the battery terminals to create a closed circuit. You may want to include an ammeter or electric device such as a light bulb in the circuit so students will see evidence of current flowing through the wire. Then give small groups of students a chance to position the compass at various points around the wire and observe the compass needle. From their observations, have them infer the relationship between an electric current and a magnetic field.

Differentiated Instruction

Pair beginning and advanced English language learners and ask partners to set up a Frayer model. They should draw a large box divided into four parts and label the parts "Definition," "Drawing," "Example," and "Non-example." Then they should fill in the four parts of the box for the concept electromagnetism.

Enrichment

Have students learn more about Oersted's discovery of electromagnetism as an example of the sometimes-serendipitous nature of scientific discovery. Ask the students to make a video about the discovery and present the video to the class. Possible resources for relevant information include:

- http://www.jsur.org/history/Oersted
- http://www.magnet.fsu.edu/education/tutorials/java/oersted/index.html

Science Inquiry

Provide groups of students with a battery, wire, and compass. Then ask groups to devise and carry out a plan to map the magnetic field around a current-carrying wire. They should draw a sketch of the magnetic field based on the results of their investigation.

Real-World Connection

Ask students to think about problems that might occur when using a compass around wires that are carrying electric current. Then tell them that electric current flowing through high-tension power lines can affect compasses more than 30 feet away from the wires, causing them to act erratically and deflecting them from pointing north. As a result, navigation in such a situation may require the use of GPS instead of compass readings.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. Define electromagnetism.
   - [Electromagnetism is magnetism produced by electric current.]
2. Describe how Oersted discovered electromagnetism.

   - [Oersted observed that placing a current-carrying wire next to a magnet caused the magnet's pointer to swing toward the wire and away from Earth's magnetic north pole. He also observed that turning off the current in the wire caused the pointer to swing back to its original position, pointing north again. Oersted had discovered than an electric current creates a magnetic field. The magnetic field created by the current in the wire was strong enough to attract the pointer of the nearby compass.]

3. What is the right hand rule?
   - [The right hand rule is a simple rule that makes it easy to find the direction of the magnetic field created by a current flowing through a wire. When the thumb of the right hand is pointing in the same direction as the current, the fingers of the right hand curl around the wire in the direction of the magnetic field.]
4. The drawing below shows part of a wire that has current flowing through it. The arrow shows the direction of the current. Apply the right hand rule, and sketch the magnetic field lines around the wire.

   - [Sketches should show that the magnetic field lines circle the wire and point down toward the bottom of the page.]
5. Relate the properties of an electric current to its magnetic field.
   - [The magnetic field created by an electric current flowing through a wire moves around the wire in concentric circles. The more current that is flowing through the wire, the stronger the magnetic field is. The direction of the current also determines the direction of the magnetic field. If the direction of the current is reversed, the magnetic field is reversed as well.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.1 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

The magnetic field created by a single wire with current flowing through it is too weak to be very useful. However, technologies have been developed to make stronger electromagnetic fields. You can learn what they are in the next lesson "Using Electromagnetism."

- What might make an electromagnetic field stronger?

One way is by increasing the current flowing through the wire.

- How might the wire that carries the current be arranged to increase the strength of the magnetic field?

The wire can be arranged in a coil to increase the strength of the magnetic field.

25.3 Lesson 25.2 Using Electromagnetism

Key Concept

A solenoid is a coil of wire with electric current flowing through it, giving the coil a magnetic field like that of a bar magnet. An electromagnet is a solenoid wrapped around a bar of iron, which adds to the strength of the magnetic field, making electromagnets the strongest of all magnets. Many common electric devices contain electromagnets. For example, an electric motor is a device that uses an electromagnet to change electrical energy to kinetic energy.

Standards

- MCR.6-8.SCI.10.2
- AAAS.6-8.3.A.3; AAAS.6-8.4.G.3; AAAS.6-8.8.C.8; AAAS.6-8.12.D.4, 9

Lesson Objectives

- State how a solenoid increases electromagnetic force.
- Explain why electromagnets can be very strong.
- Describe how doorbells and electric motors use electromagnetism.

Lesson Vocabulary

- **electric motor:** device that uses an electromagnet to change electrical energy to kinetic energy
- **electromagnet:** magnet created by electric current flowing through a coil of wire that is wrapped around a bar of iron or other ferromagnetic material
- **solenoid:** coil of wire with electric current flowing through it, giving it a magnetic field like a bar magnet

Teaching Strategies

Introducing the Lesson

Use the simple animated simulation at the URL below to introduce students to the magnetic field of a solenoid. Point out how the compass needle points to the end of the wire coil, rather than toward the coil itself as it would if a straight wire were used instead of a coil of wire. In other words, the coil of wire has a magnetic field like a bar magnet, unlike the circular magnetic field of a straight wire. Tell students they will learn more about the magnetic field around a current-carrying wire coil when they read this lesson.

- http://micro.magnet.fsu.edu/electromag/java/compass/index.html

Demonstration

Demonstrate to the class how much stronger the magnetic field of an electromagnet is than the magnetic field of a solenoid that is identical to the electromagnet except for the iron core in the electromagnet. You can make a simple solenoid with a coil of wire and a battery and test the strength of its magnetic field by picking up paper clips with it. Then you can turn the solenoid into an electromagnet by inserting a piece of iron, such as an iron nail, inside the solenoid. Test the strength of the electromagnet's magnetic field in the same way, by picking up paper clips. The electromagnet should be able to pick up more paper clips than the solenoid.

Discussion

Discuss the benefits of using electromagnets, rather than permanent magnets, in devices that make use of magnetism. A crane with an electromagnet for picking up very heavy metal items, such as the crane pictured in the chapter opener, is a good example. Ask students how useful the crane would be for moving the metal items if it had a permanent magnet, rather than an electromagnet.

Differentiated Instruction

To help students focus on the most important points in the lesson, provide them with a list of cloze prompts to complete as they read. Sample cloze prompts for the first two headings in the lesson are given below (with sample answers in brackets). Make sure students realize that each blank requires at least a few words to fill in correctly.

Sample cloze prompts:

1. A solenoid is a coil of wire with electric current flowing through it, giving it __________. [a magnetic field]
2. The magnetic field of a solenoid has __________. [north and south poles like a bar magnet]
3. The magnetic field of a solenoid is affected by factors such as __________. [amount and direction of current and number of turns of wire]
4. An electromagnet is a solenoid wrapped around __________. [a bar of iron or other ferromagnetic material]
5. You can increase the strength of an electromagnet by __________. [adding more turns of wire in the coil, increasing the current, or using a bigger iron bar]

Enrichment

Interested students can make a very simple DC motor by following the instructions at the URL below. You can order a kit for the activity at the Web site, but the parts required are easy and inexpensive to obtain elsewhere. After students build and test their motor, ask them to demonstrate it to the class and explain how it works.

- http://www.miniscience.com/projects/magnet_motor_kit/index.html

Science Inquiry

Have groups of students make a simple electromagnet by coiling a thin insulated wire around an iron nail and connecting both ends of the wire to the terminals of a 12-volt battery. Ask students to use a bar magnet to determine the polarity of their electromagnet and then try to reverse its polarity. (They should change the direction of the current by reconnecting the ends of the wire to the opposite terminals.) They can see if they were successful by using the bar magnet again to check the electromagnet's polarity.

Real-World Connection

Give students an opportunity to take apart a hair dryer or other small, commonly used electric device that contains an electric motor. Help them identify the parts of the motor and what the motor does. You can learn more about the motor inside a hair dryer at these URLs, which also include diagrams:

- http://home.howstuffworks.com/hair-dryer2.htm
- http://www.petervaldivia.com/technology/electricity/electrical-power.php
- http://home.howstuffworks.com/how-to-repair-small-appliances9.htm

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Physical Science for Middle School Workbook*. Ask students to complete the worksheets alone or in pairs to reinforce lesson content.

Lesson Review Questions

Have students answer the Review Questions listed at the end of the lesson in the FlexBook®.

1. What is a solenoid?
   - [A solenoid is a coil of wire with electric current flowing through it, giving it a magnetic field.]
2. What determines the strength of a solenoid's magnetic field?
   - [The strength of a solenoid's magnetic field is determined by the number of turns of wire in the coil and the amount of current flowing through the wire.]
3. Describe how a doorbell uses an electromagnet.
   - [A doorbell uses an electromagnet to move the clapper of the bell. When current flows through the circuit, the electromagnetic turns on and its magnetic field attracts the clapper, causing it to hit the bell. When the clapper moves to hit the bell, it opens the circuit and turns off the electromagnet. As a result, the clapper returns to its original position. This closes the circuit, and the cycle repeats as long as the doorbell button is being pressed.]
4. Draw a labeled sketch of an electric motor to show how it uses electromagnetism to convert electrical energy to kinetic energy.
   - [Sketches may vary but should show that students understand how an electric motor uses electromagnetism to change electrical energy to kinetic energy. Sketches should be adequately labeled to show how the motor works. They might resemble the above figure of an electric motor.]
5. Assume that an electromagnetic and a solenoid have the same number of turns in their wire coil and the same amount of current flowing through the wire. Which device has the stronger magnetic field? Explain your answer.
   - [The electromagnetic field of the electromagnet is stronger than that of the solenoid because the electromagnet contains a bar of iron or other ferromagnetic material in addition to the coil of wire. Both the bar and coil contribute to the strength of the electromagnet's magnetic field.]

Lesson Quiz

Check students' mastery of the lesson with Lesson 25.2 Quiz in *CK-12 Physical Science for Middle School Quizzes and Tests*.

Points to Consider

In this lesson, you saw how electric current can be used to create a strong electromagnetic field. In the next lesson, "Generating and Using Electricity," you'll find out how a magnetic field can be used to generate an electric current.

- Can you predict how this might be done?

Current can be generated with a magnetic field by moving an electric conductor, such as a coil of wire, across magneti

- A device that uses a magnetic field to generate electricity is called a generator. What do you already know about generators from previous chapters? (*Hint*: Look at the figure on how energy constantly changes form in the "Introduction to Energy" chapter.)

Generators change kinetic energy to electrical energy.