UNIT 6

Energy and Heat

A Thermogram shows the relative temperature of objects. It can be used to detect heat loss in a house.

FLORIDA BIG IDEA 11

Energy Transfer and Transformations

What Do You Think?

See all the red areas in this thermogram? These areas show where energy (in the form of heat) is escaping through gaps around windows and doors. Why is it important to reduce this loss of energy from a home? As you explore this unit, gather evidence to help you state and support a claim.

UNIT 6

Energy and Heat

CITIZEN SCIENCE

Saving Energy

Humans use many sources of energy in our everyday lives. For example, we need electricity to see at night, fuel to keep our cars running, and food to nourish our bodies. But we need to be careful in our use of energy resources. And you can help!

1 Ask a Question

How can individuals avoid wasting energy resources at home?

Make a list of all the sources of energy, such as electricity or natural gas, used in your home. Then, write down what those energy sources are used for, and estimate how much your family uses them each week. For example: "We use natural gas for cooking on our stove approximately three hours each week." Can your family reduce energy consumption in any areas? Work with your family to develop your ideas.

Using a programmable thermostat can help conserve energy.

Image Credits: (bkgd) ©GIPhotoStock/Photo Researchers, Inc.

2 Think About It

What is one source of energy used in your home?

Where is energy used most often in your school?

Where is energy used most often in your home?

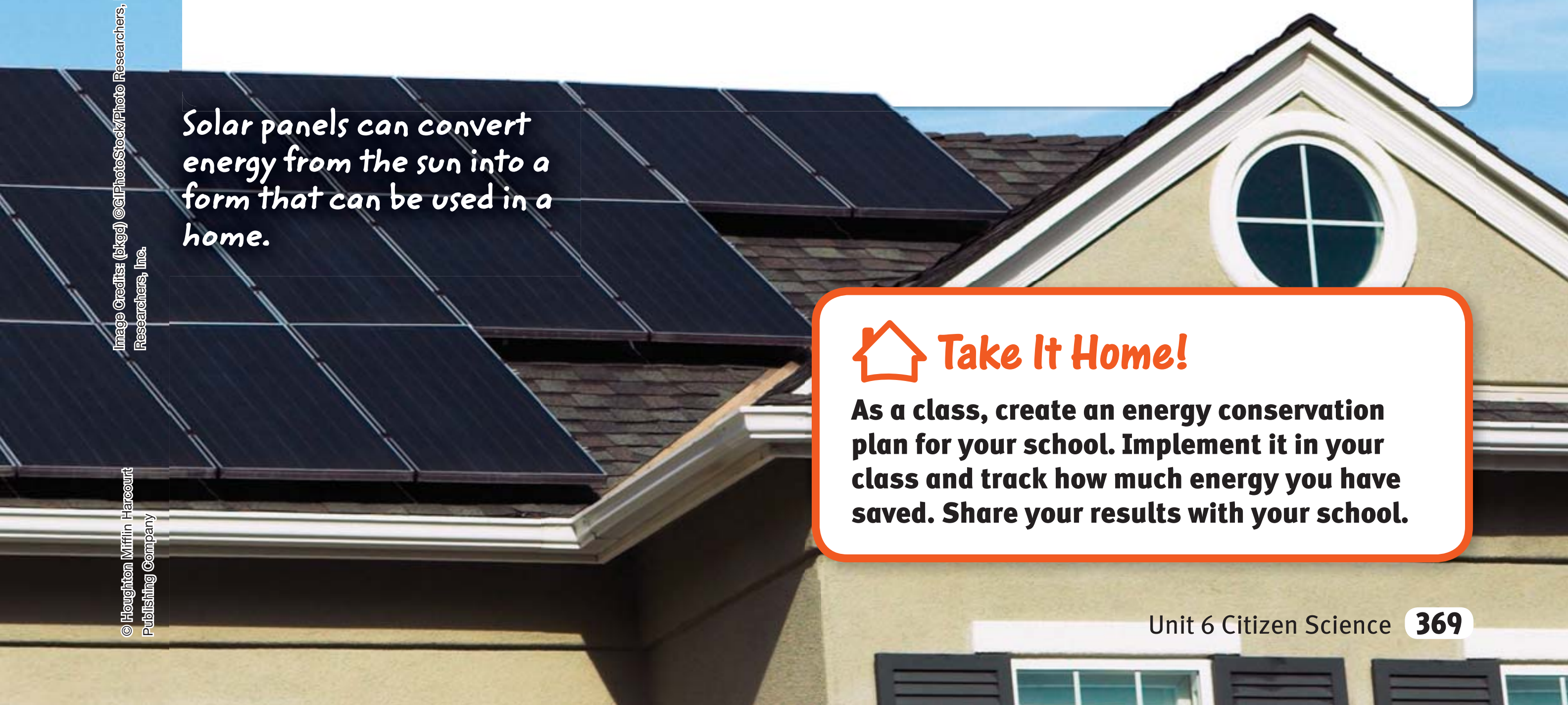
What are some possible areas in the home and at school where energy usage can be easily reduced?

3 Apply Your Knowledge

A Choose some of the places you identified in your home. Develop strategies for reducing the amount of energy your family uses in those areas.

Area	Strategy

B Apply the strategies you listed above. Track how your energy usage changes as you conserve energy. Examine your utility bill if you have access to it.



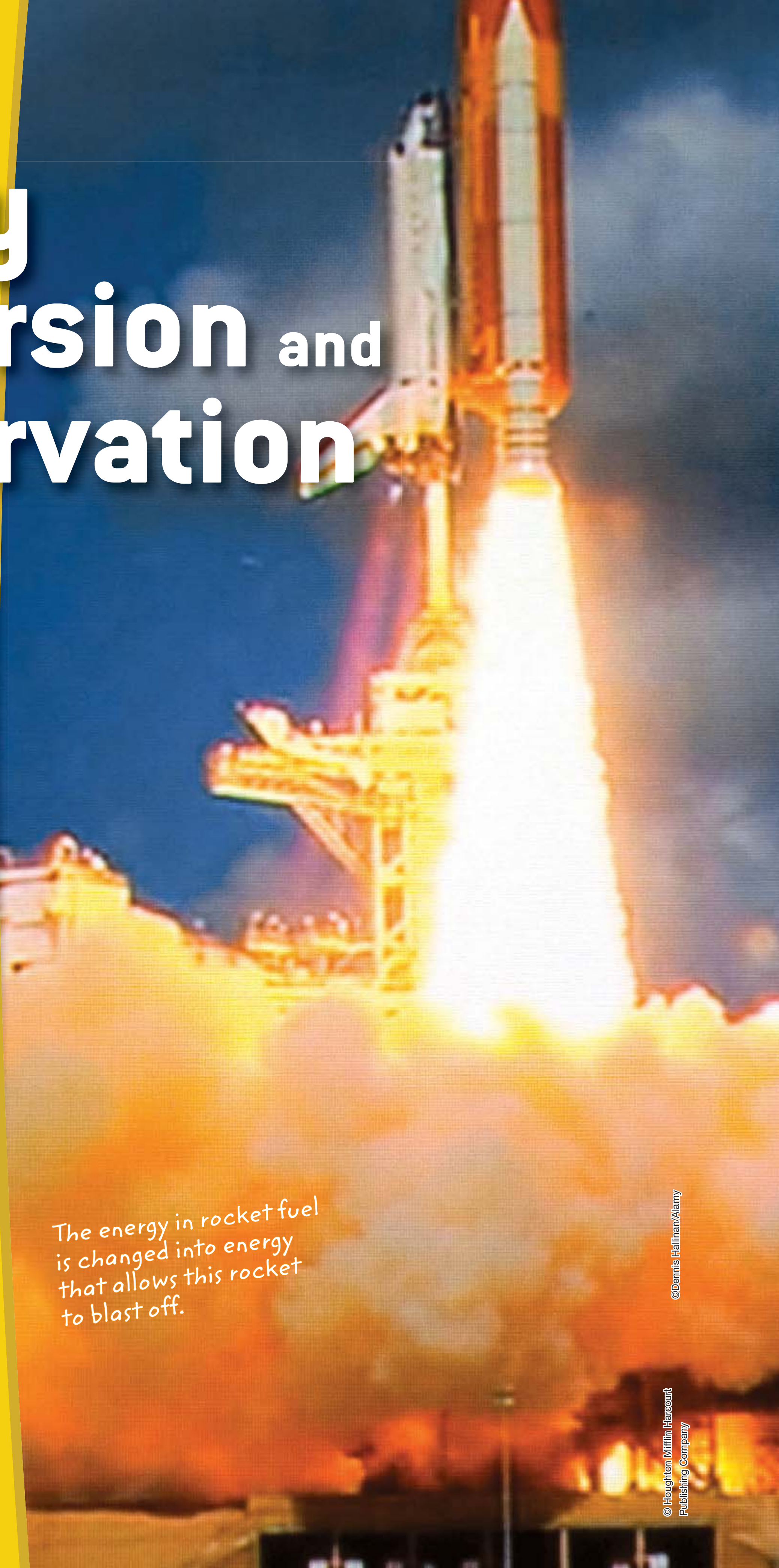
Solar panels can convert energy from the sun into a form that can be used in a home.

Take It Home!

As a class, create an energy conservation plan for your school. Implement it in your class and track how much energy you have saved. Share your results with your school.

LESSON 1

Energy Conversion and Conservation


The energy in rocket fuel is changed into energy that allows this rocket to blast off.

ESSENTIAL **QUESTION**

How is energy conserved?

By the end of this lesson, you should be able to analyze how energy is conserved through transformations between different forms.

SC.7.P.11.2 Investigate and describe the transformation of energy from one form to another. **SC.7.P.11.3** Cite evidence to explain that energy cannot be created nor destroyed, only changed from one form to another.

Lesson Labs

Quick Labs

- Electrical, Light, and Heat Energy
- Conservation of Energy

Engage Your Brain

1 Explain Draw a diagram that shows what you think happens when a light bulb is turned on. When making your diagram, think about what happens to the energy.

2 Describe What do you know about energy? Using the first letters of the word *energy*, make an acrostic poem that describes energy.

E ______________________________

N ______________________________

E ______________________________

R ______________________________

G ______________________________

Y ______________________________

ACTIVE **READING**

3 Apply Many scientific terms, such as *transformation* and *efficiency*, also have everyday meanings. Use context clues to write your own definition for each underlined word.

Example sentence

After she learned how to play soccer, she went through a complete transformation. Now she practices every day.

transformation:

____

____

Example sentence

He finished all of his homework in two hours, and he got everything correct. I wish that I could work with such efficiency.

efficiency:

____

____

Vocabulary Terms

- **energy transformation**
- **law of conservation of energy**
- **efficiency**

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Perfect Form

What are some forms of energy?

Remember that energy is the ability to cause change. Energy is measured in joules (J). Energy can come in many different forms. Some common forms of energy are discussed below.

ACTIVE READING

5 Identify As you read, underline examples of energy provided in the text.

Mechanical Energy

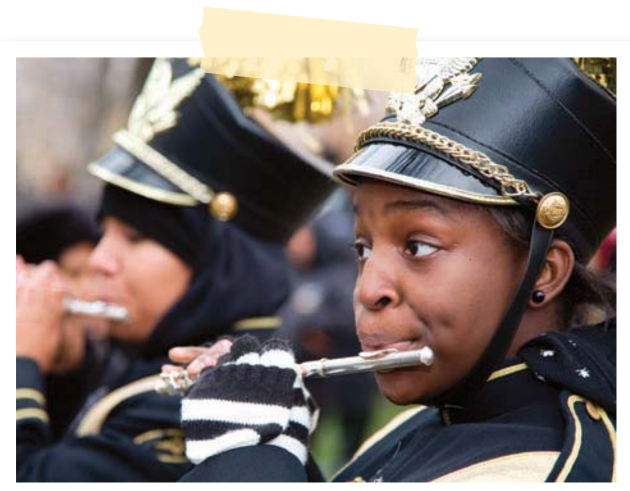
Mechanical energy is the sum of an object's kinetic energy and potential energy. The energy that a car has while moving is mechanical energy, as is the energy a book has on top of a desk.

Sound Energy

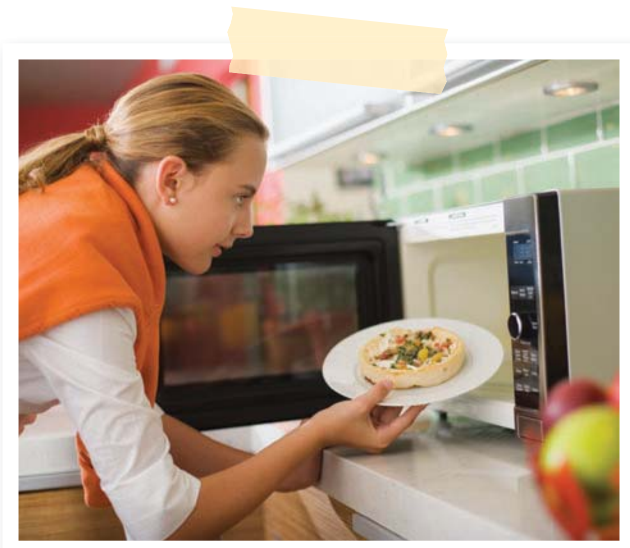
Sound energy results from the vibration of particles. People are able to detect these tiny vibrations with structures in their ears that vibrate due to the sound. When you hear a car, you are detecting vibrations in the air that transfer sound energy. Sound cannot travel through empty space. If there were no air or other substance between you and the car, then you would not hear sounds from the car.

Electromagnetic Energy

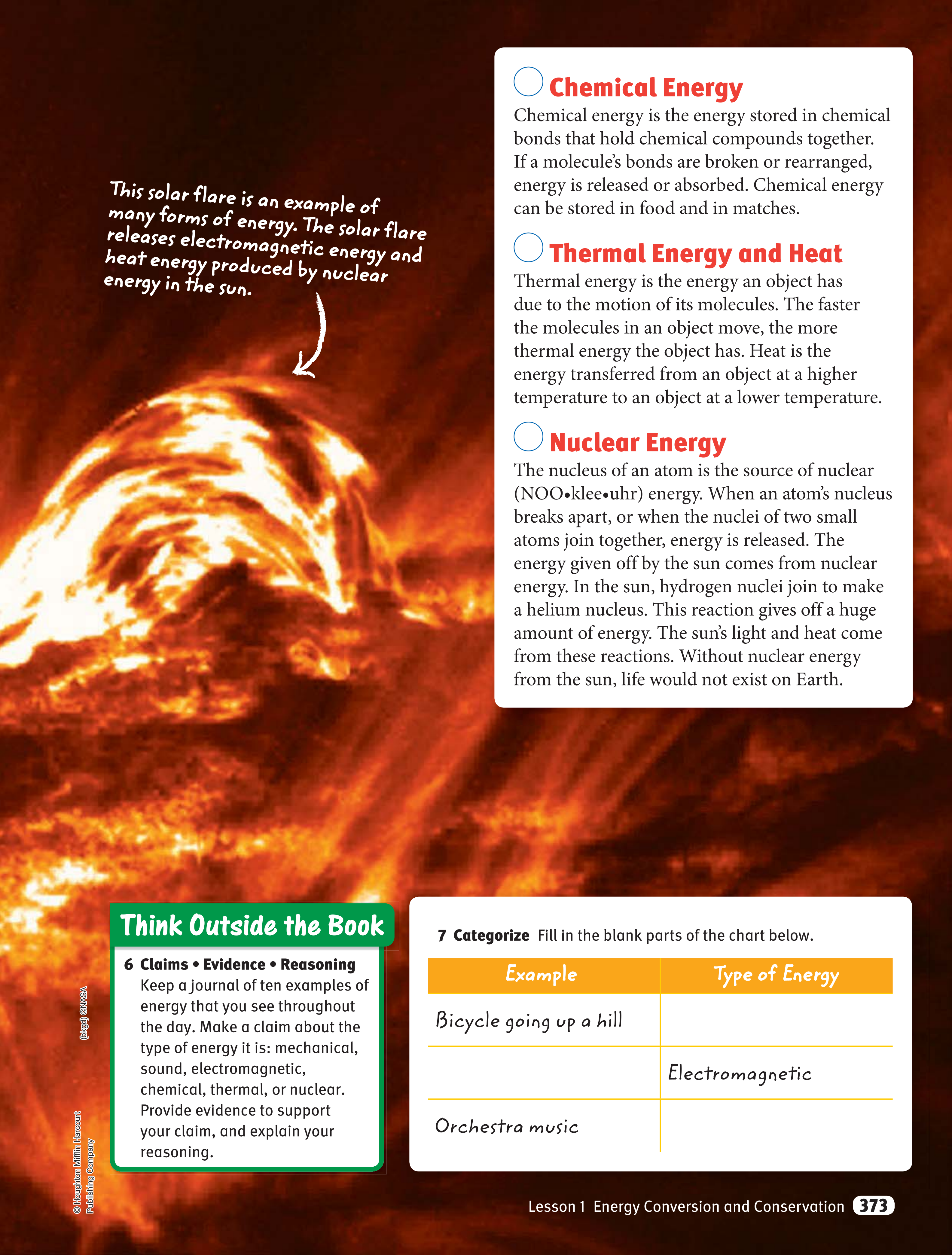
Electromagnetic (ee•LEK•troh•mag•NEH•tik) energy is transmitted through space in the form of electromagnetic waves. Electromagnetic waves can be produced by the vibration of electrically-charged particles. Unlike sound, electromagnetic waves can travel through empty space. Light energy is a form of electromagnetic energy. Some examples of electromagnetic energy are visible light, x-rays, and microwaves. X-rays are high-energy waves used by doctors to look at your bones. Microwaves can be used to cook food. The sun releases a large amount of electromagnetic energy, some of which is absorbed by Earth.



The piccolo player is producing sound energy.



Microwaves use electromagnetic energy to warm food.



This solar flare is an example of many forms of energy. The solar flare releases electromagnetic energy and heat energy produced by nuclear energy in the sun.

Chemical Energy

Chemical energy is the energy stored in chemical bonds that hold chemical compounds together. If a molecule's bonds are broken or rearranged, energy is released or absorbed. Chemical energy can be stored in food and in matches.

Thermal Energy and Heat

Thermal energy is the energy an object has due to the motion of its molecules. The faster the molecules in an object move, the more thermal energy the object has. Heat is the energy transferred from an object at a higher temperature to an object at a lower temperature.

Nuclear Energy

The nucleus of an atom is the source of nuclear (NOO•klee•uhr) energy. When an atom's nucleus breaks apart, or when the nuclei of two small atoms join together, energy is released. The energy given off by the sun comes from nuclear energy. In the sun, hydrogen nuclei join to make a helium nucleus. This reaction gives off a huge amount of energy. The sun's light and heat come from these reactions. Without nuclear energy from the sun, life would not exist on Earth.

Think Outside the Book

6 Claims • Evidence • Reasoning Keep a journal of ten examples of energy that you see throughout the day. Make a claim about the type of energy it is: mechanical, sound, electromagnetic, chemical, thermal, or nuclear. Provide evidence to support your claim, and explain your reasoning.

7 Categorize Fill in the blank parts of the chart below.

Example	Type of Energy
Bicycle going up a hill	
	Electromagnetic
Orchestra music	

Transformers

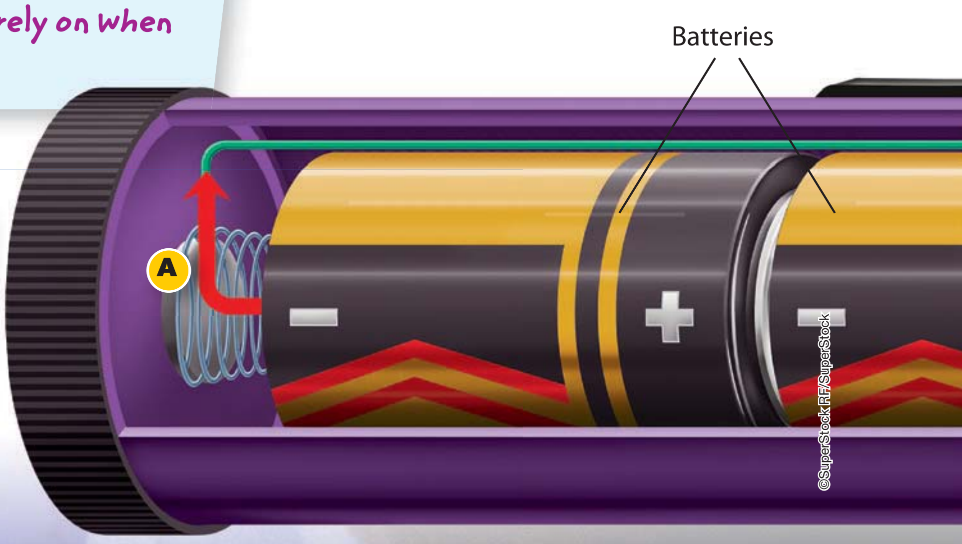
What is an energy transformation?

An **energy transformation** takes place when energy changes from one form into another form. Any form of energy can change into any other form of energy. Often, one form of energy changes into more than one form. For example, when you rub your hands together, you hear a sound and your hands get warm. The kinetic energy of your moving hands was transformed into both sound energy and thermal energy.

Another example of an energy transformation is when chemical energy is converted in the body. Why is eating breakfast so important? Eating breakfast gives your body the energy needed to help you start your day. Your chemical potential energy comes from the food you eat. Your body breaks down the components of the food to access the energy contained in them. This energy is then changed to the kinetic energy in your muscles. Some of the chemical energy is converted into thermal energy that allows your body to stay warm.

Visualize It!

Some examples of energy transformation are illustrated in this flashlight. Follow the captions to learn how energy is transformed into the light energy that you rely on when you turn on a flashlight!



A *The chemical energy from the batteries is transformed into electrical energy.*

8 Claims • Evidence • Reasoning
Identify two other examples of chemical energy being transformed into electrical energy. Provide evidence to support your claim, and explain your reasoning.

____

____

Is energy conserved?

A closed system is a group of objects that transfer energy only to one another. For example, a roller coaster can be considered a closed system if it includes everything involved, such as the track, the cars, and the air around them. Energy is conserved in all closed systems. The **law of conservation of energy** states that energy cannot be created or destroyed. It can only change forms. All of the different forms of energy in a closed system always add up to the same total amount of energy. It does not matter how many energy conversions take place.

For example, on a roller coaster some mechanical energy gets transformed into sound and thermal energy as it goes down a hill. The total of the coaster's reduced mechanical energy at the bottom of the hill, the increased thermal energy, and the sound energy, is the same amount of energy as the original amount of mechanical energy. In other words, total energy is conserved.

Think Outside the Book

11 Claims • Evidence • Reasoning Have you ever thought about how a music player works? Make a claim about what type of energy may be used inside of a music player. Provide evidence to support your claim, and explain your reasoning.

ACTIVE READING

10 Relate How are energy transformations related to the law of conservation of energy?

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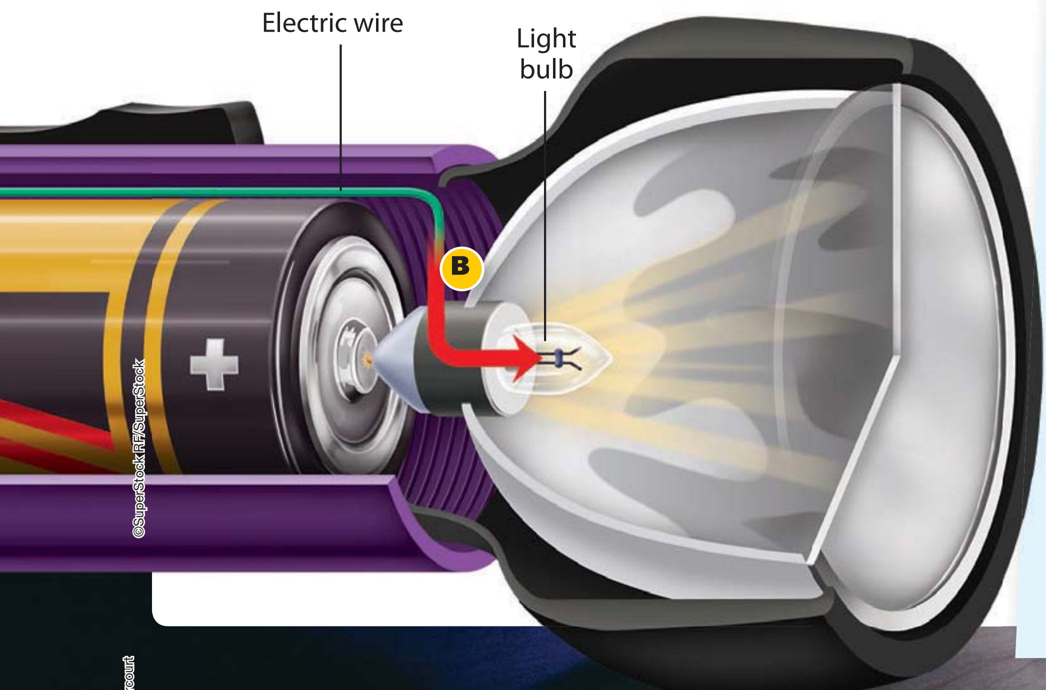

©SuperStock RF/SuperStock

B *The electrical energy in the wire is transformed into light energy in the light bulb. Some of the electrical energy is also transferred to the surroundings as heat.*

9 Describe Give another example of electrical energy being transformed into light energy.

______

______

______

______

______

______

Efficiency Expert!

How is efficiency measured?

When energy is transformed from one form to another form, some energy is turned into useful energy, but some energy is always transformed into an unintended form. One of the most common unintended forms of energy in an energy transformation is heat. No transformation can ever be 100% efficient. **Efficiency** (ee•FIH•shuhn•see) is the ratio of useful output energy to input energy. Energy efficiency is a comparison of the amount of useful energy after a conversion with the amount of energy before a conversion. Energy efficiency is highly desirable in any system. An efficient process means that as much energy as possible is converted to useful forms of energy. You may have heard that a car is energy efficient if it gets good gas mileage, and that your home may be energy efficient if it is well insulated. Energy conversions that are more efficient waste fewer resources.

The chemical energy in a laptop battery is converted into electrical energy that runs the machine. However, some of the energy is converted into unwanted heat and sound energy.

ACTIVE READING

12 Explain How does the scientific use of the word *efficiency* differ from the everyday use of the word?

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Using a Ratio

Efficiency is the ratio of useful output energy to input energy.

$$\text{Percent efficiency} = \frac{\text{Energy out}}{\text{Energy in}} \times 100\%$$

Energy efficiency is expressed as a percentage. Improving the efficiency of machines is important because greater efficiency results in less waste. If less energy is wasted, less energy is needed to operate a machine. We can use calculations of efficiency to compare different machines to see which is more efficient.

Do the Math

Sample Problem

An old refrigerator required 400 J of energy to give out 50 J of energy. What is its efficiency?

Identify

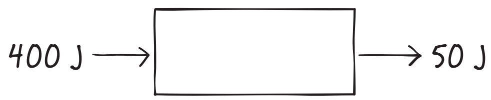
A. What do you know?

Energy in = 400 J, Energy out = 50 J

B. What do you want to find out? Efficiency

Plan

C. Draw and label a sketch:



D. Write the formula:

Efficiency = (Energy out / Energy in) × 100%

E. Substitute into the formula:

Efficiency = (50 J / 400 J) × 100%

Solve

F. Calculate and simplify: Efficiency = (50 J / 400 J) × 100% = 12.5%

G. Check that your units agree:

Answer is a percentage. Efficiency is also a percentage. Units agree.

Answer: 12.5%

You Try It

13 Calculate You would like to replace the refrigerator from the previous problem with a more efficient model. One option requires 300 J of energy and gives out 50 J of energy. What is this refrigerator's efficiency? Is it more efficient than the refrigerator in the previous problem?

Identify

A. What do you know?

B. What do you want to find out?

Plan

C. Draw and label a sketch:

D. Write the formula:

E. Substitute into the formula:

Solve

F. Calculate and simplify:

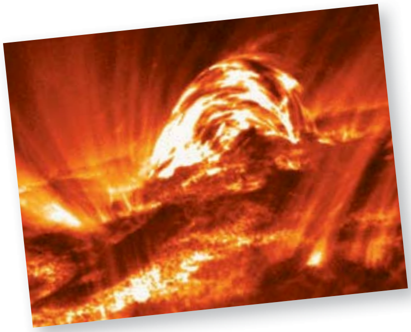
G. Check that your units agree:

Answer:

This old refrigerator is not as efficient as many new refrigerators that are made today.

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. You can use this page to review the main concepts of the lesson.



Energy Conversions

Energy can come in many different forms such as mechanical energy, sound energy, electromagnetic energy, thermal energy, chemical energy, and nuclear energy.

14 A dog running through the yard is an example of ________________ energy.

15 Energy is measured in units called __________

One form of energy can transform into another form of energy.

16 Energy cannot be ______________ or ____________________

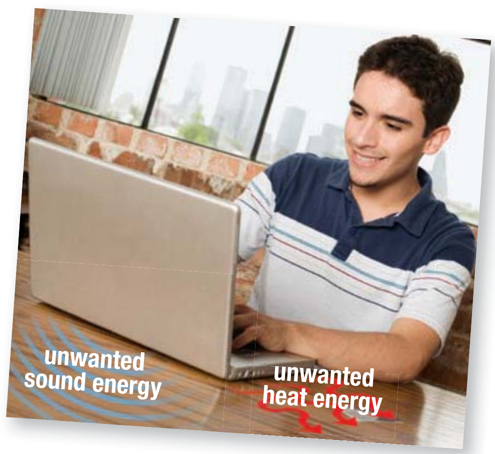
17 Energy in a flashlight's battery changes from ________________ energy to electrical energy.

Efficiency is a ratio of useful output energy to input energy.

$$\text{Percent efficiency} = \left(\frac{\text{Energy out}}{\text{Energy in}}\right) \times 100\%$$

18 No energy transformation can ever be __________________ efficient.

19 A common form of unwanted energy in an energy transformation is ______________



20 Claims • Evidence • Reasoning Describe a process in which energy changes form twice. Make a claim about any unwanted forms of energy produced during the energy transformation. Provide evidence to support your claim, and explain your reasoning.

Lesson Review

LESSON 1

Vocabulary

In your own words, define the following terms.

1 Law of conservation of energy:

2 Efficiency:

Key Concepts

3 Contrast Describe the difference between nuclear energy and light energy.

4 Provide Give an example of an energy conversion. Make sure to discuss which forms of energy are involved.

5 Describe Give an example of an energy conversion that produces an unwanted form of energy.

6 Calculate Suppose a vacuum cleaner uses 120 J of electrical energy. If 45 J are used to pull air into the vacuum cleaner, how efficient is the vacuum cleaner?

Use this photo to answer the following questions.

7 Analyze List one example of each of the following forms of energy found in the photo.

sound energy:

chemical energy:

mechanical energy:

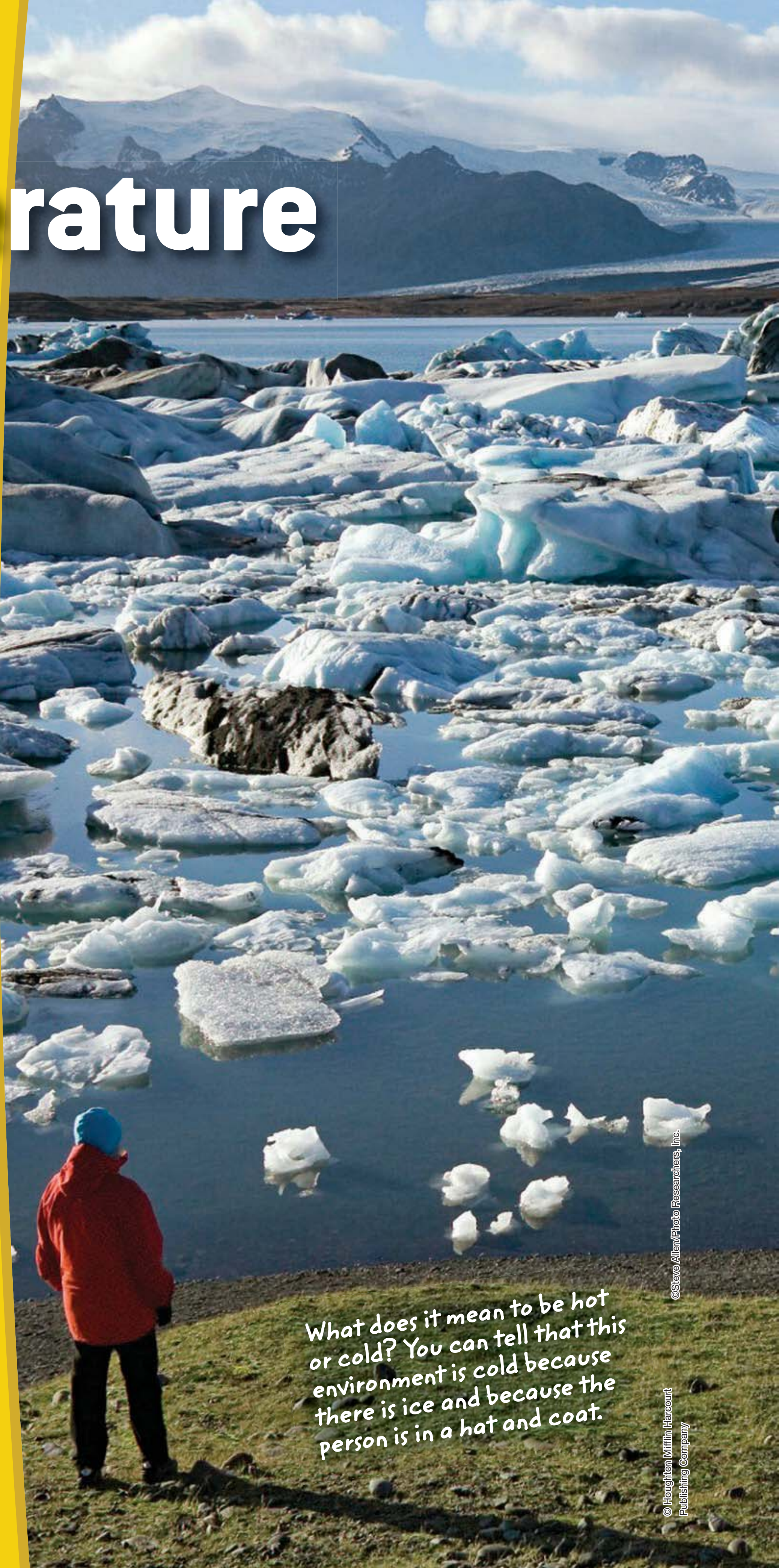
8 Analyze List two examples of energy transformations necessary for the sporting event to take place.

Critical Thinking

9 Claims • Evidence • Reasoning Make a claim about the statement, “You can move parts of your body because of energy from the sun.” Use evidence to support your claim, and explain your reasoning.

LESSON 2

Temperature



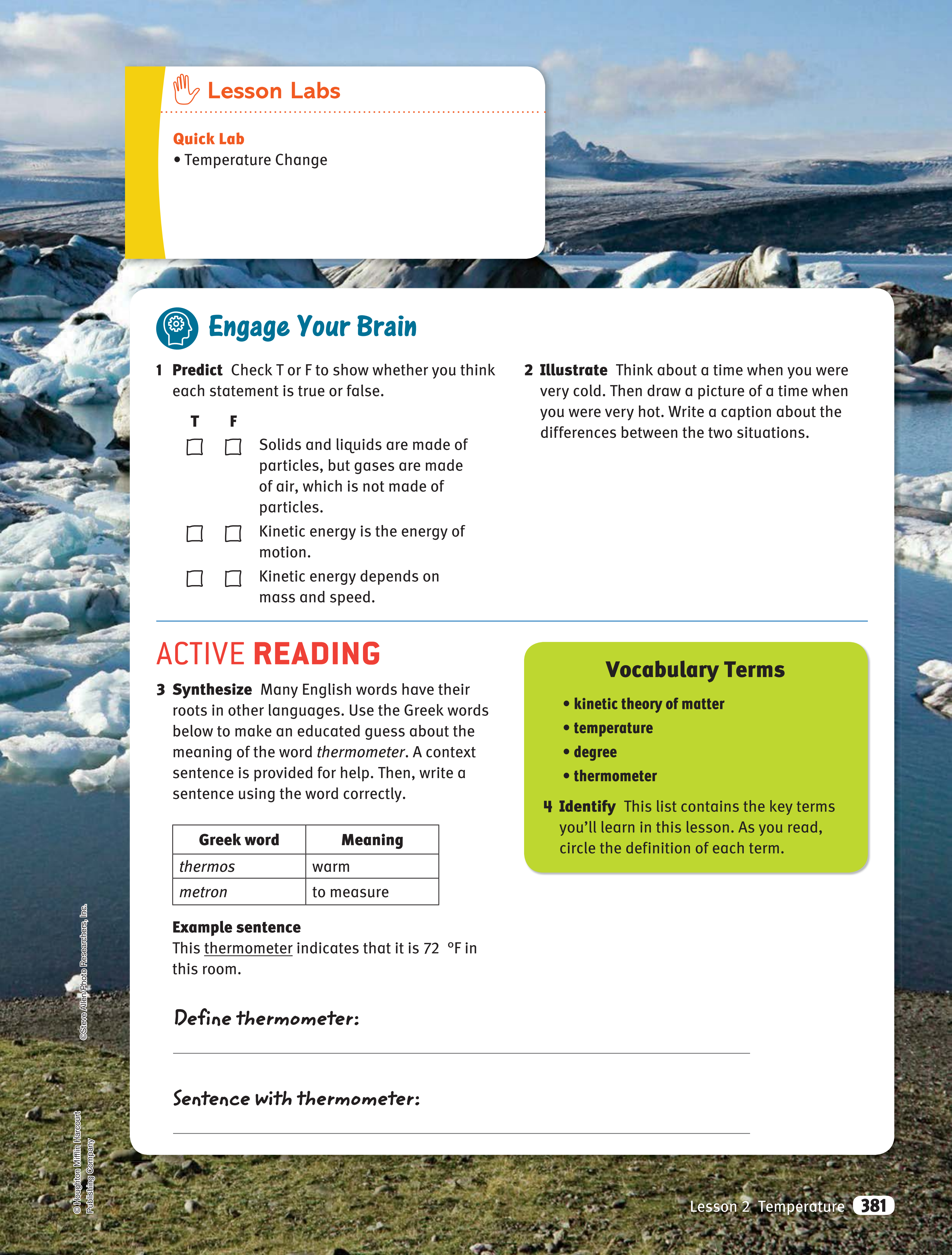
What does it mean to be hot or cold? You can tell that this environment is cold because there is ice and because the person is in a hat and coat.

ESSENTIAL **QUESTION**

How is temperature related to kinetic energy?

By the end of this lesson, you should be able to relate the temperature of a substance to the kinetic energy of its particles.

SC.7.P.11.1 Recognize that adding heat to or removing heat from a system may result in a temperature change and possibly a change of state. **SC.7.P.11.4** Observe and describe that heat flows in predictable ways, moving from warmer objects to cooler ones until they reach the same temperature.



Lesson Labs

Quick Lab
- Temperature Change

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

T	F	
☐	☐	Solids and liquids are made of particles, but gases are made of air, which is not made of particles.
☐	☐	Kinetic energy is the energy of motion.
☐	☐	Kinetic energy depends on mass and speed.

2 Illustrate Think about a time when you were very cold. Then draw a picture of a time when you were very hot. Write a caption about the differences between the two situations.

ACTIVE **READING**

3 Synthesize Many English words have their roots in other languages. Use the Greek words below to make an educated guess about the meaning of the word *thermometer*. A context sentence is provided for help. Then, write a sentence using the word correctly.

Greek word	Meaning
thermos	warm
metron	to measure

Example sentence
This thermometer indicates that it is 72 °F in this room.

Define thermometer:

____

Sentence with thermometer:

____

Vocabulary Terms

- **kinetic theory of matter**
- **temperature**
- **degree**
- **thermometer**

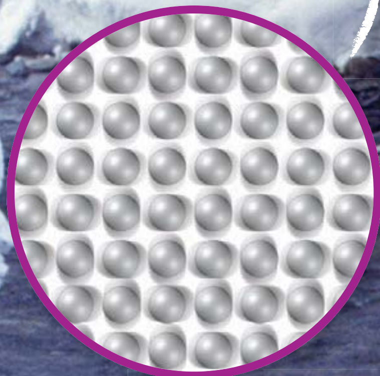
4 Identify This list contains the key terms you'll learn in this lesson. As you read, circle the definition of each term.

Particle Party

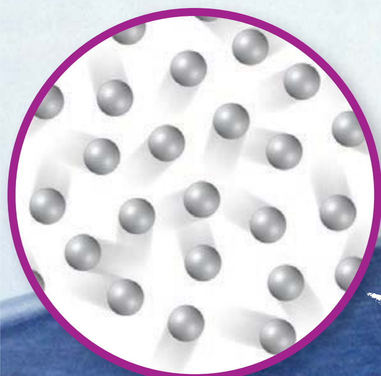
What is the kinetic theory of matter?

All matter is made of atoms. These particles are always moving, even if it doesn't look like they are. The **kinetic theory of matter** states that all of the particles that make up matter are constantly in motion. Because the particles are in motion, they have kinetic energy. The faster the particles are moving, the more kinetic energy they have.

While the particles of matter are constantly moving, the particles move in different directions and at different speeds. This motion is random. Therefore, the individual particles of matter have different amounts of kinetic energy. The average kinetic energy of all these particles takes into account their different random movements. As seen in this picture, solids, liquids, and gases have different average kinetic energies.

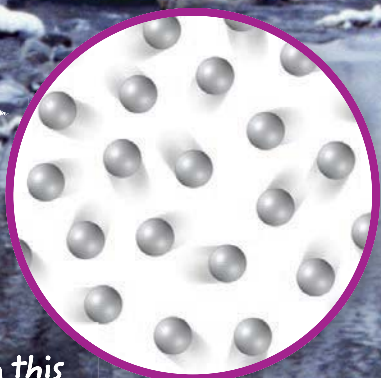


This bridge is a solid, so its particles are close together and vibrate.



In this hot pool, the liquid particles are moving around.

The particles in the gas in the air are far apart and moving quickly.



The particles in this cold river water are moving freely.

How do particles move in solids, liquids, and gases?

The kinetic theory of matter explains the motion of particles in solids, liquids, and gases.

- The particles in a solid, such as concrete, are not free to move around very much. They vibrate back and forth in the same position and are held tightly together by forces of attraction.
- The particles in a liquid, such as water in a pool, move much more freely than particles in a solid. They are constantly sliding around and tumbling over each other as they move.
- In a gas, such as the air around you, particles are far apart and move around at high speeds. Particles collide with one another, but otherwise they do not interact much.

ACTIVE **READING**

5 Describe In your own words, describe the difference between the movement of particles in liquids and the movement of particles in gases.

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Visualize It!

6 Claims • Evidence • Reasoning Locate another solid, liquid, or gas in this photo. Sketch a representation of the particles that make up the solid, liquid, or gas. Make a claim as to how fast you think the particles might be moving based on temperature. Use evidence to support your answer. Write a caption to explain your reasoning.

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___

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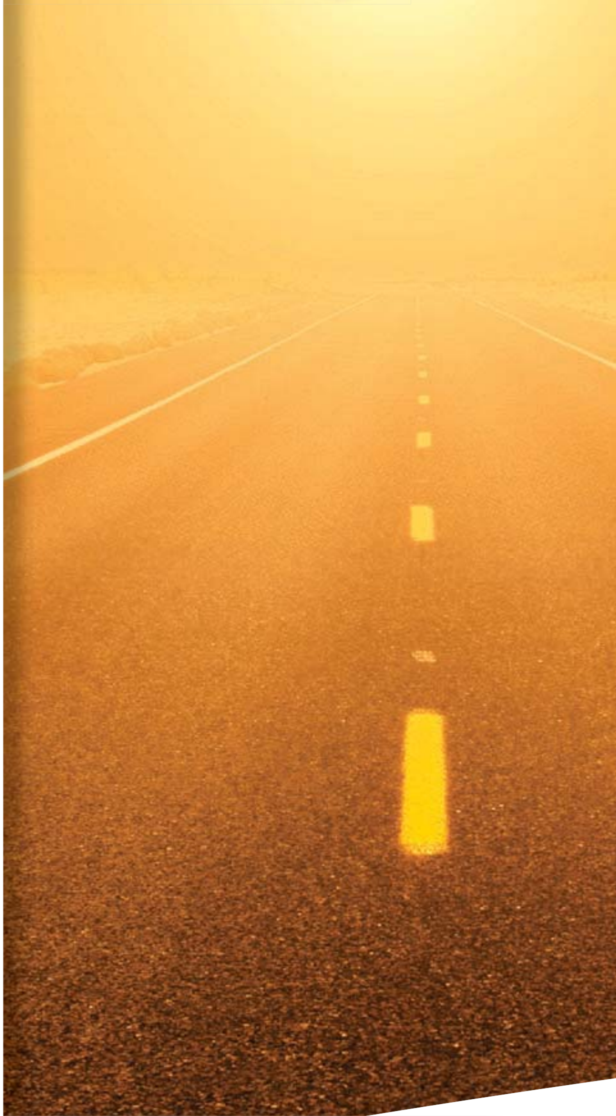
Mercury Rising



How does temperature relate to kinetic energy?

Temperature (TEM•per•uh•chur) is a measure of the average kinetic energy of all the particles in an object. In the picture on the previous page, the particle diagrams for two different liquids are shown. For the colder liquid, the particles are moving slower. For the warmer liquid, the particles are moving faster. If an iron is hot, the particles in the solid are vibrating very fast and have a high average kinetic energy. If the iron has a low temperature, the particles in the solid are vibrating more slowly and have a lower average kinetic energy.

Absolute zero is the temperature at which the motion of particles stops. It is not possible to actually reach absolute zero, though temperatures very close to absolute zero have been reached in laboratories.

How is temperature measured?

Suppose you hear on the radio that the temperature outside is 30 degrees. Do you need to wear a warm coat to spend the day outside? The answer depends on the temperature scale being used. There are three common temperature scales, all of which measure the average kinetic energy of particles. These scales are called Celsius, Fahrenheit, and Kelvin. However, 30 degrees on one scale is quite different from 30 degrees on the other scales.

To establish a temperature scale, two known values and the number of units between the values are needed. The freezing and boiling points of pure water are often used as the standard values. These points are always the same under the same conditions, and they are easy to reproduce. In the Celsius and Fahrenheit scales, temperature is measured in units called degrees. **Degrees** (°) are equally spaced units between two points. The space between degrees can vary from scale to scale. In the Kelvin scale, no degree sign is used. Instead, the unit is just called a kelvin. Temperature is measured using an instrument called a **thermometer**.

ACTIVE READING

7 Claims • Evidence • Reasoning Make a claim about how a substance's temperature changes when the average kinetic energy of its particles increases and when it decreases. Use evidence to support your claim, and explain your reasoning.

Think Outside the Book

8 Produce Write a story about someone who travels from one extreme temperature to another. Make sure to talk about how your character adjusts to the change in temperature. How are the character's daily activities or decisions affected?

Celsius Scale

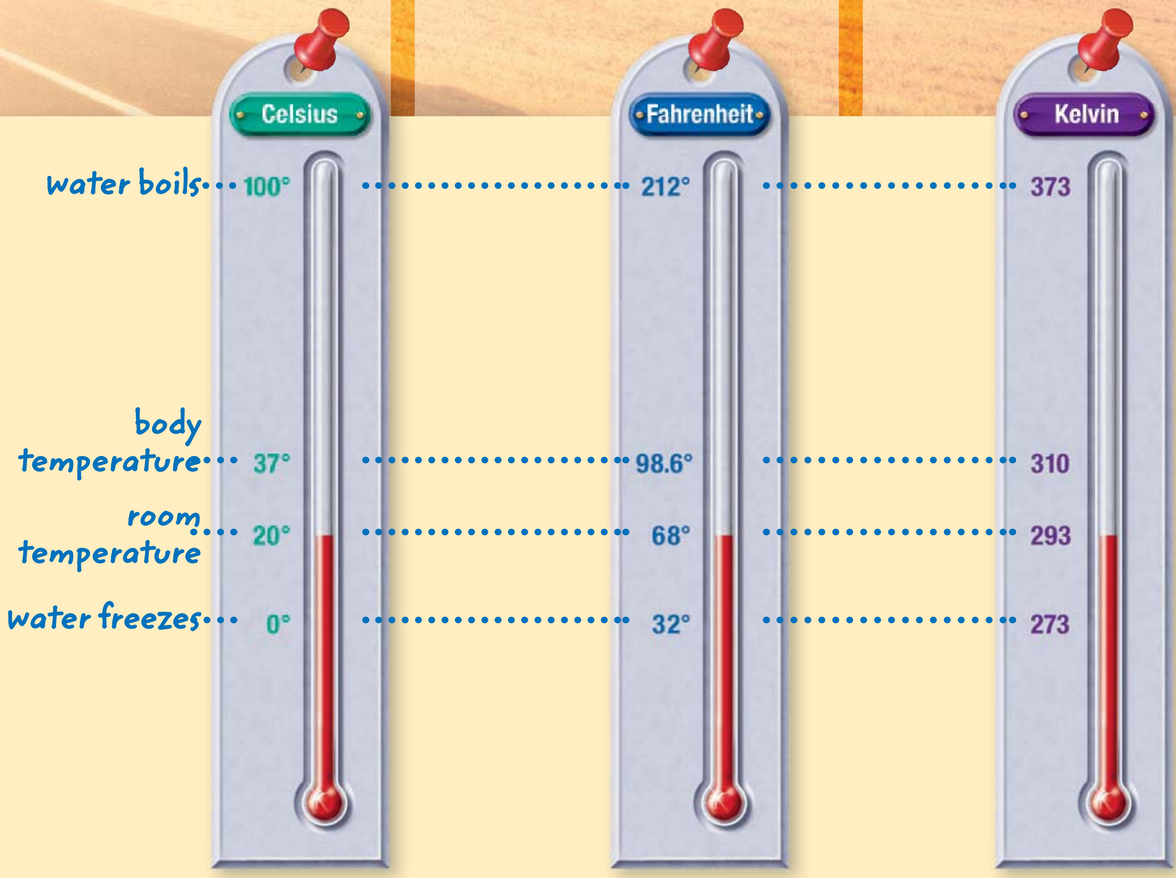
The temperature scale most commonly used around the world, and often used by scientists, is the Celsius (SEL•see•uhs) scale (°C). This scale was developed in the 1740s by Anders Celsius. On the Celsius scale, pure water freezes at 0 °C and boils at 100 °C, so there are 100 degrees—100 equal units—between these two temperatures.

Fahrenheit Scale

The scale used most commonly in the United States for measuring temperature is the Fahrenheit scale (°F). It was developed in the early 1700s by Gabriel Fahrenheit. On the Fahrenheit scale, pure water freezes at 32 °F and boils at 212 °F. Thus, there are 180 degrees—180 equal units—between the freezing point and the boiling point of water.

Kelvin Scale

A temperature scale used commonly by physicists is the Kelvin scale. This scale was not developed until the 20th century. The equal units in the Kelvin scale are called kelvins, not degrees. On the kelvin scale, pure water freezes at 273 K and boils at 373 K. There are 100 kelvins—100 equal units—between these two temperatures. The lowest temperature on the Kelvin scale is absolute zero, or 0 K.



Visualize It!

9 Identify What is body temperature in the Celsius scale? In the Fahrenheit scale? In the Kelvin scale?

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10 Claims • Evidence • Reasoning The water in swimming pools is typically about 80 °F. Mark this temperature on the Fahrenheit thermometer above. Make a claim about what temperature this is in the Celsius and Kelvin scales. Support your claim with evidence, and explain your reasoning.

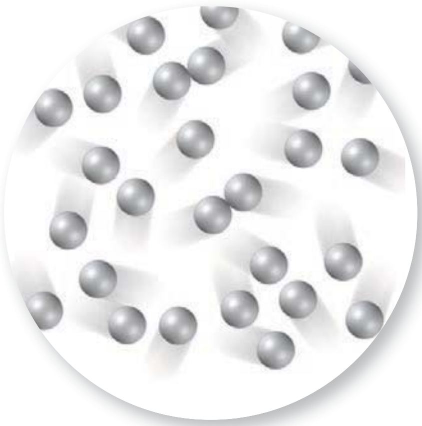
____

Visual Summary

To complete this summary, fill in the blanks with the correct word. You can use this page to review the main concepts of the lesson.

Temperature

All of the particles that make up matter are constantly in motion.



11 The particles in a hot liquid move ________________ than the particles in a cold liquid.

Temperature is a measure of the average kinetic energy of all the particles in an object. Temperature is measured using one of three scales: Celsius, Fahrenheit, or Kelvin.

12 Temperature is measured using a ________________.

13 Claims • Evidence • Reasoning If a puddle of water is frozen, do particles in the ice have kinetic energy? Use evidence to support your claim and explain your reasoning.

Lesson Review

LESSON 2

Vocabulary

For each pair of terms, write a sentence using both words that demonstrates the definition of each word.

1 kinetic theory of matter and temperature

2 thermometer and degree

Key Concepts

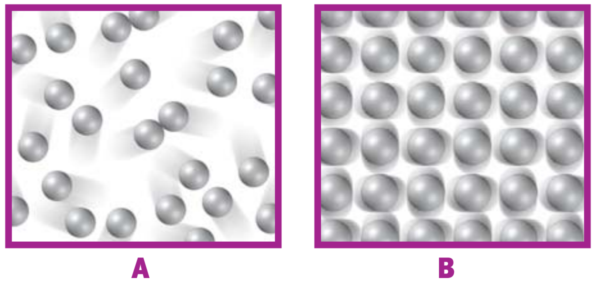
3 **Relate** Describe the relationship between temperature and kinetic energy.

4 **Apply** Particles in a warmer substance have a ____________ average kinetic energy than particles in the substance when it is cooler.

5 **Identify** What are the three scales used to measure temperature? What are the units of each scale?

Critical Thinking

Use the art below to answer the following questions.



6 **Observe** Which illustration represents the substance at a higher temperature? Explain your reasoning.

7 **Claims • Evidence • Reasoning** Make a claim about what would happen to the particles in illustration A if the substance were chilled and if the particles in illustration B were warmed. Use evidence to support your claim, and explain your reasoning.

8 **Claims • Evidence • Reasoning** Using your knowledge of the differences between the three different temperature scales, what do you think would happen if a human's body temperature were 98.6 °C? Make a claim about why doctors worry more about a fever of a couple of degrees Celsius than a fever of a couple of degrees Fahrenheit. Provide evidence to support your claim, and explain your reasoning.

THINK SCIENCE

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics analyze information, make predictions, and defend conclusions.

Planning an Investigation

Scientists ask many questions and develop hypotheses about the natural world. They conduct investigations to help answer these questions. A scientist must plan an investigation carefully. The investigation should gather information that might support or disprove the hypothesis.

Tutorial

Use the following steps to help plan an investigation.

1. **Write a hypothesis.**
The hypothesis should offer an explanation for the question that you are asking. The hypothesis must also be testable. If it is not testable, rewrite the hypothesis.

2. **Identify and list the possible variables in your experiment.**
Select the independent variable and the dependent variable. In your investigation, you will change the independent variable to see any effect it may have on the dependent variable.

3. **List the materials that you will need to perform the experiment.**
This list should also include equipment that you need for safety.

4. **Determine the method you will use to test your hypothesis.**
Clearly describe the steps you will follow. If you change any part of the procedure while you are conducting the investigation, record the change. Another scientist should be able to follow your procedure to repeat your investigation.

5. **Analyze the results.**
Your data and observations from all of your experiments should be recorded carefully and clearly to maintain credibility. Record how you analyze your results so others can review your work and spot any problems or errors in your analysis.

6. **Draw conclusions.**
Describe what the results of the investigation show. Tell whether the results support your hypothesis.

You Try It!

You are a member of a research team that is trying to design and test a roof system that can maintain a comfortable temperature inside a building during hot days. The system you design and test will be a scale model. To begin, you need to find an answer to the following question: What material will minimize the rate of heat transfer inside a building?

1 **Forming a Hypothesis** Write down your hypothesis. How does your hypothesis explain or answer your question? Is your hypothesis testable?

2 **Identifying Variables** List the possible variables in this experiment. Identify dependent variables and independent variables.

3 **Selecting Materials** What equipment and tools will you need to test this variable? What might happen if you select inappropriate tools?

4 **Testing Your Hypothesis** What will your system look like? Will it support your testing? You may sketch the system on a separate page.

5 **Maintaining Accurate Records** What steps will you need to follow in order to test your hypothesis? What kinds of measurements will you collect? What kind of graphic organizer will you use to record your information?

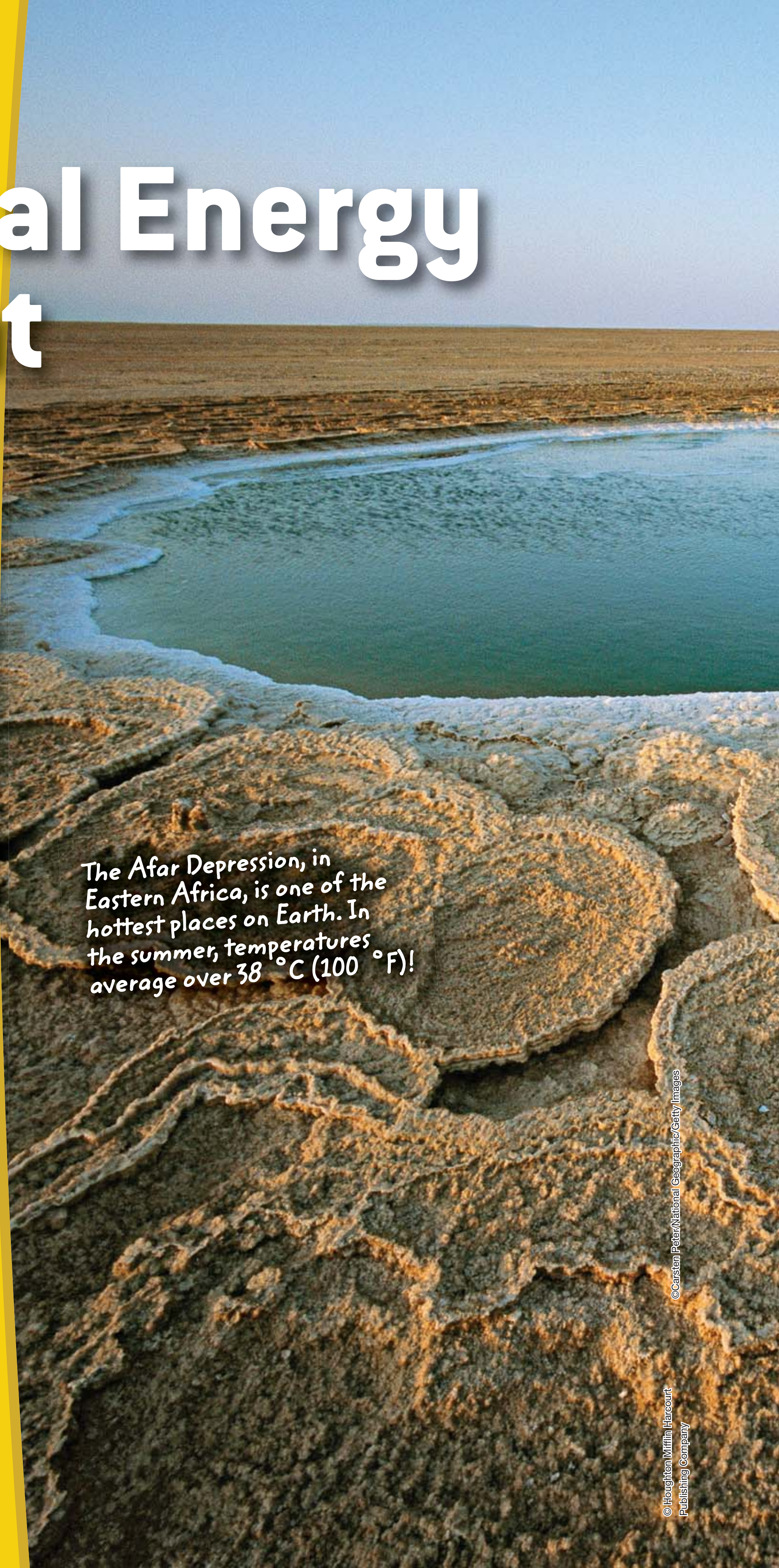
6 **Claims • Evidence • Reasoning** Make a claim about the material you tested, and use evidence from your data to support your claim. Was your hypothesis helpful? Explain your reasoning.

Take It Home

Look closely at objects and materials in your home. Write a list of things that help to prevent the transfer of energy as heat. Design an investigation using one or more of these items to learn more about the job they do. Record your observations. Evaluate your results to see if they might point to a further investigation or an improvement to a product. Present your results in a pamphlet.

LESSON 3

Thermal Energy and Heat



The Afar Depression, in Eastern Africa, is one of the hottest places on Earth. In the summer, temperatures average over 38 °C (100 °F)!

ESSENTIAL **QUESTION**

What is the relationship among, heat, temperature, and thermal energy?

By the end of this lesson, you should be able to analyze the relationship between heat, temperature, and thermal energy.

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions. **SC.7.P.11.1** Recognize that adding heat to or removing heat from a system may result in a temperature change and possibly a change of state. **SC.7.P.11.4** Observe and describe that heat flows in predictable ways, moving from warmer objects to cooler ones until they reach the same temperature.

Lesson Labs

Quick Labs
- Simple Heat Engine
- Exploring Thermal Conductivity
- Heat Transfer by Conduction

Exploration Lab
- Changes of State

S.T.E.M. Lab
- Modeling Geothermal Power

Engage Your Brain

1 Describe Fill in the blanks with the words that you think correctly complete the following sentences.

When you put your hands on a cold object, like a glass of ice water, your hands become ______________________ The glass of water becomes ______________________ if you leave your hands on it for a long time. If you leave the glass of ice water out in the sun, the ice will start to ______________________

2 Describe Write your own caption for this photo.

____

____

____

ACTIVE **READING**

3 Apply Many scientific words, such as *conductor*, also have everyday meanings. Use context clues to write your own definition for each meaning of the word *conductor*.

Example sentence
That school's band is very good because its <u>conductor</u> is a great teacher.

conductor:

____

____

Example sentence
That metal spoon is a good <u>conductor</u>, so it will get hot if you put it into boiling soup.

conductor:

____

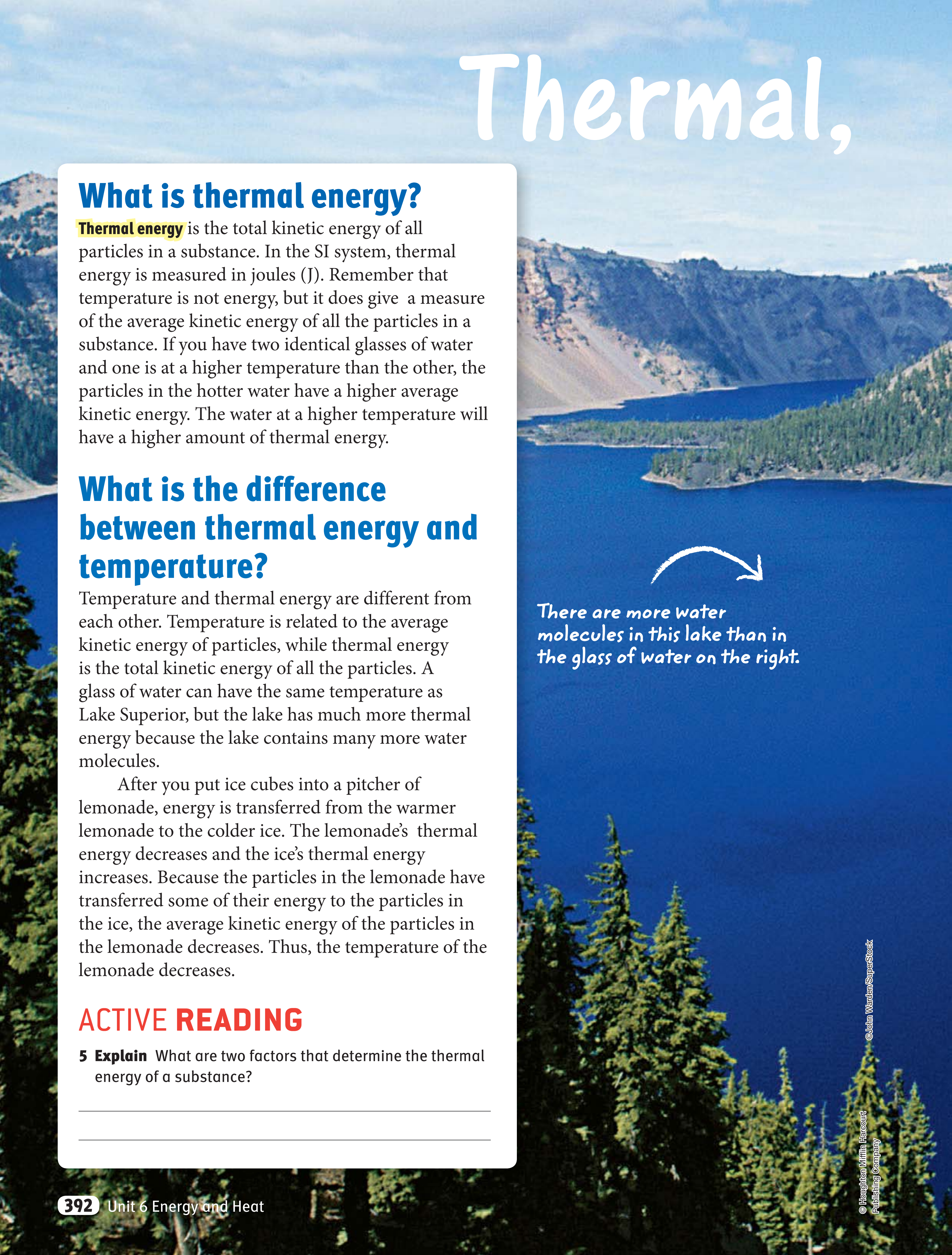
____

Vocabulary Terms

- **thermal energy**
- **heat**
- **calorie**
- **conduction**
- **conductor**
- **insulator**
- **convection**
- **radiation**

4 Apply As you learn the definition of each vocabulary term in this lesson, create your own definition or sketch to help you remember the meaning of the term.

Thermal,



There are more water molecules in this lake than in the glass of water on the right.

What is thermal energy?

Thermal energy is the total kinetic energy of all particles in a substance. In the SI system, thermal energy is measured in joules (J). Remember that temperature is not energy, but it does give a measure of the average kinetic energy of all the particles in a substance. If you have two identical glasses of water and one is at a higher temperature than the other, the particles in the hotter water have a higher average kinetic energy. The water at a higher temperature will have a higher amount of thermal energy.

What is the difference between thermal energy and temperature?

Temperature and thermal energy are different from each other. Temperature is related to the average kinetic energy of particles, while thermal energy is the total kinetic energy of all the particles. A glass of water can have the same temperature as Lake Superior, but the lake has much more thermal energy because the lake contains many more water molecules.

After you put ice cubes into a pitcher of lemonade, energy is transferred from the warmer lemonade to the colder ice. The lemonade's thermal energy decreases and the ice's thermal energy increases. Because the particles in the lemonade have transferred some of their energy to the particles in the ice, the average kinetic energy of the particles in the lemonade decreases. Thus, the temperature of the lemonade decreases.

ACTIVE **READING**

5 Explain What are two factors that determine the thermal energy of a substance?

____

____

Under Where?

6 Apply For each object pair in the table below, circle the object that has more thermal energy. Assume that both objects are at the same temperature.

bowl of soup	small balloon	tiger
pot of soup	large balloon	house cat

Heat It Up!

What is heat?

You might think of the word *heat* as having to do with things that feel hot. But heat also has to do with things that feel cold. Heat causes objects to feel hot or cold or to get hot or cold under the right conditions. You probably use the word *heat* every day to mean different things. However, in science, **heat** is the energy transferred from an object at a higher temperature to an object at a lower temperature.

When two objects at different temperatures come into contact, energy is always transferred from the object that has the higher temperature to the object that has the lower temperature. Energy in the form of heat always flows from hot to cold. For example, if you put an ice cube into a glass of water, energy is transferred from the warmer water to the colder ice cube.

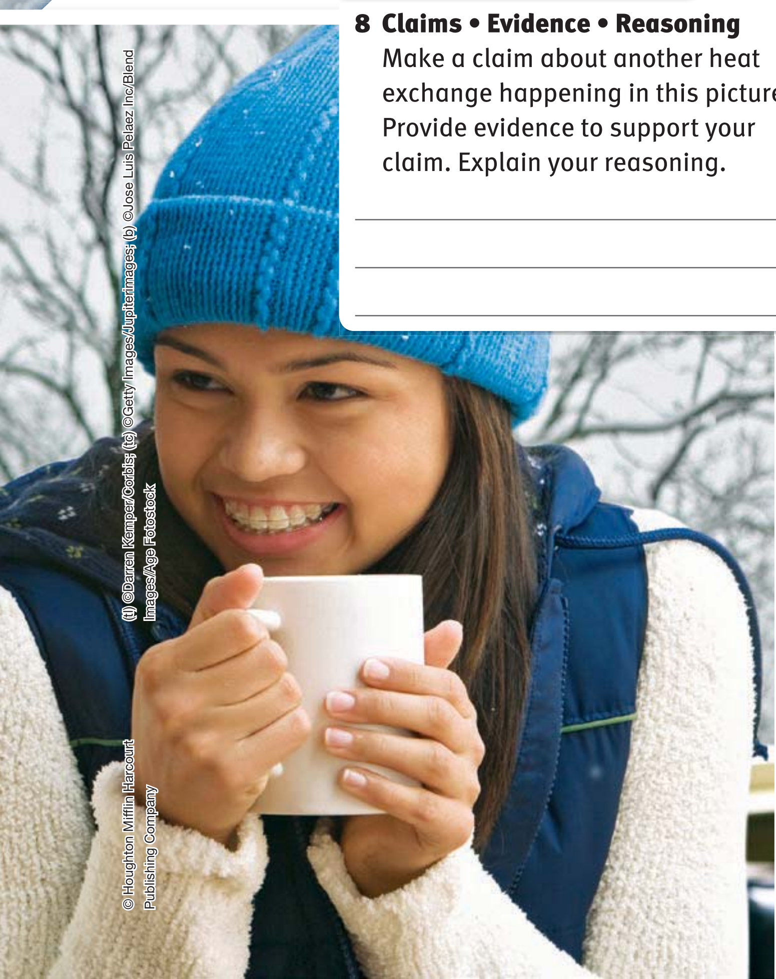
Energy in the form of heat flows from the warm drinks to the cold ice. The ice melts.

7 Apply For each object pair in the table below, draw an arrow in the direction in which energy in the form of heat would flow.

Object 1	Direction of heat flow	Object 2
metal rod		fire
hat		snowman
ice cube		glass of warm water

Energy in the form of heat flows from the hot fire to the marshmallow. The marshmallow gets so hot that it catches on fire!

Energy in the form of heat flows from the warm mugs to the girls' cold hands. Their hands get warmer.



Visualize It!

8 Claims • Evidence • Reasoning Make a claim about another heat exchange happening in this picture. Provide evidence to support your claim. Explain your reasoning.

____

____

____

How is heat measured?

Heat is measured in two ways. One way is the calorie (cal). One **calorie** is equal to the amount of energy needed to raise the temperature of 1 g of water by 1 °C. Heat can also be measured in joules (J) because heat is a form of energy. One calorie is equal to 4.18 J.

You probably think of calories in terms of food. However, in nutrition, one Calorie—written with a capital C—is actually one kilocalorie, or 1,000 calories. This means that one Calorie (Cal) contains enough energy to raise the temperature of 1 kg of water by 1 °C. Each Calorie in food contains 1,000 cal of energy.

To find out how many Calories are in an apple, the apple is burned inside an instrument called a calorimeter. A thermometer measures the increase in temperature, which is used to calculate how much energy is released. This amount is the number of Calories.

How is heat related to thermal energy?

Adding or removing heat from a substance will affect its temperature and thermal energy. Heat, however, is not the same as thermal energy and temperature. These are properties of a substance. Heat is the energy involved when these properties change.

Think of what happens when two objects at different temperatures come into contact. Energy as heat flows from the object at the higher temperature to the object at the lower temperature. When both objects come to the same temperature, no more energy as heat flows. Just because the temperature of the two objects is the same does not mean they have the same thermal energy. One object may be larger than the other and thus have more particles in motion.

ACTIVE READING

9 Relate What will happen if two objects at different temperatures come into contact?

____

____

How can heat affect the state of an object?

The matter that makes up a frozen juice bar is the same whether the juice bar is frozen or has melted. The matter is just in a different form, or state. Remember that the kinetic theory of matter states that the particles that make up matter move around at different speeds. The state of a substance depends on the speed of its particles. Adding energy in the form of heat to a substance may result in a change of state. The added energy may cause the bonds between particles to break. This is what allows the state to change. Adding energy in the form of heat to a chunk of glacier may cause the ice to melt into water. Removing energy in the form of heat from a substance may also result in a change of state.

ACTIVE **READING**

11 Predict What are two ways to change the state of a substance?

___

___

Think Outside the Book

10 State Your Claim Have you ever needed to touch a very hot object? What did you use to touch it without burning yourself? Have you ever needed to protect yourself from being cold? What did you use? Compare the objects you used. Make a claim about what they have in common.

Keep Your Cool

What is conduction?

There are three main ways to transfer energy as heat: conduction, convection, and radiation. **Conduction** is the transfer of energy as heat from one substance to another through direct contact. It occurs any time that objects at different temperatures come into contact with each other. The average kinetic energy of particles in the warmer object is greater than the average kinetic energy of the particles in the cooler object. As the particles collide, some of the kinetic energy of the particles in the warmer object is transferred to the cooler object. As long as the objects are in contact, conduction continues until the temperatures of the objects are equal.

Conduction can also occur within a single object. In this case, energy in the form of heat is transferred from the warmer part of the object to the cooler part of the object. Imagine you put a metal spoon into a cup of hot cocoa. Energy will be conducted from the warm end of the spoon to the cool end until the temperature of the entire spoon is the same.

This is a photo of polar bear hair magnified about 350 times! Notice that it is hollow inside. The air inside is a good insulator.

Conductors

Some materials transfer the kinetic energy of particles better than others. A **conductor** is a material that transfers heat very well. Metals are typically good conductors. You know that when one end of a metal object gets hot, the other end quickly becomes hot as well. Consider pots or pans that have metal handles. A metal handle becomes too hot to touch soon after the pan is placed on a hot stove.

Insulators

An **insulator** (IN•suh•lay•ter) is a material that is a poor conductor of heat. Some examples of insulators are wood, paper, and plastic foam. Plastic foam is a good insulator because it contains many small spaces that are filled with air. A plastic foam cup will not easily transfer energy in the form of heat by conduction. That is why plastic foam is often used to keep hot drinks hot. Think about the metal pan handle mentioned above. It can be dangerous to have handles get hot so quickly. Instead, pot handles are often made of an insulator, such as wood or plastic. Although a plastic handle will also get hot when the pot is on the stove, it takes a much longer time for it to get hot than it would for a metal handle.

12 Classify Decide whether each object below is a conductor or an insulator. Then check the correct box.

Flannel shirt	☐ Conductor ☐ Insulator
Iron skillet	☐ Conductor ☐ Insulator
Copper pipe	☐ Conductor ☐ Insulator
Oven mitt	☐ Conductor ☐ Insulator

What is convection?

Energy in the form of heat can also be transferred through the movement of gases or liquids. **Convection** (kuhn•VEK•shuhn) is the transfer of energy as heat by the movement of a liquid or gas. In most substances, as temperature increases, the density of the liquid or gas decreases. Convection occurs when a cooler, denser mass of a gas or liquid replaces a warmer, less dense mass of a gas or liquid by pushing it upward.

When you boil water in a pot, the water moves in roughly circular patterns because of convection. The water at the bottom of the pot gets hot because there is a source of heat at the bottom. As the water heats, it becomes less dense. The warmer water rises through the denser, cooler water above it. At the surface, the warm water begins to cool. The particles move closer together, making the water denser. The cooler water then sinks back to the bottom, is heated again, and the cycle repeats. This cycle causes a circular motion of liquids or gases. The motion is due to density differences that result from temperature differences. The motion is called a *convection current.*

ACTIVE READING

13 Identify As you read, underline examples of heat transfer.

This pot of boiling water shows how convection currents move.

What is radiation?

Radiation is another way in which heat can be transferred. **Radiation** is the transfer of energy by electromagnetic waves. Some examples of electromagnetic waves include visible light, microwaves, and infrared light. The sun is the most significant source of radiation that you experience on a daily basis. However, all objects—even you—emit radiation and release energy.

When radiation is emitted from one object and then absorbed by another, the result is often a transfer of heat. Like conduction and convection, radiation can transfer heat from warmer to cooler objects. However, radiation differs from conduction and convection in a very significant way. Radiation can travel through empty space, as it does when it moves from the sun to Earth.

14 Classify Fill in the blanks in the chart below.

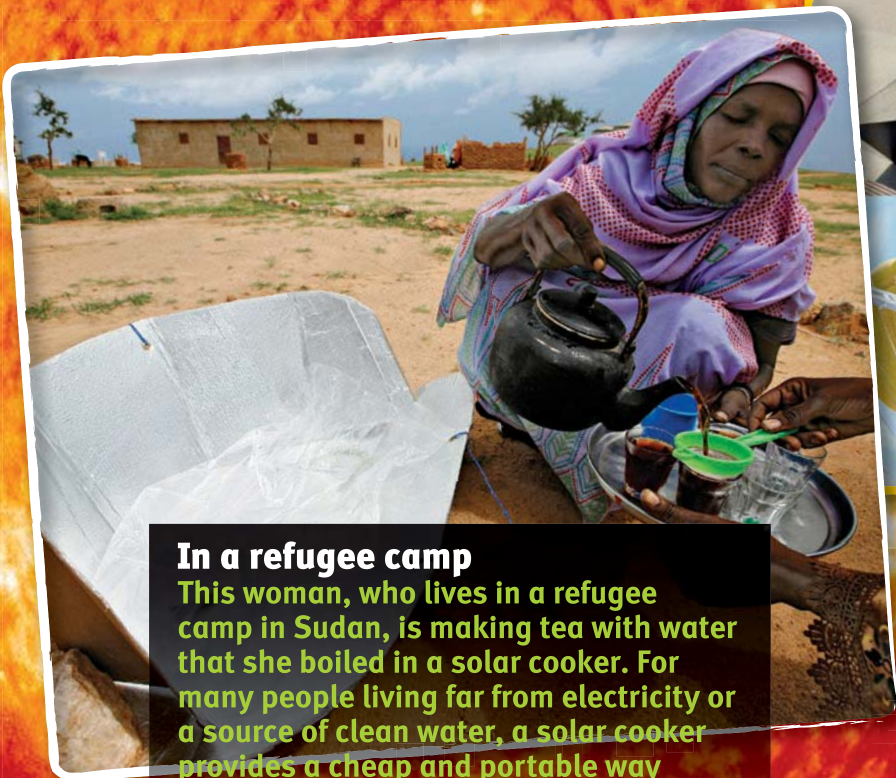
Example	Conduction, Convection, or Radiation
When you put some food in the microwave, it gets hot.	
	Conduction
A heater on the first floor of the school makes the air on the second floor warm.	

WHY IT MATTERS

SOCIETY AND TECHNOLOGY

Practical Uses of Radiation

Do you think that you could cook your food using the energy from the sun? Using a device called a solar cooker, you could! A solar cooker works by concentrating the radiation from the sun into a small area using mirrors. Solar cookers aren't just fun to use—they also help some people eat clean food!



In a refugee camp
This woman, who lives in a refugee camp in Sudan, is making tea with water that she boiled in a solar cooker. For many people living far from electricity or a source of clean water, a solar cooker provides a cheap and portable way to sterilize their water. This helps to prevent disease.

As a hobby
This woman demonstrates how her solar cooker works. Many people like to use solar cookers because they do not require any fuel. They also do not release any emissions that are harmful to the planet.

Extend

15 **Claims • Evidence • Reasoning** Two examples of radiation are shown in the photos above. Make a claim about the source of the radiation. Use evidence to support your claim, and explain your reasoning.

16 **Relate** Research other places throughout the world where solar cookers are being used.

17 **Produce** Explain how solar cookers are useful to society by doing one of the following:
- Make a solar cooker and demonstrate how it works.
- Write a story about a family who uses a solar cooker to stay healthy and safe.

Visual Summary

To complete this summary, circle the correct word or phrase. You can use this page to review the main concepts of the lesson.

Thermal energy is the total kinetic energy of all particles in a substance.

18 If two objects are at the same temperature, the one with more / fewer / the same amount of particles will have a higher thermal energy.

Heat is the energy transferred from an object at a higher temperature to an object at a lower temperature.

19 Heat always flows from cold to hot / hot to cold / left to right.

Heat

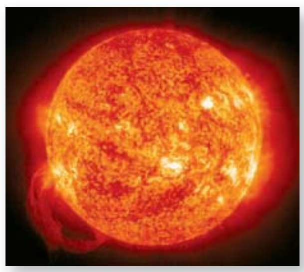
Heat can change the state of a substance.

20 Adding heat to an object causes bonds between particles to form / break / combine. This is what allows the state change.

There are three main ways to transfer energy as heat: conduction, convection, and radiation.

conduction

convection



radiation

21 Conduction is the transfer of energy from a warmer object to a cooler object through a gas / empty space / direct contact.

22 Energy from the sun travels to Earth through conduction / convection / radiation.

23 Claims • Evidence • Reasoning Suppose you are outside on a hot day and you move into the shade of a tree. Make a claim to describe which form of energy transfer you are avoiding. Use evidence to explain your reasoning.

Lesson Review

Vocabulary

In your own words, define the following terms.

1 heat

2 thermal energy

3 conduction

4 convection

5 radiation

Use this photo to answer the following questions.

8 **Classify** Which type of energy transfer is occurring at each lettered area?

A

B

C

Key Concepts

6 **Compare** What is the difference between heat and temperature?

7 **Claims • Evidence • Reasoning** Two objects at different temperatures are in contact with each other. Make a claim about what happens to their temperatures. Support your claim with evidence, and explain your reasoning.

Critical Thinking

9 **Synthesize** Describe the relationships among temperature, heat, and thermal energy.

10 **Synthesize** Do you think that solids can undergo convection? Explain your reasoning.

SC.7.N.1.1 Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

S.T.E.M. ENGINEERING & TECHNOLOGY

Evaluating Technological Systems

Skills
✓ Identify inputs
✓ Identify outputs
✓ Identify system processes
✓ Identify system feedback
Examine system interactions
Apply system controls
✓ Communicate results

Objectives
Identify inputs and outputs of a physical system.
Differentiate between convective and radiative heat transfer.
Graph temperature data versus time.
Analyze and communicate results of an experiment.

Analyzing a Greenhouse

A greenhouse is an enclosed space that maintains a consistent environment and temperature to let people grow plants where the natural climate is not ideal. A greenhouse system needs to heat up and cool off in order to effectively grow plants. How the sun warms a greenhouse involves both radiation and convection. Objects on the ground absorb sunlight and become warm. At the same time, objects cool off primarily in two ways: (1) they get rid of heat by transferring energy as visible light or infrared (in•fruh•RED) light (radiation), or (2) they transfer energy in the form of heat to the air, which then carries it away (convection). A greenhouse retains energy in the form of heat primarily because its roof and walls prevent its warmed air from moving out into the atmosphere.

1 Infer Identify the processes shown at labels A and B as either convection or radiation.

A ______________________

B ______________________

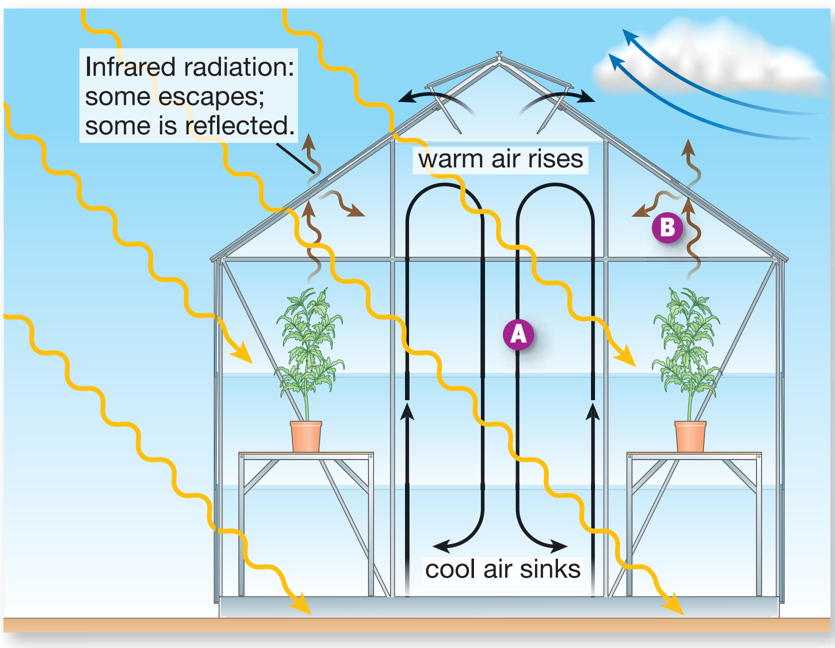
Infer Why is convection the main process regulating the temperature in a greenhouse?

____

____

____

____



Greenhouse Systems

Greenhouses are systems that have inputs and outputs. The inputs are air, water, sunlight, young plants or seeds, and plant nutrients. The outputs are energy in the form of heat and mature plants, fruits, or vegetables. The main uses of greenhouses are agriculture (farming) and horticulture (HOHR•tih•kuhl•cher) (gardening). Typical outputs of agricultural greenhouses are fruits and vegetables. Typical outputs of horticultural greenhouses are ornamental plants and flowers. Greenhouses can vary in size from very large to the size of a shoebox. Gardeners call small greenhouses *cold frames*.

2 Infer Three different types of greenhouses are shown here. Label each type of greenhouse agriculture, horticulture, or cold frame, and list the likely outputs of each.

A

______

______

______

B

______

______

______

C

______

______

______

You Try It!

Now it's your turn to make a greenhouse and analyze how it works.

You Try It!

Now it's your turn to construct a mini-greenhouse and analyze its inputs, how it heats up, and how its temperature is regulated.

You Will Need

- ✓ small box, 8 in. (length) x 5 in. (width) x 3 in. (height)
- ✓ thermometer, digital if possible (1)
- ✓ marking pens, brown or black
- ✓ clear plastic wrap
- ✓ tape or rubber bands
- ✓ aluminum foil
- ✓ lamp

1 Identify Inputs

What are the inputs of your greenhouse?

____

____

2 Identify Outputs

What are the outputs of your greenhouse?

____

____

3 Identify System Processes

A First, record the room-temperature reading of your thermometer. ______________

B Then, begin to construct your greenhouse using the materials listed. With a marking pen, color the inside of your box to simulate the color of dirt.

C Place your thermometer in the box so that it does not touch any part of the box but so that you can still read it. Why should the thermometer not touch the box?

____

____

____

D Using the foil, make a tent-style barrier in the box to shade the thermometer so the lamp does not directly shine on it. Why is it important to shade the thermometer?

____

____

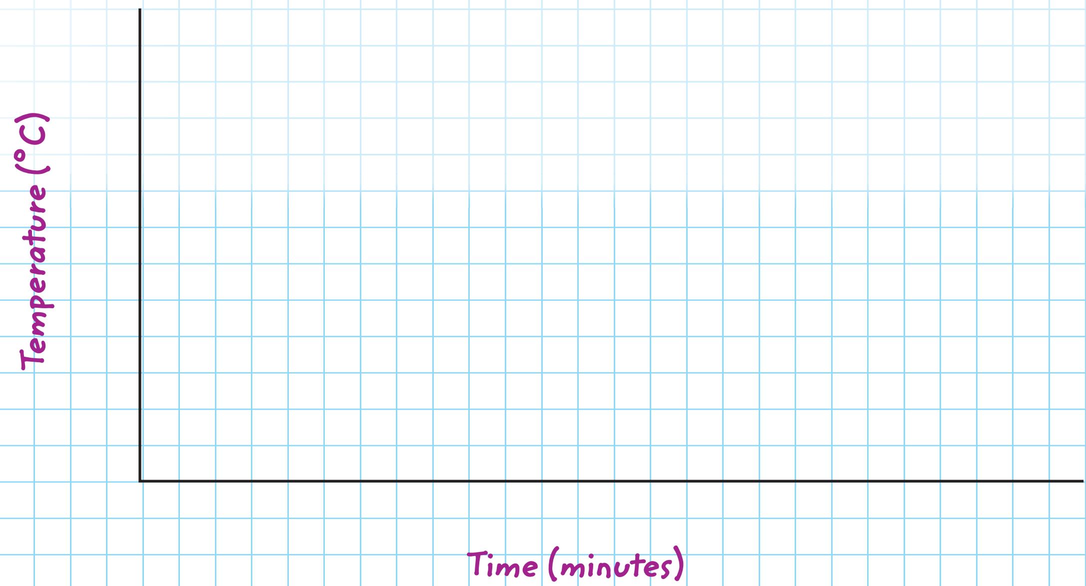
____

E Cover the box with clear plastic wrap, and seal it as best you can with tape or a rubber band to minimize air leaks. Place the lamp above the box to act as the sun.

F What physical processes are involved in your greenhouse system as it accumulates heat energy?

4 Identify System Feedbacks

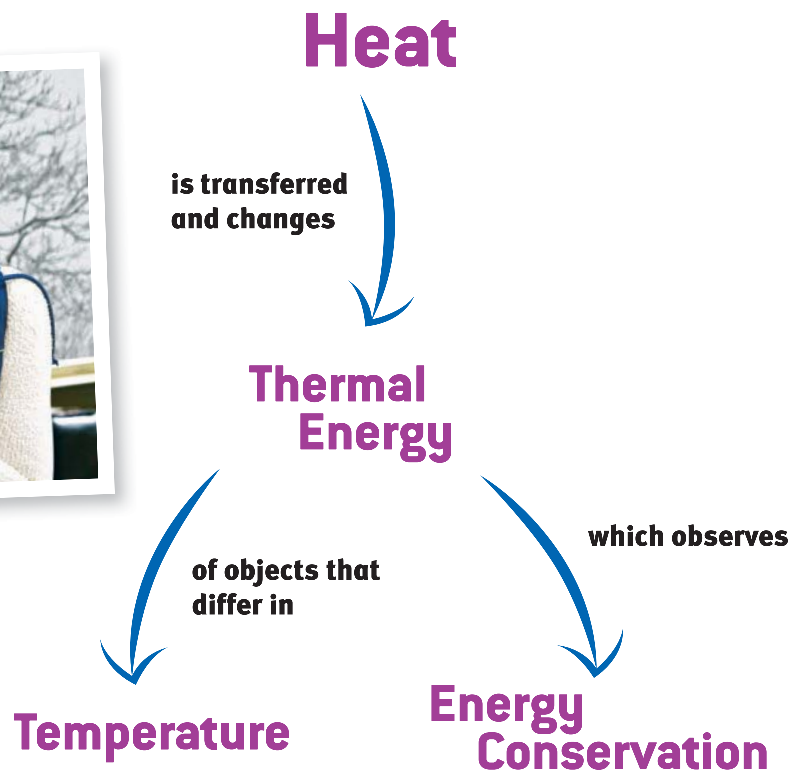
Record the temperature of the air in the greenhouse every 5 minutes for at least 30 minutes. Add scale values on tick marks to both axes. Then, graph the temperature versus time in the space provided.



5 Communicate Results

Claims • Evidence • Reasoning Make a claim about what you learned from your greenhouse experiment. Support your claim with evidence, and explain your reasoning.

Summary



1 Interpret The Graphic Organizer above shows that thermal energy observes energy conservation. Give an example of energy conservation involving thermal energy.

2 Compare Describe conductors and insulators in terms of energy.

3 Claims • Evidence • Reasoning Make a claim about the movement of particles in a cold glass as thermal energy is transferred to it from warm hands. Support your claim with evidence and explain your reasoning.

4 Support Your Claim Can you use a thermometer to measure thermal energy? Support your claim with evidence.

Benchmark Review

UNIT 6

Name ______________________

Vocabulary

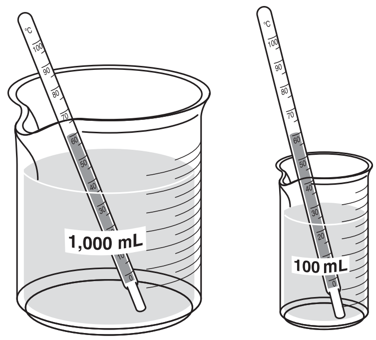
Check the box to show whether each statement is true or false.

T	F	
☐	☐	**1** Mechanical energy is the sum of an object's kinetic and potential energy.
☐	☐	**2** The kinetic theory of matter states that all of the particles that make up matter are in a fixed position.
☐	☐	**3** Heat is the energy transferred from an object at a higher temperature to an object at a lower temperature.

Key Concepts

Identify the choice that best completes the statement or answers the question.

4 These two beakers contain the same liquid substance at the same temperature.



How does the thermal energy of the liquid in the larger beaker compare with the thermal energy of the liquid in the smaller beaker?

A The liquid in the larger beaker has less thermal energy than the liquid in the smaller beaker.

B The liquid in the larger beaker has more thermal energy than the liquid in the smaller beaker.

C The liquid in the larger beaker has the same amount of thermal energy as the liquid in the smaller beaker.

D The exact volume of liquid in each beaker must be known to compare the thermal energy of the liquids.

5 During science class, Sophie measures the temperature of water every minute as it is heating. After a few minutes, the temperature is 82 °C. How far below the boiling point of water is this?

F 8 °C

G 18 °C

H 130 °C

I 191 °C

6 Ella holds an ice cream cone in her hand. She soon notices that her hand begins to feel cold. What is different about the particles that make up her hand?

A They are getting larger.

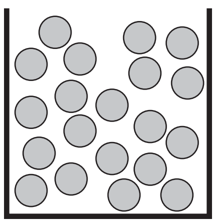
B They are gaining average energy.

C They are moving slower on average.

D They are joining together.

7 Deval drew the models of particles in a substance shown below. Which model **best** represents the particles in a solid?

F



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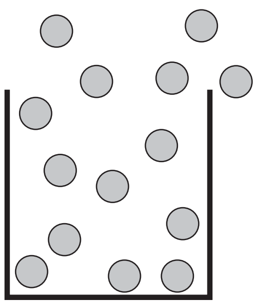

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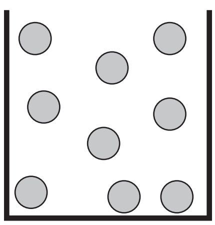
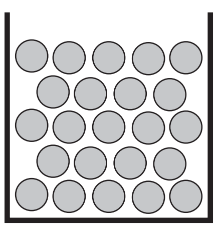


I



8 Ms. Lewis is a chemist mixing two solutions together. A chemical reaction takes place, and the solution becomes warm. Which statement **best** describes what has happened?

A Energy has been created in the form of thermal energy.

B Energy has been transformed from one form to another.

C More energy has been created than has been destroyed.

D The chemical energy of the solution has been destroyed.

Name ______________________________

9 A group of sheep is grazing in a field. As they eat, the sheep break down the molecules in the grass, which releases energy. Which form of energy is stored in the grass?

F chemical energy

G elastic energy

H nuclear energy

I thermal energy

10 Laith notices that the air in his science classroom is much warmer than the air in his math classroom. Which statement describes how the air particles are different in his colder math classroom?

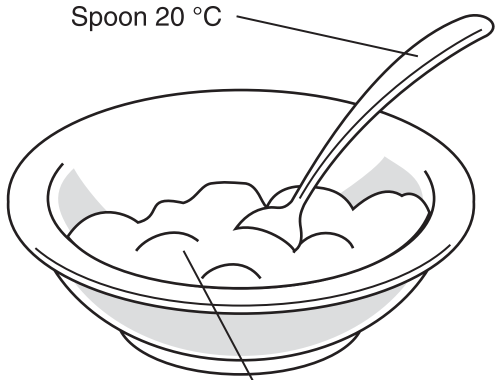
A They move faster on average.

B They are vibrating.

C They have less average energy.

D They move more freely.

11 Kito puts his metal spoon into a helping of fresh, hot mashed potatoes as shown in the figure below.



Which process takes place when the two objects come together?

F The temperature of the spoon increases, but its thermal energy does not change.

G Energy in the form of heat is transferred from the warmer mashed potatoes to the cooler spoon.

H The thermal energy of both the mashed potatoes and the spoon increases as heat flows between them.

I The average temperature of the spoon does not change.

12 Gordon throws a baseball into the air. It rises, stops momentarily when it reaches its greatest height, and then falls back to the ground. At what point does kinetic energy convert to potential energy?

A when the baseball is rising

B when the baseball is falling

C just after the baseball hits the ground

D while the baseball is at the highest point

13 Damon is a musician playing in a band. At the end of a song, he plucks a single guitar string and the string vibrates rapidly. Which of these statements explains what happens to the kinetic energy of the moving string?

F The kinetic energy is changed into potential energy and stored.

G The kinetic energy is converted to sound energy and thermal energy.

H The kinetic energy is slowly destroyed until no energy remains.

I Some of the energy is converted to sound energy, but the rest is destroyed.

Critical Thinking

Answer the following questions in the space provided.

14 Consider a roller coaster car moving along a track. Is energy conserved in this system? Use evidence of energy transformations in this system and the total energy of the car to support your claim and explain your reasoning.

15 An ice cube sits in an open container of water placed outside on a sunny day.

Make a claim about how adding energy as heat to a system may result in a change of state. Support your claim with evidence and reasoning. Include how the water transfers energy to the ice cube and a comparison of the speeds of particles in the ice, water, and air.