Lesson 1

Energy Transfer

ESSENTIAL QUESTION

How does energy move through Earth's system?

By the end of this lesson, you should be able to summarize the three mechanisms by which energy is transferred through Earth's system.

6.ESS2.1, 6.ESS2.2, 6.ESS2.3, 6.PS3.1, 6.PS3.4

Ice absorbs energy from the sun. This can cause ice to melt—even when the temperature is below freezing.

Lesson Labs

Quick Labs

- The Sun's Angle and Temperature
- How Does Color Affect Temperature?
- Modeling Convection

S.T.E.M. Lab

- Heat from the Sun

Engage Your Brain

1 Describe Fill in the blank with the word or phrase that you think correctly completes the following sentences.

An example of something hot is

_____

An example of something cold is

_____

The sun provides us with

_____

A thermometer is used to measure

_____

2 Explain If you placed your hands around this mug of hot chocolate, what would happen to the temperature of your hands? Why do you think this would happen?

_____

_____

_____

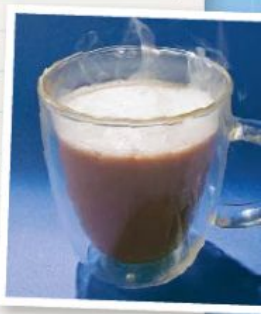
_____

_____

_____

_____

_____



Active Reading

3 Apply Many scientific words, such as *heat*, are used to convey different meanings. Use context clues to write your own definition for each meaning of the word *heat*.

The student won the first heat of the race.

heat:

_____

_____

The man wondered if his rent included heat.

heat:

_____

_____

Energy in the form of heat was transferred from the hot pan to the cold counter.

heat:

_____

_____

Vocabulary Terms

- **temperature**
- **thermal energy**
- **thermal expansion**
- **atmosphere**
- **radiation**
- **convection**
- **conduction**
- **heat**

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

Hot and Cold

How are energy and temperature related?

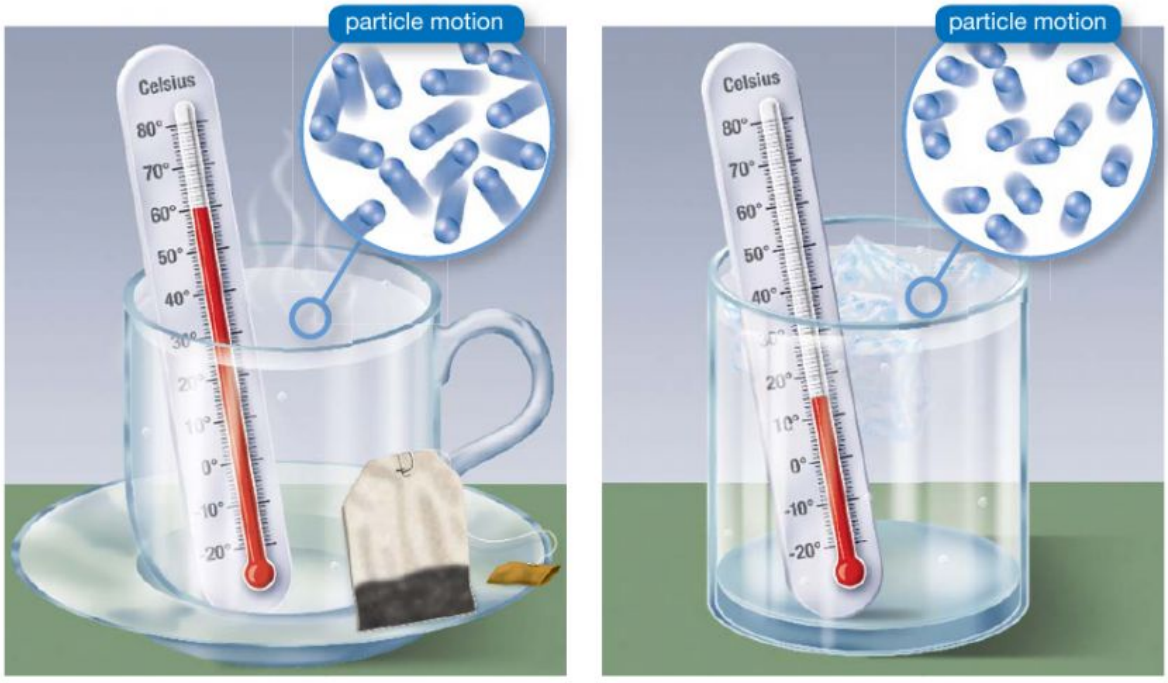
All matter is made up of moving particles, such as atoms or molecules. When particles are in motion, they have kinetic energy. Because particles move at different speeds, each has a different amount of kinetic energy.

Temperature (TEMM•per•uh•choor) is a measure of the average kinetic energy of particles. The faster a particle moves, the more kinetic energy it has. As shown below, the more kinetic energy the particles of an object have, the higher the temperature of the object. Temperature does not depend on the number of particles. A teapot holds more tea than a cup. If the particles of tea in both containers have the same average kinetic energy, the tea in both containers is at the same temperature.

Thermal energy is the total kinetic energy of particles. A teapot full of tea at a high temperature has more thermal energy than a teapot full of tea at a lower temperature. Thermal energy also depends on the number of particles. The more particles there are in an object, the greater the object's thermal energy. The tea in a teapot and a cup may be at the same temperature, but the tea in the pot has more thermal energy because there is more of it.

Visualize It!

5 Analyze Which container holds particles with the higher average kinetic energy?



What is thermal expansion?

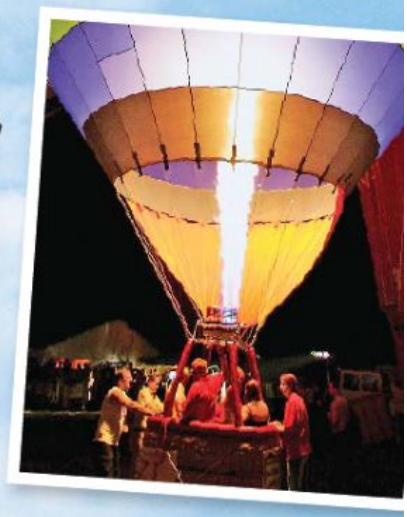
When the temperature of a substance increases, the substance's particles have more kinetic energy. Therefore, the particles move faster and move apart. As the space between the particles increases, the substance expands. The increase in volume that results from an increase in temperature is called **thermal expansion**. Most substances on Earth expand when they become warmer and contract when they become cooler. Water is an exception. Cold water expands as it gets colder and then freezes to form ice.

Thermal expansion causes a change in the density of a substance. *Density* is the mass per unit volume of a substance. When a substance expands, its mass stays the same but its volume increases. As a result, density decreases. Differences in density that are caused by thermal expansion can cause movement of matter. For example, air inside a hot-air balloon is warmed, as shown below. The air expands as its particles move faster and farther apart. As the air expands, it becomes less dense than the air outside the balloon. The less-dense air inside the balloon is forced upward by the colder, denser air outside the balloon. This same principle affects air movement in the atmosphere, water movement in the oceans, and rock movement in the geosphere.

Inquiry

7 Apply Why would an increase in the temperature of the oceans contribute to a rise in sea level?

6 Predict What might happen to the hot-air balloon if the air inside it cooled down?



When the air in this balloon becomes hotter, it becomes less dense than the surrounding air. So, the balloon goes up, up, and away!

Getting Warm

What is heat?

Active Reading

8 Identify As you read, underline the direction of energy transfer between objects that are at different temperatures.

You might think of the word *heat* when you imagine something that feels hot. But heat also has to do with things that feel cold. In fact, heat is what causes objects to feel hot or cold. You may often use the word *heat* to mean different things. However, in this lesson, the word *heat* has only one meaning. **Heat** is the energy that is transferred between objects that are at different temperatures.

Energy Transferred Between Objects

When objects that have different temperatures come into contact, energy will be transferred between them until both objects reach the same temperature. The direction of this energy transfer is always from the object with the higher temperature to the object with the lower temperature. When you touch something cold, energy is transferred from your body to that object. When you touch something hot, like the pan shown below, energy is transferred from that object to your body.

Visualize It!

9 Predict Draw an arrow to show the direction in which energy is transferred between the pan and the oven mitts.

What is Earth's atmosphere?

The mixture of gases that surrounds Earth is the **atmosphere**. This mixture is most often referred to as air. The atmosphere has many important functions. It protects you from the sun's damaging rays and also helps to maintain the right temperature range for life on Earth. For example, the temperature range on Earth allows us to have an abundant amount of liquid water. Many of the components of the atmosphere are essential for life, such as the oxygen you breathe.

Why can the temperatures of land, air, and water differ?

When the same amount of energy is being transferred, some materials will get warmer or cooler at a faster rate than other materials. Suppose you are walking along a beach on a sunny day. You may notice that the land feels warmer than the air and the water, even though they are all exposed to the same amount of energy from the sun. This is because the land warms up at a faster rate than the water and air do.

Specific Heat

The different rates at which materials become warmer or cooler are due to a property called *specific heat*. A substance that has a high specific heat requires a lot of energy to show an increase in temperature. A substance with a lower specific heat requires less energy to show the same increase in temperature. Water has a higher specific heat than land. So, water warms up more slowly than land does. Water also cools down more slowly than land does.

10 Predict Air has a lower specific heat than water. Once the sun goes down, will the air or the water cool off faster? Why?

The temperatures of land, water, and air may differ—even when they are exposed to the same amount of energy from the sun.

Heat

How is energy transferred by radiation?

On a summer day, you can feel warmth from the sun on your skin. But how did that energy reach you from the sun? The sun transfers energy to Earth by radiation. **Radiation** is the transfer of energy as electromagnetic (ee•LEK•troh•mag•NEH•tik) waves. Radiation can transfer energy between objects that are not in direct contact with each other. Many objects other than the sun also radiate energy as light and heat. These include a hot burner on a stove and a campfire, shown below.

Electromagnetic Waves

Energy from the sun is called *electromagnetic radiation*. This energy travels in waves. You are probably familiar with one form of radiation called *visible light*. You can see the visible light that comes from the sun. Electromagnetic radiation includes other forms of energy, which you cannot see. Most of the warmth that you feel from the sun is infrared radiation. This energy has a longer wavelength and lower energy than visible light. Higher-energy radiation includes x-rays and ultraviolet light.

Visualize It!

11 Analyze Write a caption for the campfire photo on the right. Make sure the caption relates the image to radiation.

Energy from this hot burner is being transferred by radiation.

Where does radiation occur on Earth?

We live almost 150 million km from the sun. Yet almost all of the energy on Earth is transmitted from the sun by radiation. The sun is the major source of energy for processes at Earth's surface. Receiving that energy is absolutely vital for life on Earth. The electromagnetic waves from the sun also provide energy that drives the water cycle.

When solar radiation reaches Earth, some of the energy is reflected and scattered by Earth's atmosphere. But much of the energy passes through Earth's atmosphere and reaches Earth's surface. Some of the energy that Earth receives from the sun is absorbed by the atmosphere, geosphere, and hydrosphere. Then, the energy is changed into thermal energy. This thermal energy may be reradiated into the Earth system or into space. Much of the energy is transferred through Earth's systems by the two other ways—convection and conduction.

12 Summarize Give two examples of what happens when energy from the sun reaches Earth.

Think Outside the Book

13 Apply Research ultraviolet radiation from the sun and its role in causing sunburns.

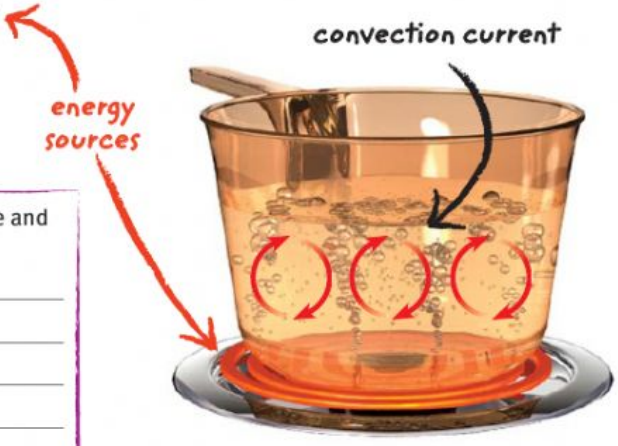
Heating Up

How is energy transferred by convection?

Have you ever watched a pot of boiling water, such as the one below? If so, you have seen convection. **Convection** (kun•VECK•shuhn) is the transfer of energy due to the movement of matter. As water warms up at the bottom of the pot, some of the hot water rises. At the same time, cooler water from other parts of the pot sink and replace the rising water. This water is then warmed and the cycle continues.

Convection Currents

Convection involves the movement of matter due to differences in density. Convection occurs because most matter becomes less dense when it gets warmer. When most matter becomes warmer, it undergoes thermal expansion and a decrease in density. This less-dense matter is forced upward by the surrounding colder, denser matter that is sinking. As the hot matter rises, it cools and becomes more dense. This causes it to sink back down. This cycling of matter is called a *convection current*. Convection most often occurs in fluids, such as water and air. But convection can also happen in solids.



Visualize It! Inquiry

14 Apply How is convection related to the rise and fall of wax in lava lamps?