Name _____ Class _____ Date _____

SECTION 2 What Is Heat?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is heat?
- What is thermal energy?
- How is thermal energy transferred?

National Science Education Standards

PS 3a, 3b

What Is Heat?

You might use the word *heat* to describe things that feel hot. However, heat also has to do with things that feel cold. Heat is what makes objects feel hot or cold. **Heat** is the energy that moves between objects that are at different temperatures. ☑

Why do some things feel hot, and other things feel cold? When two objects touch each other, energy moves from one object to the other. This energy is heat. Heat always moves from an object with a higher temperature to an object with a lower temperature. If you touch a cold piece of metal, energy from your hand moves to the metal. So, the metal feels cold when you touch it.

The metal stethoscope feels cold because of heat.

STUDY TIP

Describe Describe one example of energy transfer by each method—conduction, convection, and radiation—that occurs in your science classroom.

READING CHECK

1. Describe What is heat?

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TAKE A LOOK

2. Identify In the figure, which way is heat flowing if the stethoscope feels cold?

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STANDARDS CHECK

PS 3b Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

3. Compare When two objects at different temperatures are touching, what will energy do?

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HEAT AND THERMAL ENERGY

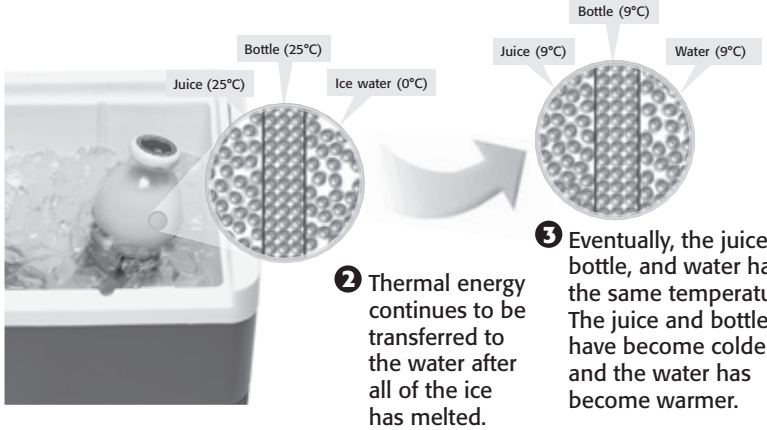
If heat is the movement of energy, what kind of energy is moving? The answer is thermal energy. **Thermal energy** is the total kinetic energy of the particles that make up a substance. Thermal energy is measured in joules (J). Thermal energy depends on the substance's temperature and how much of the substance there is. For example, a large lake contains more thermal energy than a smaller lake if both are at the same temperature.

REACHING THE SAME TEMPERATURE

When two objects with different temperatures touch each other, energy moves. Energy moves from the warmer object to the cooler object. This happens until both objects are at the same temperature. When they have the same temperature, the thermal energy of the objects no longer changes. One object might have more thermal energy than the other, but the temperature of both objects is the same.

Transfer of Thermal Energy

❶ Energy is transferred from the particles in the juice to the particles in the bottle. These particles transfer energy to the particles in the ice water, causing the ice to melt.



❷ Thermal energy continues to be transferred to the water after all of the ice has melted.

❸ Eventually, the juice, bottle, and water have the same temperature. The juice and bottle have become colder, and the water has become warmer.

Say It

Brainstorm The ice melts in a cooler used to keep a six-pack of cola cold on a hot day. Discuss with a partner energy transfers that occur in the cooler of ice that cause the ice to melt.

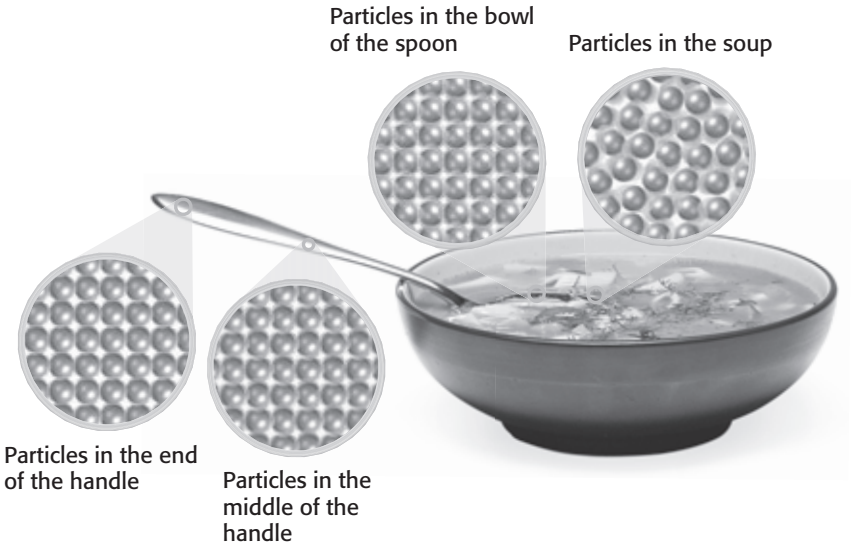
How Is Thermal Energy Transferred?

Every day you see some ways that energy is transferred. Stoves transfer energy to soup in a pot. The temperature of your bath water can change by adding hot or cold water. There are three ways that thermal energy moves from one object to another. They are *conduction*, *convection*, and *radiation*.

CONDUCTION

What happens when you put a cold metal spoon in a bowl of hot soup? The spoon warms up. Even the handle of the spoon gets warm, and it is not touching the soup. The whole spoon gets warm because of conduction. This is shown in the figure below. **Thermal conduction** is the transfer of thermal energy when two objects touch each other. ☑

Conduction also happens within a substance. This is how the handle of the spoon gets warm.



The circles show the energy in the particles of the spoon and the soup. Energy will move from the soup to the spoon until all of the particles have the same energy. Even the handle of the spoon will have the same energy.

When two objects touch, their particles bump into each other. Thermal energy moves from the higher-temperature substance to the lower-temperature substance. When the particles bump into each other, their kinetic energy moves from one particle to another. This makes some particles move faster, and some move slower. This happens until the particles have the same average kinetic energy. Then, both objects will be at the same temperature. ☑

READING CHECK

4. Describe What is thermal conduction?

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READING CHECK

5. Identify What kind of energy is the same for objects at the same temperature?

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CONDUCTORS AND INSULATORS

Substances that transfer thermal energy easily are called **thermal conductors**. The cold metal spoon from the figure on the previous page is an example of a conductor. Energy moves easily from the soup to the spoon.

Some substances do not transfer thermal energy very well and are called **thermal insulators**. The bowl from the figure on the previous page does not get hot as quickly as the spoon. Energy does not move easily from the soup to the bowl, so the bowl is an insulator. The table below shows some examples of common conductors and insulators.

Critical Thinking

6. Compare What is the difference between thermal conductors and thermal insulators?

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Common Conductors and Insulators	
Conductors	**Insulators**
Curling iron	Flannel shirt
Cookie sheet	Oven mitt
Iron pan	Plastic spatula
Copper pipe	Fiberglass insulation
Stove	Ceramic bowl

CONVECTION

The second way thermal energy can be transferred is by convection. **Convection** is the transfer of thermal energy by the movement of a liquid or gas. Look at the figure below. When you boil water in a pot, the water moves in a circular motion because of convection. This circular motion is called a *convection current*. ☑

READING CHECK

7. Describe What is convection?

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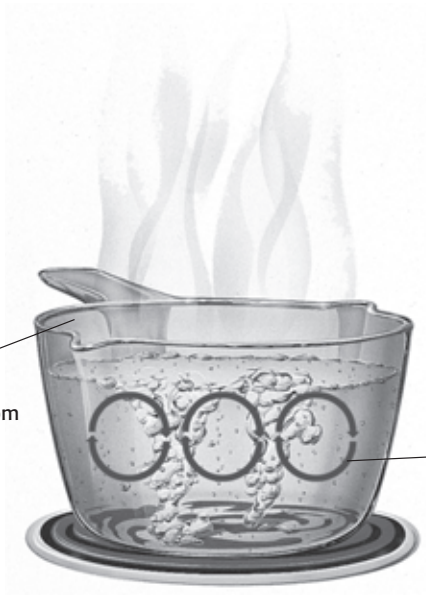
TAKE A LOOK

8. Identify Fill in the missing words in the figure.



❶ The cooler water on the surface of the pan is denser, and it _____ back to the bottom of the pan.

❷ The water moves in the pan because it heats up and cools down. This forms _____ _____, which are shown by the arrows.

The repeated rising and sinking of water during boiling are due to convection.

RADIATION

The third way thermal energy is transferred is by radiation. **Radiation** is the transfer of energy by electromagnetic waves. Some examples of electromagnetic waves are visible light and infrared waves. Radiation can transfer energy between particles or through a vacuum, like outer space. Conduction or convection cannot transfer energy through outer space. ☑

All objects radiate electromagnetic waves. The sun gives off visible light that you see. The sun also gives off other waves, like infrared and ultraviolet waves, that you cannot see. When your body takes in infrared waves, you feel warmer.

READING CHECK

9. Identify Radiation is transferred by what kind of waves?

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RADIATION AND THE GREENHOUSE EFFECT

The atmosphere of Earth acts like the windows of a greenhouse. The sun's visible light goes through it. A greenhouse stays warm because it traps energy. The atmosphere traps energy, too. This is called the *greenhouse effect*. You can see how this works in the figure below.

Greenhouse gases absorb infrared light from the sun. This energy is trapped in the atmosphere. Some of these gases are water vapor, carbon dioxide, and methane. Some scientists are concerned about increasing amounts of greenhouse gases in the atmosphere. They think that too much energy will become trapped and make Earth too warm. ☑

READING CHECK

10. Describe Why are some scientists concerned about increasing amounts of greenhouse gas in the atmosphere?

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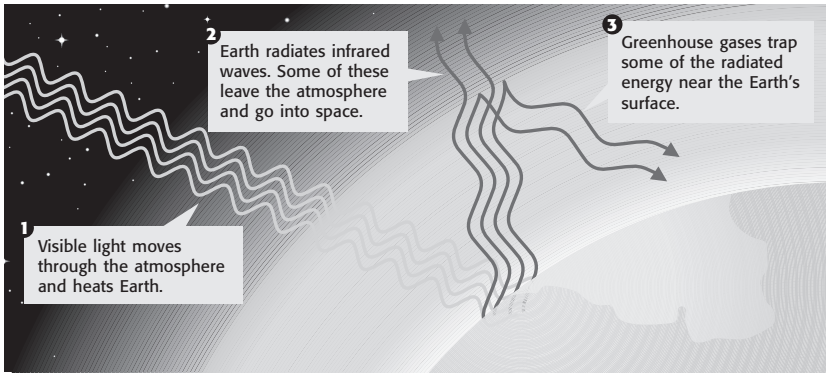

Why Are Some Substances Warmer Than Others?

Have you ever put on your seat belt on a hot summer day? If so, the metal buckle may have felt hotter than the cloth belt did. Why?

THERMAL CONDUCTIVITY

One reason is because the metal buckle has a higher thermal conductivity than the cloth belt. *Thermal conductivity* is a measure of how fast a substance transfers thermal energy. When you touch the metal, energy moves quickly from the belt to your hand. The cloth and the metal are at the same temperature, but the metal feels hotter. ☑

READING CHECK

11. Identify Which has a higher thermal conductivity, a piece of metal or a piece of cloth?

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SPECIFIC HEAT

Another difference between the metal and the cloth is how easily each changes temperature. When the same amount of energy is given to equal masses of metal and cloth, the metal gets hotter. The temperature change depends on the substance's specific heat. **Specific heat** is the amount of energy it takes to change the temperature of 1 kg of a substance by 1°C. ☑

READING CHECK

12. Define What is the specific heat of a substance?

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The higher the specific heat of something is, the more energy it takes to raise its temperature. The specific heat of the cloth is more than two times the specific heat of the metal buckle. So, the same thermal energy will raise the temperature of the metal two times as much as the cloth. The table below shows the specific heat of many common substances. The table shows that most metals have very low specific heats.

Math Focus

13. Identify and Explain Suppose that the same mass of each substance in the table gains the same amount of energy. Which substance will have the greatest increase in temperature? Explain why.

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Specific Heat of Some Common Substances

Substance	Specific heat (J/kg•°C)	Substance	Specific heat (J/kg•°C)
Lead	128	Glass	837
Gold	129	Aluminum	899
Copper	387	Cloth of seat belt	1,340
Iron	448	Ice	2,090
Metal of seat belt	500	Water	4,184

CALCULATING HEAT

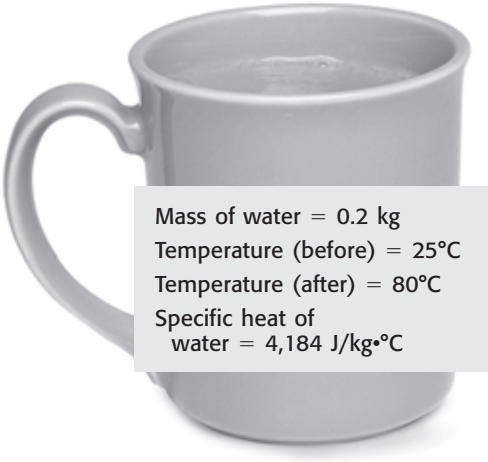
When a substance changes temperature, the temperature change alone does not tell you how much energy has been transferred. To calculate energy transfer, you must know the substance's mass, its change in temperature, and its specific heat. The equation below is used to calculate the energy, or heat, transferred between objects. ☑

heat = specific heat × mass × change in temperature

How much energy is needed to heat a cup of water to make tea? Using the equation above, you can calculate the heat that is transferred to the water. The temperature of the water increases, so heat is a positive number. You can also use this equation to calculate the heat that leaves an object when it cools down. The value for heat when it cools is negative because the temperature decreases.

READING CHECK

14. Describe What data are needed to calculate the amount of energy transferred to a substance?



Information used to calculate heat, the amount of energy transferred to the water, is shown here.

Let's try a problem. You heat 2.0 kg of water to make pasta. The temperature of the water before you heat it is 40°C. The temperature of the water after you heat it is 100°C. How much heat was transferred to the water? (The specific heat of water is 4,184 J/kg•°C).

Math Focus

15. Calculate Use the data in the figure to determine the energy needed to warm the water in the cup.

Step 1: Write the equation.

heat = specific heat × mass × change in temperature

Step 2: Place values into the equation, and solve.

heat = 4,184 J/kg•°C × 2.0 kg × (100°C − 40°C) = 502,080 J.

The heat transferred is 502,080 J.

Name _____ Class _____ Date _____

Section 2 Review

NSES **PS 3a, 3b**

SECTION VOCABULARY

convection the transfer of thermal energy by the circulation or movement of a liquid or gas	**thermal conduction** the transfer of energy as heat through a material
heat the energy transferred between objects that are at different temperatures	**thermal conductor** a material through which energy can be transferred as heat
radiation the transfer of energy as electromagnetic waves	**thermal energy** the kinetic energy of a substance's atoms
specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume	**thermal insulator** a material that reduces or prevents the transfer of heat

1. Explain Why can heat describe both hot and cold objects?

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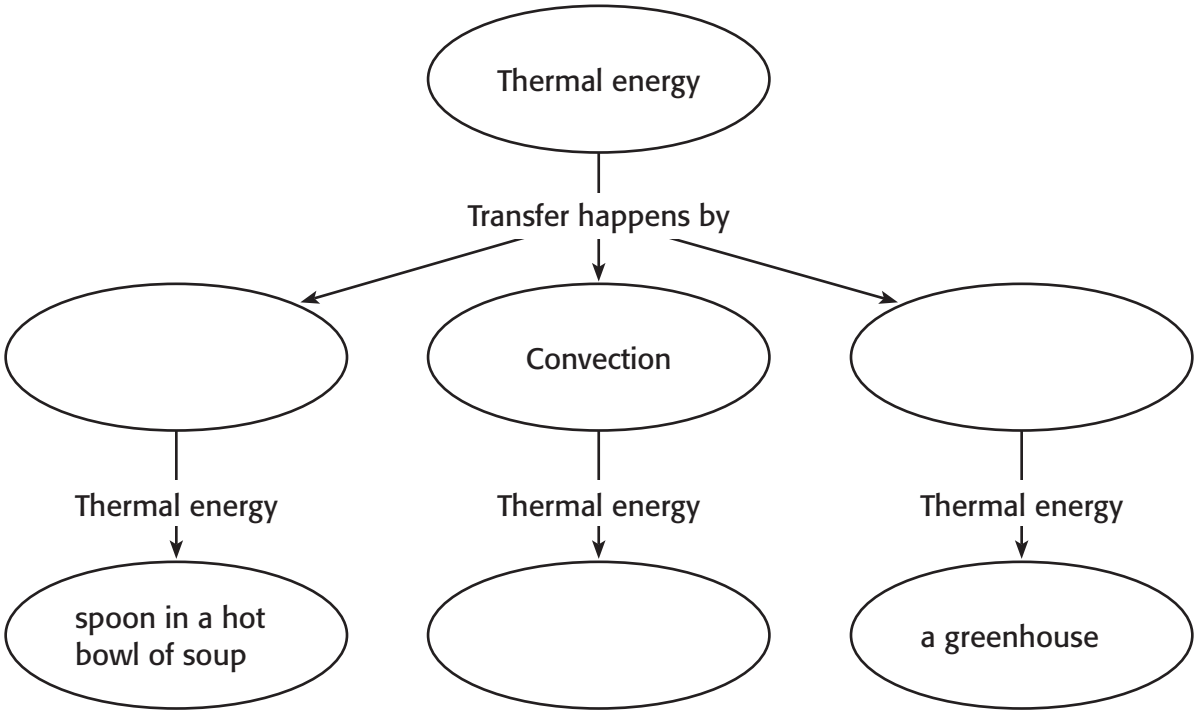
2. Identify Use the following Concept Map to describe how thermal energy moves from one object to another.



3. Calculate The specific heat of lead is 128 J/kg•°C. How much heat is needed to raise the temperature of a 0.015 kg sample of lead by 10°C? Show your work.