**Thermal Energy**

**Thermal Energy, Temperature, and Heat**

--- **Before You Read**

**What do you think?** Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you’ve read this lesson, reread the statements to see if you have changed your mind.

<table>
<thead>
<tr>
<th>Before</th>
<th>Statement</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Temperature is the same as thermal energy.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Heat is the movement of thermal energy from a hotter object to a cooler object.</td>
<td></td>
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</tbody>
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--- **Read to Learn**

**Kinetic and Potential Energy**

What do a soaring soccer ball and the particles that make up hot maple syrup have in common? They have energy, or the ability to cause change. What type of energy does a moving soccer ball have? Recall that any moving object has kinetic energy. When an athlete kicks a soccer ball and puts it in motion, the ball has kinetic energy.

In addition to having kinetic energy when it is in the air, the soccer ball also has potential energy. Potential energy is stored energy due to the interaction between two objects. For example, think of Earth as one object and the ball as another. When the ball is in the air, it is attracted to Earth due to gravity. This attraction is called gravitational potential energy. In other words, because the ball has the potential to change, it has potential energy. And, the higher the ball is in the air, the greater the potential energy of the ball.

You also might recall that the potential energy plus the kinetic energy of an object is the mechanical energy of the object. When a soccer ball is flying through the air, you could describe the mechanical energy of the ball by describing its kinetic and potential energy. On the next page, you will read about how the particles that make up maple syrup have energy, just like a soaring soccer ball.

--- **Key Concepts**

- How are temperature and kinetic energy related?
- How do heat and thermal energy differ?

--- **Study Coach**

**Building Vocabulary** Work with another student to write a question about each vocabulary term in this lesson. Answer the questions and compare your answers. Reread the text to clarify the meaning of the terms.

--- **Foldables**

Make a three-column chart book to organize your notes on the properties of heat, temperature, and thermal energy.

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What is thermal energy?

Every solid, liquid, and gas is made up of trillions of particles that are constantly moving. The particles that make up your book, or any solid, vibrate in place. The particles that make up the air around you, or any gas, spread out and move freely and quickly. Because the particles are in motion, they have kinetic energy. The faster particles move, the more kinetic energy they have.

The particles that make up matter also have potential energy because they interact with and are attracted to one another. The particles that make up solids usually are held very close together by attractive forces. The particles that make up a liquid are slightly farther apart than those that make up a solid. And, the particles that make up a gas are much more spread out than those that make up either a solid or a liquid. The greater the average distance between particles, the greater the potential energy of the particles.

Recall that a flying soccer ball has mechanical energy, which is the sum of its potential energy and its kinetic energy. The particles that make up the ball, or any material, have thermal energy. **Thermal energy is the sum of the kinetic energy and the potential energy of the particles that make up a material.** Thermal energy describes the energy of the particles that make up a solid, a liquid, or a gas.

What is temperature?

You probably think of temperature as a measurement of how warm or cold something is. However, scientists define temperature in terms of kinetic energy.

**Average Kinetic Energy and Temperature**

The particles that make up the air inside and outside a house on a cold night are moving. However, the particles are not all moving at the same speed. The air particles inside the warm house move faster and have more kinetic energy than the air particles outside. **Temperature represents the average kinetic energy of the particles that make up a material.**

The greater the average kinetic energy of particles, the greater the temperature is. The temperature of the air in the house is higher because the particles that make up the air inside the house have greater average kinetic energy than the particles outside. The particles of air inside the house are moving at a greater average speed than those outside. Because temperature represents the average kinetic energy of particles, the temperature of the outside air is lower.
Thermal Energy and Temperature

Temperature and thermal energy are related, but they are not the same thing. For example, as a frozen pond melts, ice and water are present and they have the same temperature. The particles of ice and water have the same average kinetic energy, or speed. The particles do not have the same thermal energy. This is because the average distance of the particles that make up liquid water and ice are different. The particles that make up the liquid water and the solid water have different potential energies and thermal energies.

Measuring Temperature

How can you measure temperature? It would be impossible to measure the kinetic energy of individual particles and then calculate their average kinetic energy to determine the temperature. Instead, you can use thermometers, such as the ones in the figure below, to measure temperature.

A bulb thermometer is a common type of thermometer. It is a glass tube connected to a bulb that contains a liquid such as alcohol. When the temperature of the alcohol increases, the alcohol expands and rises in the glass tube. When the temperature of the alcohol decreases, the alcohol contracts back into the bulb. The height of the alcohol in the tube indicates the temperature. An electronic thermometer measures changes in the resistance of an electric circuit. It converts this measurement to a temperature.

Reading Check

4. Explain Why do particles in liquid water have greater potential energy than particles in ice?

5. Differentiate between a bulb thermometer and an electronic thermometer.

Visual Check

6. Identify Are these bulb thermometers or electronic thermometers?
Temperature Scales

In a weather report, the temperature might be given in degrees Fahrenheit and degrees Celsius. On the Fahrenheit scale, water freezes at 32° and boils at 212°. On the Celsius scale, water freezes at 0° and boils at 100°. The Celsius scale is used by scientists worldwide.

Scientists also use the Kelvin scale. On the Kelvin scale, water freezes at 273 K and boils at 373 K. The lowest possible temperature for any material is 0 K. This is known as absolute zero. If a material were at 0 K, the particles in that material would not be moving and would no longer have kinetic energy. Scientists have not been able to cool any material to 0 K.

What is heat?

Have you ever held a cup of hot cocoa on a cold day? Hot cocoa has a high temperature. Thermal energy is transferred from the cup to its surroundings. As you hold the cup, thermal energy moves from the warm cup to the air and to your hands. *The movement of thermal energy from a warmer object to a cooler object is called heat.* Another way to say this is that thermal energy from the cup heats your hands, or the cup is heating your hands.

Just as temperature and thermal energy are not the same thing, neither are heat and thermal energy. All objects have thermal energy. However, something is heated when thermal energy transfers from one object to another. When you hold the cup of cocoa, your hands are heated because thermal energy transfers from the hot cocoa to your hands.

The rate at which heating occurs depends on the difference in temperatures between the two objects. The difference in temperatures between the hot cocoa and the air is greater than the difference in temperatures between the hot cocoa and the cup. The hot cocoa heats the air more than it heats the cup. Heating continues until all objects that are in contact are the same temperature.

Math Skills

To convert Fahrenheit to Celsius, use the following equation:

\[ ^\circ C = \frac{(^\circ F - 32)}{1.8} \]

For example, to convert 176°F to Celsius:

a. Always perform the operation in parentheses first.

\[ 176 - 32 = 144 \]

b. Divide the answer from Step a by 1.8.

\[ \frac{144}{1.8} = 80^\circ C \]

To convert Celsius to Fahrenheit, follow the same steps using the following equation:

\[ ^\circ F = (^\circ C \times 1.8) + 32 \]

7. Convert Between Temperature Scales

Convert 86°F to Celsius.

Convert 37°C to Fahrenheit.

**Key Concept Check**

8. Explain How do heat and thermal energy differ?
Mini Glossary

**heat:** the movement of thermal energy from a warmer object to a cooler object

**temperature:** the average kinetic energy of the particles that make up a material

**thermal energy:** the sum of the kinetic energy and the potential energy in the particles that make up a material

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining the difference between heat and temperature.

2. Imagine that you are preparing for a snowball fight with a friend. Identify each activity listed in the diagram by one of the terms listed below. An activity might involve more than one of these terms.

<table>
<thead>
<tr>
<th>potential energy</th>
<th>heat</th>
<th>kinetic energy</th>
<th>Example of . . .</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You cup some snow in your hands, and it melts enough to hold the ball of snow together.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The finished snowball sits on top of your pile of snowy ammunition.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The contest begins, and you pick up the top snowball and fire it at your friend.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Have a classmate select one of the questions you wrote as you read the lesson. Without checking against the text, answer the question in the space below.

What do you think? Now?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?