Chapter Resources

Thermal Energy

Includes:

Reproducible Student Pages

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Hands-On Activities
Comparing Rates of Melting

Procedure
1. Prepare ice water by filling a glass with ice and then adding water. Let the glass sit until all the ice melts.
2. Place an ice cube in a coffee cup.
3. Place a similar-sized ice cube in another coffee cup and add ice water to a depth of about 1 cm.
4. Time how long it takes both ice cubes to melt.

Data and Observations

<table>
<thead>
<tr>
<th>Coffee cup</th>
<th>Starting Time</th>
<th>Ending Time</th>
<th>Melting Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
1. Which ice cube melted fastest? Why?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

2. Is air or water a better insulator? Explain.

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
Mini LAB
Observing Convection

Procedure
1. Fill a 250-mL beaker with room-temperature water and let it stand undisturbed for at least 1 min.
2. Using a hot plate, heat a small amount of water in a 50-mL beaker until it is almost boiling.
   WARNING: Do not touch the heated hot plate.
3. Carefully drop a penny into the hot water and let it stand for about 1 min.
4. Take the penny out of the hot water with metal tongs and place it on a table. Immediately place the 250-mL beaker on the penny.
5. Using a dropper, gently place one drop of food coloring on the bottom of the 250-mL beaker of water.
6. Observe what happens in the beaker for several minutes.

Analysis
What happened when you placed the food coloring in the 250-mL beaker? Why?
Name  Date  Class

**LAB** Heating Up and Cooling Down

Lab Preview
Directions: Answer these questions before you begin the Lab.

1. Why is it important that similar beakers are used for each part of this experiment?

2. What will the $x$-axis and the $y$-axis be on your graph?

_Do you remember how long it took for a cup of hot chocolate to cool before you could take a sip? The hotter the chocolate, the longer it seemed to take to cool._

**Real-World Question**
How does the temperature of a liquid affect how quickly it warms or cools?

**Materials**
- thermometers (5)
- 400-mL beakers (5)
- stopwatch
  *watch with second hand*
- hot plate
  *Alternate materials*

**Goals**
- Measure the temperature change of water at different temperatures.
- Infer how the rate of heating or cooling depends on the initial water temperature.

**Safety Precautions**
**WARNING:** Do not use mercury thermometers. Use caution when heating with a hot plate. Hot and cold glass appears the same.

**Procedure**
1. Use the data table on the next page to record the temperature of water in five beakers every minute from 0 to 10 min.
2. Fill one beaker with 100 mL of water. Place the beaker on a hot plate and bring the water to a boil. Carefully remove the hot beaker from the hot plate.
3. Record the water temperature in your data table at minute 0, and then every minute for 10 min.
4. Repeat step 3 starting with hot tap water, cold tap water, refrigerated water, and ice water with the ice removed.
Hands-On Activities

**Communicating Your Data**

Share your data and graphs with other classmates and explain any differences among your data.

---

**Conclude and Apply**

1. **Graph** your data. **Plot and label** the lines for all five beakers on one graph.

2. **Calculate** the rate of heating or cooling for the water in each beaker by subtracting the initial temperature of the water from the final temperature and then dividing this answer by 10 min.

3. **Infer** from your results how the difference between room temperature and the initial temperature of the water affected the rate at which it heated up or cooled down.
Insulated beverage containers are used to reduce heat transfer. What kinds of containers do you most often drink from? Aluminum soda cans? Paper, plastic, or foam cups? Glass containers? In this investigation, compare how well several different containers block heat transfer.

### Real-World Question
Which types of beverage containers are most effective at blocking heat transfer from a hot drink?

### Form a Hypothesis
Predict the temperature change of a hot liquid in several containers made of different materials over a time interval.

### Possible Materials
- hot plate
- large beaker
- water
- 100-mL graduated cylinder
- alcohol thermometers
- various beverage containers
- material to cover the containers
- stopwatch
- tongs
- thermal gloves or mitts

### Goals
- **Predict** the temperature change of a hot drink in various types of containers over time.
- **Design** an experiment to test the hypothesis and collect data that can be graphed.
- **Interpret** the data.

### Safety Precautions
**WARNING:** Use caution when heating liquids. Use tongs or thermal gloves when handling hot materials. Hot and cold glass appear the same. Treat thermometers with care and keep them away from the edges of tables.

### Test Your Hypothesis

#### Make a Plan
1. **Decide** what types of containers you will test. Design an experiment to test your hypothesis. This is a group activity, so make certain that everyone gets to contribute to the discussion.
2. **List** the materials you will use in your experiment. Describe exactly how you will use these materials. Which liquid will you test? What temperature will the liquid begin at? How will you cover the hot liquids in the container? What material will you use as a cover?
Hands-On Activities

Communicating Your Data
Compare your data and graphs with other classmates and explain any differences in your results or conclusions.

LAB (continued)

3. **Identify** the variables and controls in your experiment.
4. **Design** a data table on a separate sheet of paper to record the observations you make.

Follow Your Plan

1. Ask your teacher to examine the steps of your experiment and your data table before you start.
2. To see the pattern of how well various containers retain heat, you will need to graph your data. What kind of graph will you use?

Analyze Your Data

1. **Graph** your data. Use one graph to show the data collected from all your containers. Label each line on your graph.
2. **Interpret Data** How can you tell by looking at your graphs which containers retain heat best?
3. **Evaluate** Did the water temperature change as you had predicted? Use your data and graph to explain your answers.

Conclude and Apply

1. **Explain** why the rate of temperature change varies among the containers. Did the size of the containers affect the rate of cooling?
2. **Conclude** which containers were the best insulators.

Make certain you take enough measurements during the experiment to make your graph.

3. The time intervals between measurements should be the same. Be sure to keep track of time as the experiment goes along. For how long will you measure the temperature?
4. Carry out your investigation and record your observations.
The Effect of Temperature on Diffusion and Expansion

The temperature of a substance is related to the average kinetic energy of the molecules the substance is made from. The kinetic energy of a molecule or any object increases when it moves faster. Because temperature depends on the average kinetic energy of molecules, when the temperature of something increases, the kinetic energy of its molecules increases. As a result, its molecules move faster. Most materials expand as their temperature increases and their molecules move faster. Gases usually expand much more than solids or liquids as they become hotter.

When one liquid is added to another, the molecules of the two liquids will move through each other, or diffuse, at a rate that depends on the temperatures of the liquids. In this lab you will observe the effect of temperature on the diffusion of liquids and the expansion of a gas.

Strategy
You will observe the effect of temperature on the expansion of air.
You will observe the effect of temperature on the diffusion of two liquids.

Materials
- 250 mL beakers (3)
- water
- hot plate
- crushed ice
- food coloring (3 drops)
- round balloons (3)
- permanent marker
- flexible tape measure
- ice chest
- hair dryer
- round balloons (3)
- permanent marker
- flexible tape measure
- ice chest
- hair dryer
- round balloons (3)
- permanent marker
- flexible tape measure
- ice chest
- hair dryer

Procedure

Part A—Diffusion in Water
1. In groups of three or four, set up your water temperature and diffusion activity. Pour water into two beakers until they are about two thirds full. Place one beaker on the hot plate, and begin to warm the water slowly to just under a boil. Let one beaker sit at room temperature. Fill the third beaker with crushed ice. Continue with step 2 of Part A when the water in the first beaker is almost boiling and the water in the third beaker is almost melted.
2. Check that the water in the beaker on the hot plate is near boiling. Look for tiny bubbles to appear on the surface of the glass. Do not let the water boil. Remove beaker from hot plate and turn off hot plate. Convection currents in boiling water would interfere with your results.

CAUTION: Use proper protection when handling the heated beaker.

3. Have two students in the group gently move the cold and room-temperature beakers side by side. Try to disturb the water as little as possible. Have the water as still as possible before continuing. Gently let a drop of food coloring fall into the water in each beaker. Observe how the dye falls and spreads throughout the water. Do not stir or move the beakers during this time. Look how quickly the dye moves around the water. Does it sit on the bottom? In which beaker does the dye spread more quickly? Record your results in Table 1 in the Data and Observations section.
**Laboratory Activity 1 (continued)**

4. Now carefully let a drop of the dye slip into the beaker of hot water. Do not stir the water in any manner. How quickly does the dye spread throughout the water? How does the movement in the near boiling water compare to the movement of the dye in the room temperature and near freezing water? Record your observations in Table 1. What does this tell you about the speed of the molecules in each temperature of water?

**Part B—Expansion in Air**

1. Inflate three round balloons to about the same size. Blow them up so that they are almost full of air, but leave enough room for expansion. With your marker, label the balloons with your group name. Then, make a mark on each balloon at a vertical center where you will measure the circumference. Finally, label the balloons Cold, Room, and Hot.

2. Use a tape measure to measure the circumference of each balloon. Use the mark you made on the vertical center of each balloon as a guide to determine where to measure. Record the circumference of each balloon in Table 2 in the Data and Observations section.

3. Place your balloon labeled Cold in an ice chest that is about one-fourth full of ice. Close the lid and wait five minutes.

4. Meanwhile, use the hair dryer to gently sweep hot air back and forth across the surface of the balloon labeled Hot. Do not overheat. Keep the dryer at least six inches from the balloon’s surface. Heat for about three minutes. Immediately measure the circumference of the balloon again at the vertical center mark. Be as quick as possible so the air in the balloon does not cool down. Record this value in Table 2.

5. Take the balloon from the ice chest and measure its circumference at the vertical center mark. Record the measurement in Table 2.

6. Finally, measure the circumference of your balloon labeled Room. Record the value in Table 2.

7. Calculate the changes in the circumference of each balloon. Record the values in Table 2. Remember to include plus or minus signs to show whether your balloon expanded or contracted.
Laboratory Activity 1 (continued)

Data and Observations

Table 1

<table>
<thead>
<tr>
<th>Water temperature</th>
<th>Description of how dye moved through water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>1.</td>
</tr>
<tr>
<td>Cold</td>
<td>2.</td>
</tr>
<tr>
<td>Hot</td>
<td>3.</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Temperature of air in balloon</th>
<th>Circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning</td>
</tr>
<tr>
<td>Room</td>
<td></td>
</tr>
<tr>
<td>Cold</td>
<td></td>
</tr>
<tr>
<td>Hot</td>
<td></td>
</tr>
</tbody>
</table>

Questions and Conclusions

1. What happened to the circumference of the cold balloon? Explain why this happened.

2. Did the hot balloon expand or contract? Why did the circumference of the hot balloon get larger?
3. Describe and explain the change in the circumference of the room temperature balloon.

4. Describe the change in the temperature of each balloon in terms of the motion of the air molecules.

5. In which beaker were the water molecules moving the fastest?

6. Explain how the rate at which the dye diffused in the different beakers is related to the temperature of the water.

Strategy Check

_____ Can you compare the thermal energy of air molecules at different temperatures?

_____ Can you observe the thermal energy of water molecules at different temperatures?
Have you ever walked barefoot on asphalt on a sunny summer day? The black pavement is hot because heat from the sun transfers to the pavement through radiation. Radiation is the movement of energy in the form of waves. Different materials absorb radiant energy from the sun differently. In today’s experiment, you will compare how light-colored materials and dark-colored materials differ in their ability to absorb energy from the sun.

**Strategy**

You will observe how energy from the sun can increase the temperature of water. You will determine how color influences how much solar radiation is absorbed.

**Materials**
- construction paper (black)
- construction paper (white)
- containers (2 plastic, 500-mL)
- scissors
- tape
- graduated cylinder (100-mL)
- water
- thermometer (alcohol, Celsius)
- timer
- pencils (colored)

**Procedure**

**WARNING:** Use care when handling sharp objects.

1. Fasten black construction paper on the bottom and sides of one container.
2. Fasten white construction paper on the bottom and sides of the other container.
3. Add 250 mL of room-temperature water to each container.
4. Use a thermometer to find the temperature of the water in each container. Record your data in Table 1 in the Data and Observations section.
5. Place the containers side by side in direct sunlight outside on a sunny windowsill. Be sure both containers receive the same amount of sunshine.
6. Measure the temperature of the water in each container at 5-minute intervals for 30 minutes. Record your data in Table 1.
7. Using Figure 2, graph the data from the table, using a line graph. Use one colored pencil to show data for the light container and a different one to show data for the dark container. Draw lines to connect the temperature for each container of water.
Hands-On Activities

Data and Observations

Table 1

<table>
<thead>
<tr>
<th>Color of container</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Temp. (°C)—Light</td>
<td></td>
</tr>
<tr>
<td>Temp. (°C)—Dark</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2

Temperature of Water in Light and Dark Containers

1. What was the final temperature of the water in the dark container?

2. What was the final temperature of the water in the light container?

3. How many degrees did the temperature of the dark container increase?

4. How many degrees did the temperature of the light container increase?
Laboratory Activity 2 (continued)

Questions and Conclusions
1. Did one container of water heat up more quickly? Which one?

2. How do you think color influences the ability of an object to absorb energy from the sun?

3. Would you get similar results if you placed the containers in the shade? Why or why not?

4. If you were stranded in a hot desert, would you rather be wearing a dark-colored or a light-colored T-shirt? Why?

Strategy Check
- Did you observe the influence of solar radiation on water temperature?
- Did you determine how color influences the absorption of solar radiation?
Thermal Energy

Directions: Use this page to label your Foldable at the beginning of the chapter.

Temperature

Thermal Energy

Heat

Thermometers measure temperature.

Heat is thermal energy that is transferred from one object to another when the objects are at different temperatures.

Thermal energy is the sum of all kinetic and potential energy of a group of molecules.
Meeting Individual Needs
Overview
Thermal Energy

Directions: Complete the concept map using the terms in the list below.

- gases
- electromagnetic
- heat
- conduction
- thermal energy
- convection
- radiation
- liquids
- contact

1. Is the transfer of

2. By means of

3. Through

4. Waves

5. Through the movement of

6. ________________ or

7. ________________

8. Through direct

9. ________________

Directions: Correctly complete each sentence by underlining the best of the two choices in parentheses.

10. As the temperature of an object increases, the average kinetic energy of its molecules (increases/decreases).

11. An internal combustion engine converts (electromagnetic radiation/thermal energy) into mechanical energy.

12. A coolant (absorbs/increases) thermal energy inside a refrigerator.
Section 1 • Temperature and Thermal Energy

Section 2 • Heat

Directions: Solve the puzzle by writing the term that matches each description. The letters in the vertical box should spell the word that answers question 10.

1. type of energy that is greater in a swimming pool with a temperature of 24°C than in a puddle with a temperature of 24°C
   
2. thermal energy transferred from one object to another of different temperature
   
3. type of heat transfer that occurs when hot water rises to the top of a pan and cooler water sinks to the bottom
   
4. type of heat transfer that occurs between the Sun and Venus
   
5. measure of the average value of the kinetic energy of the molecules in a substance
   
6. materials like aluminum pans and metal spoons, that easily transfer heat
   
7. measure of how well a substance absorbs heat
   
8. type of energy that depends on how fast the molecules in a substance are moving
   
9. temperature scale in which a reading of 0° equals the freezing point of water
   
10. What does a doctor use to measure the average kinetic energy of the molecules in your body? ________________
Directions: Correctly complete each sentence by underlining the best of the two choices in parentheses.

1. A truck uses an (external/internal) combustion engine.

2. Some internal combustion engines convert thermal energy to mechanical energy in a process called the (heat pump/four-stroke cycle).

3. (A heat pump/An air conditioner) can be used for both heating and cooling a building.

4. An (air conditioner/refrigerator) would add heat to the air in a kitchen.

5. In an internal combustion engine, (the surrounding air/burning fuel) is used as a source of thermal energy.

6. A heat engine converts (thermal energy/electrical energy) into mechanical energy.

7. Burned gases are pushed out of the cylinder during the (power/exhaust) stroke of an internal combustion engine.

Directions: The steps below tell how a refrigerator works. Read the steps, and then put them in order from 1 to 4. The first step has been labeled for you.

8. _____ a. Coils outside the refrigerator allow the coolant to release thermal energy into the air.

     _____ b. Cold coolant absorbs thermal energy from inside the refrigerator.

     _____ c. Coolant is forced up a pipe toward the freezer unit.

     _____ d. Warm coolant passes through compressor.
Key Terms
Thermal Energy

Directions: Use the words in the list to fill in the blanks below.

thermal pollution heat temperature thermal energy conduction

1. _______________ is a measure of the average kinetic energy of a group of molecules.
2. _______________ is the direct transfer of heat between objects that are touching one another.
3. Thermal energy that is transferred between objects with different temperatures is called _______________.
4. The total kinetic and potential energy of a group of molecules is its _______________.
5. Rainwater that is heated after falling on warm roads or parking lots can cause _______________ in a lake.

Directions: Unscramble the terms in italics to complete the sentences below. Write the terms on the lines provided.

6. An _______________ is a substance, such as metal, that transfers heat easily.
7. A(n) _______________ is a device used to change thermal energy into mechanical energy.
8. _______________ is the transfer of heat by means of electromagnetic waves.
9. The transfer of heat through the movement of molecules within a liquid or gas is called _______________.
10. The amount of heat needed to increase the temperature of one kilogram of substance by 1°C is called _______________.
11. Burning fuel is the source of thermal energy in a(n) _______________ engine.
**Instrucciones: Completa el mapa de conceptos usando los términos siguientes.**

- gases
- electromagnéticas
- calor
- conducción
- energía térmica
- convección
- radiación
- líquidos
- contacto

1. ________

2.  ________

3.  ________

4.  ________

5.  ________

6.  ________

7.  ________

8.  ________

9.  ________

10. Cuando aumenta la temperatura de un objeto, la energía cinética promedio de sus moléculas (aumenta/disminuye).

11. Un motor de combustión interna convierte(radiación electromagnética/energía térmica) a energía mecánica.

12. Un refrigerante (se evapora/se condensa) cuando absorbe la energía térmica del interior del refrigerador.
Instrucciones: Resuelve el crucigrama escribiendo los términos correspondientes a cada descripción. Las letras de la caja vertical contestarán la pregunta 10.

1. tipo de energía que depende de la velocidad a la que se mueven las moléculas de una sustancia
2. transferencia de calor que ocurre cuando el agua caliente se eleva a la superficie de la olla y el agua más fría se va al fondo
3. energía térmica transferida de un objeto a otro que está a diferente temperatura
4. tipo de energía que es más alta en una piscina a una temperatura de 24°C que en un charco a los mismos 24°C
5. transferencia de calor que ocurre entre el Sol y Venus
6. medida del valor promedio de la energía cinética de las moléculas en una sustancia
7. escala de temperatura en la cual 0° es el punto de congelación del agua
8. materiales como ollas y cucharas de aluminio que transmiten el calor fácilmente
9. medida de la capacidad de absorción del calor de una sustancia
10. ¿Qué usa un médico para medir la energía cinética promedio de las moléculas de tu cuerpo?

Sección 1 • Temperatura y energía térmica
Sección 2 • Calor

Energía térmica
Instrucciones: Completa correctamente cada oración subrayando la mejor de las dos opciones entre paréntesis.

1. Un camión usa un motor de combustión (externa/interna).

2. Un motor de combustión interna convierte energía térmica a energía mecánica en un proceso llamado (bomba de calor/ciclo de cuatro tiempos).

3. Un(a) (bomba de calor/acondicionador de aire) se usa para calentar y para enfriar un edificio.

4. Un (acondicionador de aire/refrigerador) agrega calor al aire de la cocina.

5. En un motor de combustión interna, (el aire circundante/la quema de combustible) se usa como fuente de energía térmica.

6. Un motor de calor convierte (energía térmica/energía electrica) en energía mecánica.

7. Los gases quemados son empujados fuera del cilindro durante el recorrido de (potencia/escape) de un motor de combustión interna.

Instrucciones: Los pasos siguientes te dicen cómo funciona un refrigerador. Lee los pasos y luego ponlos en orden de 1 a 4. El primer paso ya está numerado.

____ 8. a. El espiral afuera del refrigerador libera energía térmica en el aire.

____  b. El refrigerante frío absorbe la energía térmica adentro del refrigerador.

____ 1 c. El refrigerante pasa por un tubo hacia el congelador.

____  d. El refrigerante calentado pasa por un compresor.
**Instrucciones:** Usa las siguientes palabras para llenar los espacios en blanco.

---

1. El(La) _________________ es una medida del promedio de la energía cinética de un grupo de moléculas.

2. El(La) _________________ es la transferencia directa de calor entre objetos que están en contacto.

3. La energía térmica que se transfiere entre objetos con temperaturas diferentes se llama _________________.

4. La energía potencial y cinética total de un grupo de moléculas es su _________________.

5. Cuando el agua de lluvia se calienta después de caer en las calles y zonas de estacionamiento puede causar el(la) _________________ en un lago.

---

**Instrucciones:** Ordena las letras de los términos en bastardilla para completar las siguientes oraciones. Escribe los términos en los espacios asignados.

6. Un(a) __________ es una sustancia, como un metal, que transfiere el calor fácilmente.

7. Un(a) __________ es un dispositivo que se usa para cambiar energía térmica a energía mecánica.

8. El(La) __________ es la transferencia de calor por medio de ondas electromagnéticas.

9. La transferencia de calor que se debe al movimiento de las moléculas dentro de un líquido o un gas se llama __________.

10. La cantidad de calor que se necesita para aumentar en 1°C la temperatura de un kilogramo de una sustancia se llama __________.

11. La quema de combustible es la fuente de energía térmica de un motor de __________.
1. If you put your hand into container A and then into container B, which would you say is warm? Which is cool?

2. Now put your hand into C, then B. Now which is warm? Which is cool?

3. What is the problem in your description of B? What would be a more accurate way of describing B?

Directions: Correctly complete each sentence by underlining the best of the three choices in parentheses.

4. Molecules of a substance are in motion (only as a gas, only above the freezing point, all of the time).

5. Temperature is relative to the (kinetic, potential, electrical) energy of the molecules.

6. On the (Kelvin, Celsius, Fahrenheit) temperature scale, freezing is 0° (C, F, K).

7. On the (Kelvin, Celsius, Fahrenheit) temperature scale, water boils at 212° (C, F, K).

8. One liter of water at 50°C has (more, less, the same) kinetic energy as 2 liters of water at 50°C.

9. Thermal energy is a measure of the (kinetic, potential, potential and kinetic) energy of a substance.

10. 100 mL of water at 20°C has (more, less, the same) thermal energy than 500 mL of water at 20°C.

Directions: Answer the following question on the lines provided.

11. The temperature of a warm spring day might be 75°F. What is that in °C and in K?
Directions: Answer the following questions on the lines provided.
1. How is heat related to thermal energy? Can an object contain heat?

2. Explain how convection could be used to heat a room with a hot radiator on one side of the room.

Directions: Fill in the blanks with the terms that best complete the statements.
3. Heat always moves from a(n) ____________________ object to a(n) ____________________ object.
4. When two objects are in contact, heat is best transferred by _________________.
5. Heat is transferred by conduction when ________________ moving molecules bump into ________________ moving molecules and transfer ____________________ energy.
6. The heat from an electric space heater is transferred to you by _________________.
7. Radiation transfers thermal energy by _________________.
8. Heat is transferred in gases or liquids primarily by _________________.

Directions: Correctly complete each sentence by underlining the best of the three choices in parentheses.
9. A small pan of water at 50°C is brought into contact with a larger pan of water at 50°C. Heat is transferred (from the large pan to the small pan, from the small pan to the large pan, not at all).
10. Convection involves (molecules moving, molecules colliding, electromagnetic waves).
11. Metals are good (reservoirs, insulators, conductors) because they transfer heat easily.
12. Cooking tools often have plastic handles because plastic is a good (conductor, insulator, reservoir) of heat.
13. A measure of how well a substance absorbs heat is its (equivalent heat, calorie content, specific heat).
14. Heat transfer by (convection, radiation, conduction) occurs when energy is transferred by electromagnetic waves.
Engines and Refrigerators

**Directions:** Answer the following questions on the lines provided.

1. What is a heat engine?

2. In a car with a four-cycle engine, why is it an advantage to have at least four cylinders?

3. In nature heat only moves from a hotter object to a cooler object. How is it possible for a heat pump to remove thermal energy from a cold object and add it to a hotter object?

**Directions:** Identify each statement as true or false. If it is false, change the italicized term to make the statement true.

4. In an air conditioner thermal energy from inside the house is absorbed by coolant within pipes.

5. If you let the air out of a bicycle tire, the valve becomes cold. This is because when a gas under pressure expands, it releases energy to the environment.

6. When a heat pump is used for heating, it removes thermal energy from the cold air outside and adds thermal energy to the warm air inside.

7. A diesel engine does not use spark plugs.

8. An engine that uses the process of burning fuel within the engine is called a(n) internal combustion engine.

9. A heat engine is any device that converts thermal energy into kinetic energy.

10. In internal combustion engines, fuel burns in a combustion chamber inside the engine.
Earth’s Liquid Solid State

Have you ever heard the expression “standing on solid ground”? This is true when you view the hard rock surface of Earth, but not when you go deeper into Earth. The layer just underneath the crust, the outer solid layer, is called the mantle. The mantle is composed of all the elements you find in the crust.

Really Hot!
The temperatures in the mantle are estimated at thousands of degrees Celsius. The thermal energy that makes this layer so hot comes from the breakdown of radioactive atoms in the very center of Earth.

Every now and again, this hot liquid erupts through Earth’s crust. It can come out through a volcano on land or through a fissure underneath the oceans. Whatever way it comes to the surface, it immediately loses its thermal energy to the surroundings. This rapid cooling converts the liquid rock to a solid.

Magma to Lava
While hot and in a liquid state, the melted rock is called magma. It contains silica, iron, hydrogen, sulfur, and a host of other elements.

When the magma reaches the surface, it is called lava. The lava often contains the same elements as the magma, although some of the elements may have escaped as gases or vapors. A common gas is water vapor, but a harmful one is hydrogen sulfide. When hydrogen sulfide gas escapes from the magma, it is dangerous and even fatal to breathe.

Cooling Magma
The condition of escaping magma is different, depending on how much of certain elements it contains. The amount of silica, a component of certain rocks, in the magma makes it more or less explosive. In a highly explosive eruption the hot components of the magma cool and fall to Earth in their solid form as dust or ash. Highly explosive eruptions produce rocks like pumice.

In less explosive eruptions the hot liquid might flow for awhile as lava down the slopes of a volcano. In the end, the lava solidifies to form a number of different rocks. These rocks are generally called basalt.

1. What is the hot liquid inside Earth called?

2. Where does the thermal energy to melt Earth’s inner rock come from?

3. Inner Earth can also produce some matter in the gaseous state. Name two of Earth’s gases.

4. What controls the viscosity of lava?
Baking and cooking food has never been so easy. Convection ovens have reduced the amount of time it takes to bake anything. In a convection oven heat is transferred more quickly from the hot oven to the cooler food.

**Uneven Heating**

In older model ovens the heat source is at the bottom or top of the oven. As a result, whether gas or electric, the temperature of the air inside the oven can be uneven. The top or sides can be hotter than the center of the oven. What this means is that the sides of the food will get hotter faster than the center. In some poorly designed ovens, food can even burn on the outside and be cool on the inside.

**Circulating the Heat**

In a convection oven there are small fans that circulate air. As the fans blow the air molecules to the top of the oven, they circulate around the inside of the oven in the same way boiling water moves in a pot.

**How it Works**

The continual movement of air molecules over the food enables heat to be absorbed more rapidly by the cooler food. The result is that large items, such as a turkey or a roast, heat more quickly and evenly than in non-convection ovens.

**Quick and Even**

Another bonus is that the heat is more evenly distributed. When baking many sheets of cookies, older style ovens were restricted to one or two sheets of cookies. The cookies on the outer edge would cook before the ones in the center because of the uneven heat distribution. In many convection ovens it is now possible to bake four or five sheets of cookies and have them all cook evenly and quickly.

Convection ovens are a great example of the study of thermal energy resulting in human benefit. The circular movement of the heated air molecules thoroughly reaches all areas of food and helps reduce the energy needed for cooking.

1. Where is the source of heat in a conventional oven?

2. Describe one problem with older type ovens.

3. How do convection ovens move hot gas molecules around the oven?

4. Why are convection ovens more efficient at cooking food?
Solar-Powered Cars

The engines in cars, trucks, buses, trains, and airplanes burn fuels that come from petroleum or crude oil. When these fuels are burned, gases such as carbon monoxide and sulfur dioxide are produced that pollute the air. Carbon dioxide is also produced which might cause Earth’s climate to warm. Many groups are developing other ways to power cars and other vehicles without burning fuels. One way is to use electricity. The energy to run an electric motor comes from batteries.

Problems with Electric Cars

Electric cars do have some problems. Most electric cars can travel only about 80 km before the batteries need to be recharged, and usually it takes several hours to charge the batteries. One solution to the battery-charging problem is to use solar energy to produce electricity that can power the electric car’s motor.

Solar Cells

In these experimental cars, solar cells are used to convert the energy in sunlight to electrical energy. When sunlight strikes a solar cell an electric current is produced. Many solar cells can be wired together to form a solar panel. The electric current generated by solar panels can be used to operate an electric motor, and to charge batteries.

Driving at Night?

The solar panel provides the energy to power the car. However, there are still some problems with making a practical, solar-powered car. One problem is what to do when no Sun is available. Another problem is the power required to run an average vehicle. How can this much power be supplied using only solar energy? Research teams from automobile companies and universities are working on these problems. Solar-powered-vehicle races are held every year. Many college students form design teams to build vehicles powered completely by the Sun.

It is hoped that these new cars will eventually replace the older gas-burning vehicles. Solar power produces no toxic emissions. This would help in reducing air pollution and avoiding the ever-increasing cost of gasoline.

1. Why are gasoline-powered cars becoming a problem?

2. What generates the electrical current in a solar car?

3. What problems prevent solar-powered cars from becoming popular?
Section 1  Temperature and Thermal Energy

A. ________________—measure of the average value of the kinetic energy of the molecules in a substance; the higher the temperature, the faster the molecules are moving

1. Objects tend to _______________ with increased temperature because their molecules speed up and move farther apart; objects tend to contract when they are cooled.
   a. The amount of expansion or contraction depends on the ________________ and the amount of change in ________________.
   b. Liquids usually expand _______________ than solids.
2. Temperature is commonly measured using a ________________.
3. Thermometers need numbers on a ________________ to give a temperature reading.
   a. The ________________ scale gives water a freezing temperature of 32°F and a boiling temperature of 212°F.
   b. The ________________ scale gives water a freezing temperature of 0°C and a boiling temperature of 100°C.
   c. The formula to convert temperature from °F to °C is °C = ________________. 
   d. The ________________ scale gives the temperature 0 K to the lowest temperature an object can have, a temperature known as absolute zero; °C = K – 273.

B. An object’s ________________ is the sum of the kinetic and potential energy of all the molecules in the object.

1. Potential energy is energy that can be ________________ into kinetic energy. Potential energy ________________ as molecules move closer together or farther apart.
2. Temperature and thermal energy are different concepts; ________________ is related to the quantity of molecules.

Section 2  Heat

A. ________________—thermal energy that is transferred from one object to another when the objects are at different temperatures

1. Thermal energy always moves from ________________ to ________________ objects.
Note-taking Worksheet (continued)

2. The transfer of heat by direct contact between the particles of substances is called ___________________; conduction occurs most easily in solids, where molecules are close together.

3. Heat transfer by __________________ occurs when electromagnetic waves carry energy through space or matter.

4. __________________ describes the transfer of thermal energy by the movement of molecules from one part (warmer) of a material to another (cooler) part.
   a. Convection occurs __________________ as a hot gas or liquid moves from one place to another; wind is caused by convection in air; rising warmer air forms a convection cycle with falling cooler air.
   b. Convection can be _______________ as when a fan blows cooler air over warmer air produced by a machine.

B. ________________ are materials that transfer heat readily; metals such as copper and gold are the best heat conductors.

C. An __________________ is a material that does not transfer heat easily; liquids and gases are usually better insulators than solids.

D. Objects absorb heat at different ______________ depending on what materials they are made of.
   1. __________________—amount of heat needed to raise the temperature of 1 kg of a substance by 1° C
   2. More heat is needed to change the temperature of a material with a ____________ specific heat (such as water) than one with a ____________ specific heat (such as sand).

E. __________________, caused by adding warmer water to a body of water.
   1. Thermal pollution can kill fish and other aquatic organisms due to a reduction in _____________ in warmer water.
   2. Thermal pollution can be reduced by ______________ water from factories, power plants, and runoff before it is released into a body of water.
Section 3 Engines and Refrigerators

A. ____________—device that converts thermal energy into mechanical energy

1. In an _____________________________, such as a steam engine, the fuel is burned outside the engine to produce thermal energy.

2. In an _____________________________, fuel burns in a combustion chamber inside the engine.

3. Most cars have a four-stroke engine with four or more ____________________________, or cylinders.
   a. Each cylinder contains a _____________ that can move up and down.
   b. A mixture of _____________________ is injected into the cylinder and ignited with a spark, which pushing the piston down.
   c. This up-and-down-motion of pistons turns a rod called a ________________, which turns the wheels of the car.

4. Other types of internal combustion engines include _______________ engines, which use high pressure instead of a spark for ignition, and two-stroke gasoline engines, commonly used in ________________.

B. A _________________ absorbs thermal energy from food and materials inside the refrigerator and transfers it to the surrounding air.

1. A __________________ is changed into a cold gas that absorbs thermal energy from the inside of the refrigerator.

2. A compressor compresses the __________________, making it warmer than room temperature.

3. The coolant gas ________________ heat to the room, then changes back into a coolant liquid, and the cycle is repeated.

4. An __________________ works much like a refrigerator to cool a house.

5. A __________________ can be used for cooling and heating a house by reversing itself based on outside temperature.
Assessment
Thermal Energy

Part A. Vocabulary Review

Directions: Use the clues below to complete the crossword puzzle.

<table>
<thead>
<tr>
<th>Across</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transfer of heat by hot liquids and gases</td>
</tr>
<tr>
<td>4. Amount of energy needed to raise 1 kg of a substance 1°C</td>
</tr>
<tr>
<td>6. Sum of the kinetic and potential energy of the molecules of an object</td>
</tr>
<tr>
<td>8. A material that does not transfer thermal energy easily</td>
</tr>
<tr>
<td>9. Thermal energy transferred between objects which have different temperature</td>
</tr>
<tr>
<td>10. Combustion inside the engine</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Down</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transfer of heat molecules by bumping into each other</td>
</tr>
<tr>
<td>2. Increasing the temperature of a body of water by adding warmer water.</td>
</tr>
<tr>
<td>3. Average kinetic energy of the molecules of a substance</td>
</tr>
<tr>
<td>5. A device that changes thermal energy into mechanical energy</td>
</tr>
<tr>
<td>7. Transfer of energy by electromagnetic waves</td>
</tr>
</tbody>
</table>
Chapter Review (continued)

Part B. Concept Review

Directions: Answer the following questions on the lines provided.

1. How does a two stroke engine combine the four strokes of a typical internal combustion engine?

2. Is it possible to add thermal energy to a substance and not raise its temperature?

Directions: Circle the term that best completes the statement.

3. The lowest possible temperature is (0 K, 0°C, –273°F).

4. For a coolant in the radiator of a car, you would choose a substance with a (low specific heat, high heat of vaporization, high specific heat).

5. When air in the cylinder of a diesel engine is compressed, it (cools, warms, doesn’t change).

6. Mercury thermometers work because mercury (expands, contracts, condenses) when it is warmed.

7. Inside the house, the refrigerant in an air conditioner (condenses, conducts, evaporates).

8. Down in a down jacket is a good insulator because (it is a solid, it is light weight, it contains many air spaces).

9. When you put your hand five or six centimeters above a candle flame, it becomes very hot. Heat has reached your hand by (conduction, radiation, convection).

10. If you add 100 mL of water at 20°C to 200 mL of water at 20°C, the average kinetic energy of the mixture (increases, decreases, remains the same).

11. When 100 mL of water at 20°C is added to 200 mL of water at 20°C, the thermal energy (increases, decreases, remains the same) for the combined mixture.

12. Temperature is a measure of the average value of the (kinetic, potential, mechanical) energy of the molecules in a substance.

13. The sum of the kinetic and potential energy of all molecules in an object is the (mechanical, thermal, molecular) energy of the object.
Transparency Activities
SECTION 1

Section Focus

Transparency Activity

Coping with Winter

Japanese macaques are one of the few species of primates that can live outside of the tropics. These macaques live on Honshu Island in Japan.

1. What do you think the air temperature is like in this photo? What is the water temperature like?
2. What do you think might explain the water’s temperature?
3. If you were told that the temperature of the water was 40 degrees, would that be meaningful? Why or why not?
Hot Times

The image below was made with a heat sensitive camera on a cool day. The colors show thermal energy escaping from this building. The color green indicates the coolest areas of the building while the color white shows the warmest. Purple, red, and yellow respresent the stages from green to white.

1. From which parts of the house is the most thermal energy escaping?
2. In what ways might the information from the photo be useful?
3. How do you feel if you sit in the shade on a sunny day? How do you feel in the Sun?
This racecar looks very different from the ones we are used to seeing. It not only looks different, it sounds different, and it uses a different type of power. This is a solar-powered racecar that was built by college students for competitions like the World Solar Challenge in Australia, as shown below.

1. What kind of engine usually powers cars? What type of fuel do these engines use?
2. In what ways do you think a solar-powered car and a car you see on the street are different? In what ways are they similar?
3. What advantages does solar power offer? Disadvantages?
Thermal Energy

Transparency Activities

How a Refrigerator Works

The compressor compresses the coolant which increases its temperature. The coolant now is warmer than room temperature air. Heat is transferred from the coolant into the room.

The cold gas passes through pipes inside the refrigerator. The cold gas absorbs heat from inside the refrigerator.

Liquid coolant passes through an expansion valve where it changes from a liquid into a cold gas.

The coolant changes from a gas into a liquid as it releases heat into the room. The coolant is pumped through the expansion valve and the cycle begins again.

Compressor

Condenser coils

Coolant liquid

Expansion valve

Freezer unit

Coolant vapor

Heat into room

The compressor compresses the coolant which increases its temperature. The coolant now is warmer than room temperature air. Heat is transferred from the coolant into the room.

The cold gas passes through pipes inside the refrigerator. The cold gas absorbs heat from inside the refrigerator.

Liquid coolant passes through an expansion valve where it changes from a liquid into a cold gas.

The coolant changes from a gas into a liquid as it releases heat into the room. The coolant is pumped through the expansion valve and the cycle begins again.
Teaching Transparency Activity (continued)

1. What is the purpose of an expansion valve in the refrigeration cycle?

2. What does the compressor do in the refrigeration cycle?

3. How is heat absorbed from the food inside the refrigerator?

4. Infer what property the coolant must have to be used in the refrigeration cycle.
Thermal Energy

Assessment Transparency Activity

Directions: Carefully review the table and answer the following questions.

<table>
<thead>
<tr>
<th>Types of Heat Transfer</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Example</td>
<td>Transfer method</td>
</tr>
<tr>
<td>Conduction</td>
<td>stove heating a pan</td>
<td>particle collision</td>
</tr>
<tr>
<td>Forced convection</td>
<td>furnace fan</td>
<td>particle movement from area to area</td>
</tr>
<tr>
<td>Natural convection</td>
<td>boiling water</td>
<td>particle movement from area to area</td>
</tr>
<tr>
<td>Radiation</td>
<td>Sun</td>
<td>electromagnetic waves</td>
</tr>
</tbody>
</table>

1. According to the table all of these types of heat transfer involve particles in motion EXCEPT ___.
   A conduction        C natural convection
   B forced convection D radiation

2. Rowena is studying outside on a sunny day. She notices she feels warmer. The Sun is most likely transferring heat to Rowena by ___.
   F forced convection H natural convection
   G radiation         J conduction

3. According to the table, heating a pot of water on a stove until it boils would demonstrate ___.
   A conduction and forced convection
   B radiation and conduction
   C natural convection and conduction
   D natural convection and forced convection