FOCUS ON SCIENCE

Physical Science

Matter and Energy

Advanced Level

Heat Is Energy

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Heat Is Energy

What are some ways that energy can be changed from one form to another?

CORE CURRICULUM STATEMENTS

Energy exists in many forms, and when these forms change energy is conserved.

Energy exists in various forms: heat, electric, sound, chemical, mechanical, light.

Energy can be transferred from one place to another.

Some materials transfer energy better than others (heat and electricity).

Energy and matter interact: water is evaporated by the Sun's heat; a bulb is lighted by means of electrical current; a musical instrument is played to produce sound; dark colors may absorb light, light colors may reflect light.

Heat can be released in many ways, for example, by burning, rubbing (friction), or combining one substance with another.

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AL

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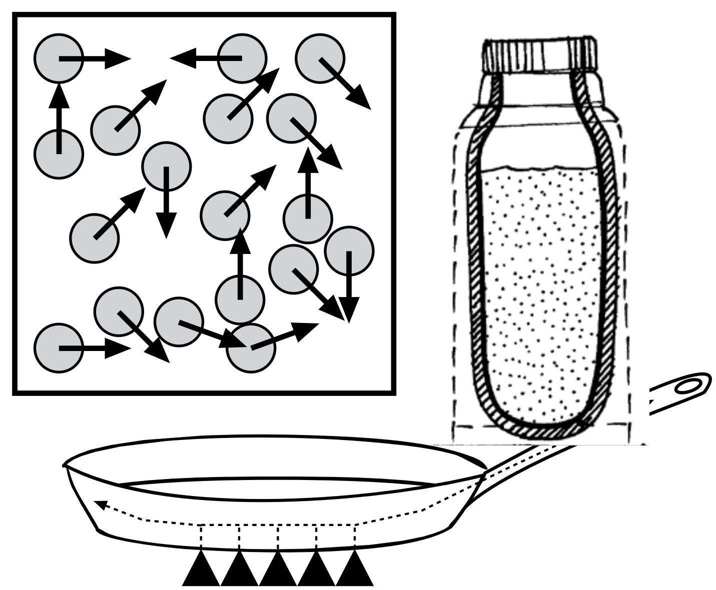
FOCUS ON SCIENCE

Physical Science

Matter and Energy

Heat Is Energy

by Caitlin Scott



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Curriculum materials for **your** content standards

Table of Contents

–Predict–
What do you think you will learn from this book?

INTRODUCTION

Heat Is Essential for Life

Do you remember a time you were outside on a cold day? You probably didn't start to get cold right away. Instead, you gradually felt colder and colder. That's because your body **generates** its own heat, but if the air is colder than your body, your body's heat is slowly lost.

You may not know much about body heat, but you probably know that in the winter you should dress in warm clothes, like a quilted or down coat, a wool or fleece hat, and mittens or gloves. Warm clothes are important because they **insulate** your body. In other words, they keep your heat from moving away from your body and out into the cold air.

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generate: to make
insulate: to keep heat from moving

What would happen if you were outside in winter and got lost or got locked out of your house? Slowly, the sun would set on the horizon. Without the sun's energy, the air around you would become colder. Your natural body heat would be lost into the air more quickly, even through the insulation of your coat, hat, and mittens. You would start to get uncomfortable, and you might be in danger of getting frostbite or actually freezing.

What could you do to warm yourself up? First, you might try jumping up and down or running around to generate more heat, but eventually this would not be enough. You would need to find another source of heat or you might die. As you can see, heat energy is essential to human life.

CHAPTER 1

Heat Versus Temperature

Heat and *temperature* are terms whose meaning people frequently confuse. Temperature is a measurement of the average amount of heat in something. Temperature is measured using a thermometer. Heat is a from of energy caused by the movement of tiny particles in matter. Think about ice, water, and steam as an example.

Ice, water, and steam are all made of the same thing—H_2O particles. In ice, these particles are arranged in a set pattern and move relatively slowly. This motion does not generate much heat, therefore, ice is extremely cold.

When water is in liquid form, the particles move around more. They move more quickly and generate more heat.

When water is a gas such as steam, the particles are very spread out. Thus, they move very rapidly and generate lots of heat.

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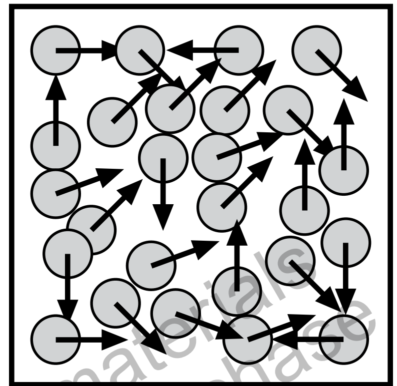
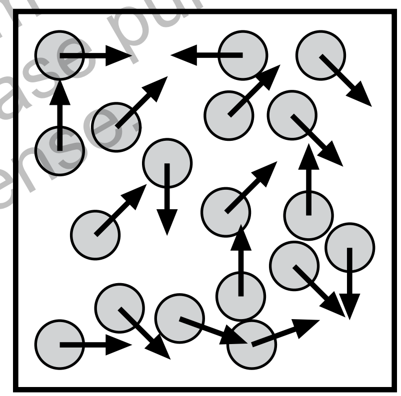


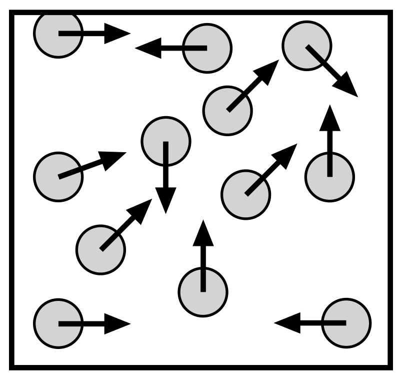
Ice

In ice, the particles are arranged in a pattern in which they don't move much, so they don't generate much heat energy.



Water

In water, particles move a bit faster and generate a bit more heat energy.



Steam

In steam, particles are furthest apart, so they move most rapidly and generate the most heat energy.

What Is Heat Energy?

You know heat is a form of energy caused by the movement of particles. Temperature measures the average amount of heat or heat energy in a substance. Heat energy describes total energy. To help you understand the difference between temperature and heat energy, think about this example.

Two teakettles are on a stove. One teakettle is so small it holds just one cup of water. The other teakettle is large and holds four cups of water. Which teakettle will need more energy to boil?

The big teakettle will need more energy to boil than a small teakettle. In fact, it will take about four times more energy, because for every one particle of water in the little teakettle there are four particles in the big teakettle.

Both teakettles will boil at the same temperature (212 degrees Fahrenheit or 100 degrees Celsius). However, once they are both boiling, the big teakettle will contain about four times more heat energy.

– Explain –
What is the difference between heat and temperature?

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Now consider this example—a cup of hot tea compared to a **glacier** that's four miles long and a mile wide. Which has the higher temperature, the tea or the glacier? That's easy to figure out. The cup of tea is close to boiling, while the glacier is frozen; therefore, the tea has a higher temperature.

Now here's the tricky question. Which has more heat energy, the tea or the glacier? Consider the number of particles in the cup of tea, compared to the number in the enormous glacier. Remember that the motion of the particles in both the tea and the glacier generate heat.

The particles in the glacier move much more slowly, but there are a lot more particles in the glacier. So, the glacier actually has more heat energy.

– Apply –
Think of other examples of temperature and heat. What are some of the coldest and hottest things on Earth? How does the temperature of each of these things compare to the heat energy?

glacier: a large mass of thick, frozen ice

CHAPTER 2

Heat Transfer

Heat moves, or transfers, from a warmer object to one that is cooler. For example, if you are outside on a cold day, your body heat is transferred to the colder air. There are three main types of heat transfer— conduction, convection, and radiation.

Conduction

Conduction is the transfer of heat through solid objects. Think about this example: a metal frying pan with a metal handle. If you are grilling a cheese sandwich for lunch, what happens to the metal handle? The handle should get hot after a while, because the heat from the stove transfers to the bottom of the frying pan and then it moves up the sides of the pan and into the handle. Heat energy moves through the pan due to conduction.

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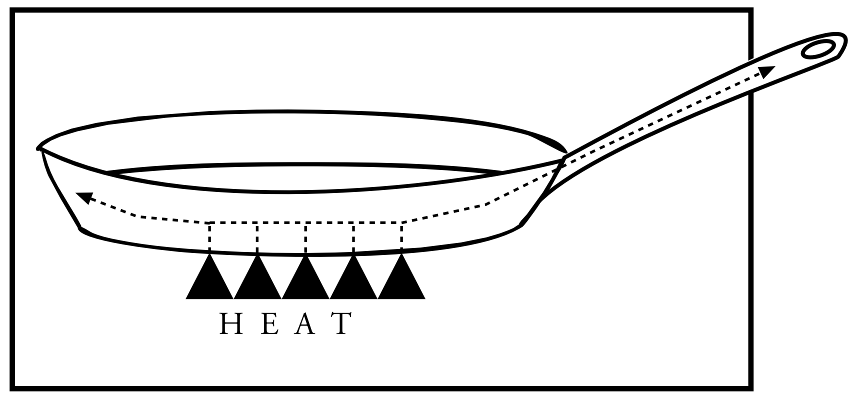
Why does heat transfer work this way? Think about the particles in the metal frying pan. As the bottom of the pan heats up, the particles in the bottom of the pan move faster. The pan doesn't melt like ice, but the particles do start to speed up and bump into the particles in the sides of the pan. These particles in the side of the pan start to move faster, too, bumping into the particles in the handle. Finally this bumping moves all the way into the handle.

What would happen if you put a metal lid on the pan? It would eventually heat up, too.



– Explain –
How does conduction cause heat to transfer from a stove to the handle of a frying pan?

Convection

Convection is like conduction because it is a type of heat transfer. But, convection moves heat through liquids and gases, while conduction moves heat through solids. During convection, heat typically moves from hotter areas of liquids and gases to colder areas.

Think about what happens when you pour cream into a cup of coffee. The coffee is very hot, but the cream is cool. Because both are liquids, composed mostly of water, the cream and coffee quickly mix together. During convection, the particles of the cooler cream sink and the particles of the hotter coffee rise. This mixing allows for a rapid transfer of heat energy from the hot particles to the cooler ones. Soon, the temperature will be the same throughout the mixture. Will it be warmer or cooler than the original temperature of the coffee?

Forced-air heating in a house is another example of convection in everyday life. This type of heating blows warm air into a house through vents in the floor. The warm and cool air mix together, just like the coffee and cream.

In forced-air heating, warm air comes through the floor, but does that mean only the floor gets warm? Of course it doesn't. Convection causes heat to transfer into the entire room, making sure the entire house is nice and warm.

Here's an interesting question. Why are heat vents always on the floor and never on the ceiling? Heat vents are on the floor of a house because warmer air tends to rise to the ceiling. This is called a convection current. The warmer air mixes with cooler air causing all the air to become warmer.

Convection currents are also found outside. In fact, they are responsible for the water cycle and for the movement of wind and weather.

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Radiation

Radiation is another form of heat transfer. During radiation, heat transfers through a vacuum, rather than a solid, liquid, or gas. A vacuum is an empty space containing nothing—no solids, liquids, or gases. Outer space is an example of a vacuum.

What's the one most important heat energy source that radiates to our planet through the vacuum of space? You're right—the sun. The light from the sun travels 93 million miles through the vacuum of outer space to reach Earth. Life on Earth would be impossible without the heat generated from the sunlight. It would also be impossible without radiation to transfer the sun's heat to Earth.

There are other examples of radiation right here on Earth, too.

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– Compare –
Explain the difference between conduction, convection, and radiation.

Radiation works with or without a vacuum. For example, a microwave uses radiant microwaves to heat food, even though there is air inside the microwave.

Think about the example of a microwave oven. When you open the microwave after cooking something, are the sides of the microwave hot? No, they aren't. The inside of the oven is cool.

This is different from what happens in a regular oven. Because a regular oven is made of metal, the metal sides of the oven heat up when the oven turns on. This is because of conduction, which transfers heat through solids like metal.

A microwave is very different from a regular oven, because it doesn't use conduction. Instead, it uses radiation. This radiation is mainly absorbed by the water in the food, causing the particles of the food to move faster. The microwaves are converted to heat energy in the food.

– Apply –
Think about all the things you touched today that felt hot. Where did the heat come from? Discuss this with a classmate.

CHAPTER 3

Transfer Materials

Remember that heat is transferred in three main ways—conduction, convection, and radiation. However, some materials allow heat to transfer more quickly. Others slow down heat transfer. Materials that speed up heat transfer are called conductors, while those that slow heat transfer down are called insulators.

Conductors

In general, solids are much better heat conductors than liquids, while liquids are much better conductors than gases. This is true because of how close together the particles are in these substances. In solids, the particles are very close together, so heat moves quickly from one particle to the next. In a liquid, however, the particles are further apart, so heat moves a little more slowly. In a gas, because the particles are even further apart, heat moves even more slowly.

What do we do when we want heat to transfer very quickly from one place to another? We use materials that are good conductors.

As you have just read, solids make especially good conductors. Let's take cooking as an example. When people cook, they want heat to transfer quickly from their stoves to their food. Given this desire, what should pots and pans be made of?

As you know, most often pots and pans are made of metals, because most metals are good conductors. Glass is also a good conductor, so some baking dishes are also commonly made of glass. Diamonds are good conductors of heat too, but diamonds are too expensive to use to make everyday objects like pots and pans.

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Insulators

Sometimes we want things to stay at a constant temperature. When we do, we use insulators. An insulator doesn't conduct heat well. In other words, it slows the movement of heat from one object to another. A wool coat is an example of an insulator that keeps you warm in winter. Wool is a good insulator.

The very best insulator for conduction or convection is a vacuum. Vacuums insulate well, because heat travels when particles bump into one another and make heat move from one particle to another. There are no particles in a vacuum, therefore heat cannot be transferred within a vacuum.

A vacuum thermos is great for keeping cold liquids cold and hot liquids hot for long periods of time. This special kind of thermos has an inner lining and an outer lining. Between these two linings is a vacuum that slows heat transfer by conduction or convection.

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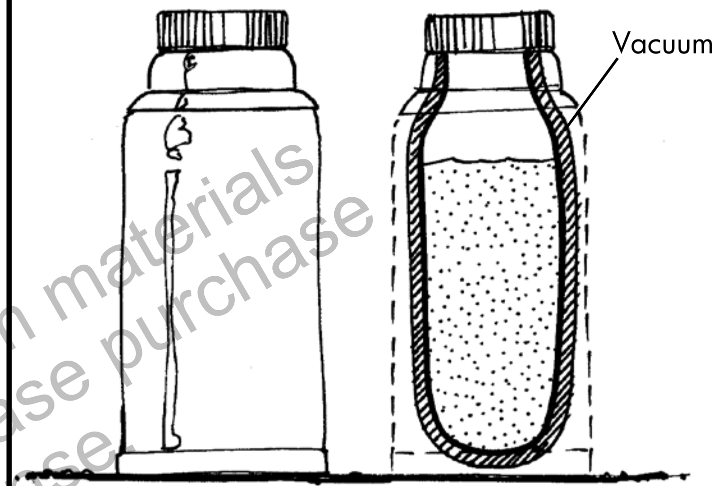
Vacuum Thermos



This vacuum thermos keeps heat from moving between the liquid inside and the air outside the thermos.

Gases are also good insulating materials. This is because the particles in gases are relatively far apart. For example, insulated windows trap gas between two pieces of glass to provide insulation.

Other non-metal materials with air spaces in them are good insulators too. For example, fiberglass is a type of plastic that has tiny air pockets. These air pockets make fiberglass an excellent insulator.

CHAPTER 4

The Mpemba Effect

Scientists from many different countries have done important scientific work to help us understand heat energy. Throughout the centuries, these scientists have been both men and women and both young and old. One important discovery about heat energy was made by Erasto B. Mpemba. Surprisingly, he made his discovery when he was just a 15 year-old high school student in Tanzania, Africa.

Before Mpemba's discovery, people thought that liquids cooled (or lost heat) at a **constant** rate. Therefore, they believed that cool water would freeze more quickly than warm water. It just seemed to make good common sense. But, Mpemba proved everyone wrong.

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constant: not changing; staying the same

Mpemba's discovery came when he was making ice cream in his high school science class. The class experiment was supposed to show how liquids change to solids. But, Mpemba did not follow all the directions. He did not cool his cream and sugar mixture before putting it in the ice cream maker. A funny thing happened. His ice cream was done before the rest of the class.

He tried the experiment with several different hot and cool mixtures. Again, the warm mixtures froze more quickly than the cool mixtures. Mpemba made an important discovery that day. Other scientists did additional experiments that showed Mpemba was right. Sometimes, warm liquids freeze faster than cold liquids.

Scientists are still trying to figure out why this happens. They call Erasto's discovery the Mpemba Effect.

– Hypothesize –
Why do you think warm liquids might freeze faster than cold liquids? Talk about it with a friend.

Glossary

constant—not changing; staying the same

generate—to make

glacier—a large mass of thick, frozen ice

insulate—to keep heat from moving

To Find Out More . . .

Want to learn more about heat?

Try these books

Energy Projects for Young Scientists by Richard Craig Adams and Robert Gardner. Franklin Watts, 2003.

Environmental Experiments About Renewable Energy by Thomas R. Rybolt and Robert C. Mebane. Enslow Publishers, 1994.

Access these Web sites

Energy Kids Page: The Energy Information Administration
http://www.eia.doe.gov/kids/

U.S. Department of Energy for Students and Kids
http://www.energy.gov/forstudentsandkids.htm

Write for More Information

Energy Information Administration
1000 Independence Ave., SW
Washington, DC 20585
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

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Published by FOCUScurriculum

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Order Number: PS-23AL

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Physical Science

Matter and Energy

Advanced Level

Assessments

Heat Is Energy

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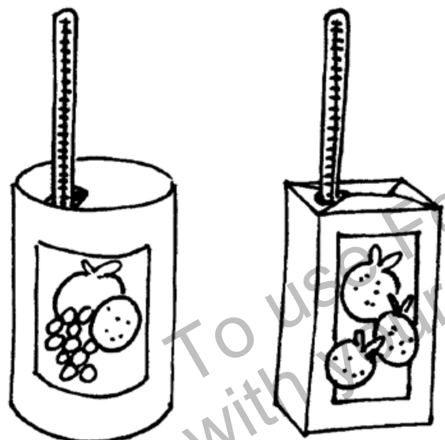
Print pages 20–22 of this PDF for the assessments.

Heat Is Energy

Check Understanding

Shade the circle next to the correct answer.

1. Two juice containers are outside on a table in the hot sun. One container is wax-coated paper box and the other is a metal can. The can feels hotter than the box. Students place a thermometer in each container. They find that the juice in the can and box are the same temperature.



Why does the can feel hotter than the box?

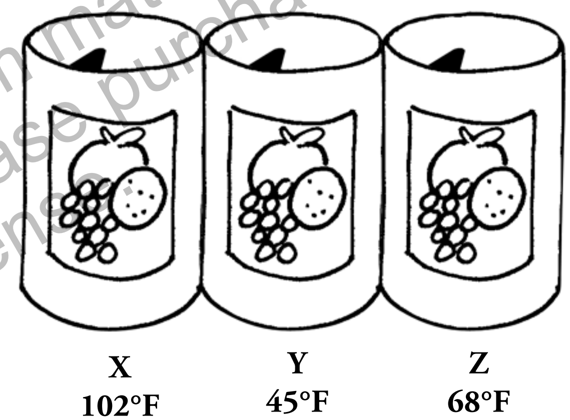
Ⓐ Metal is a better insulator of heat energy.

Ⓑ Metal is a better conductor of heat energy.

Ⓒ Paper is a better conductor of heat energy.

Ⓓ The metal can hold hotter juice than the paper box.

2. Three juice cans are pushed into contact with each other. One can came from the refrigerator, one came from a room in the house. The other was sitting in the hot sun outside. The starting temperatures of each is shown.



Which traces the transfer of heat energy among the cans?

Ⓐ X ➔ Y ← Z

Ⓑ X ← Y ← Z

Ⓒ X ← Y ➔ Z

Ⓓ X ➔ Y ➔ Z

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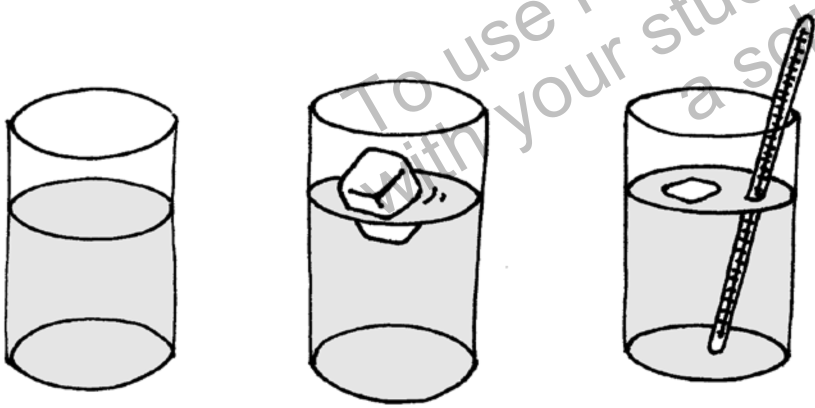
Heat Is Energy

Check Understanding

Write your answer on the lines provided.

3. A student wants to conduct an experiment to see if the temperature of a liquid changes if an ice cube is placed in it. He fills a glass with water as shown. He takes an ice cube from the freezer and puts it into the water. Ten minutes later he measures and records the temperature of the liquid. The temperature of the liquid is 15°C.



Identify **one** problem with the student's experiment.

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Explain why that problem prevented the student from obtaining any useful information.

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Heat Is Energy

Assessment Scoring Guidelines

1. Answer B is correct
2. Answer A is correct. Heat moves to cold.
3. The student did not measure and record the temperature of the water before putting the ice cube in it.

   The student would not be able to compare the before and after data

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Physical Science

Matter and Energy

Advanced Level

English Language Arts Activities

Heat Is Energy

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Print pages 24–28 of this PDF for the reading activities.

Make Inferences

An inference is not stated direct in the text. Instead, it is a logical conclusion you can draw based on facts stated in the text.

Here is a selection from *Heat Is Energy*. The graphic organizer shows one inference you might make, as well as the facts that support this inference.

Two kettles are on a stove. One is small. It holds just one cup of water. The other is large and holds four cups of water. Which will take more energy to boil?

The big kettle will take more energy. In fact, it will take about four times more energy, because for every one particle of matter in the little kettle there are four particles in the big kettle.

Inference

Larger amounts of liquid take more energy to boil.

Facts

- The large kettle holds four cups of water.
- The big kettle will take more energy to boil.
- The large kettle will take about four times more energy. For every one particle of matter in the little kettle there are four particles in the big kettle.

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TRY THE SKILL

Read this passage from *Heat Is Energy*.

Here's the tricky question. Which has more heat energy, a cup of tea or a glacier? Think about the number of particles in the cup of tea, compared to the number in an enormous glacier. The motion of the particles in both the tea and the glacier generate heat.

The particles in the glacier move much more slowly, but there are a lot more particles in the glacier. So, the glacier actually has more heat energy.

Inference

Facts

Question and Answer

TRY THE SKILL

You can monitor your understanding of what you read by asking questions about the topic and then reading to find the answer. Sometimes authors will even write a question in the text and then answer it.

Read the paragraphs from *Heat Is Energy*.

> Which has more heat energy, the tea or the glacier? Consider the number of particles in the tea, compared to the number in the enormous glacier. Remember that the motion of the particles in both the tea and the glacier generates heat.
>
> The particles in the glacier move much more slowly, but there are a lot more particles in the glacier. So, the glacier actually has more heat energy.

What is the question?

Which has more heat energy, the tea or the glacier?

What is the answer?

The glacier actually has more heat energy. The particles in the glacier move much more slowly, but there are a lot more particles in the glacier, so there is more energy.

Read the question from *Heat Is Energy*. Write an answer in your own words.

1. What do we do when we want heat to transfer very quickly from one place to another?

____

____

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____

2. Now think of another question you could ask based on *Heat Is Energy*. Write the question. Then, write an answer in your own words.

Question: ______________________________________

____

Answer: ____

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Cause and Effect

A cause is why something happens. An effect tells what happens. Sometimes the cause is stated first, but sometimes the effect is first. Words such as *because, if, as,* and *when* are often used to state cause and effect.

Read this passage from *Heat Is Energy* and try to identify cause and effect.

> The big teakettle will take more energy to boil than a small kettle. In fact, it will take about four times more energy, because for every one particle of water in the little teakettle there are four particles in the big teakettle.

Which part of the passage describes the effect?

The big teakettle will take more energy to boil than a small kettle. In fact, it will take about four times more energy.

This tells what happens. Which part of the passage describes the cause?

For every one molecule of water in the little teakettle there are four particles in the big teakettle.

This tells why the larger kettle takes more energy to boil.

TRY THE SKILL

Read this passage and write the cause and the effect in the graphic organizers.

> Think about this example—a metal frying pan with a metal handle. If you are grilling a cheese sandwich for lunch, what happens to the metal handle? The handle should get hot after a while, because the heat from the stove transfers to the bottom of the frying pan and then moves up the sides of the pan and into the handle. Heat energy moves through the pan due to conduction.

CAUSE	EFFECT

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Locating Information

Text features in nonfiction books help you to locate information quickly. For example:

- A table of contents tells you where to find information in a book and usually contains chapter headings and subheadings within the chapters.
- An index gives you page references for topics not listed in the table of contents and an index tells what page a word or topic occurs on.
- Chapter headings tell what a chapter is going to be about. Subheadings tell more about the information within a chapter.
- A glossary gives the definition of unusual words.

In *Heat Is Energy*, what page and chapter would give you information about heat versus temperature?

The table of contents says this information is on page 6 in Chapter 1.

Where could you find information about radiation?

The Index lists radiation on pages 14–15.

Where could you find the meaning of the word *molecule*?

In the glossary, because the glossary gives the definition of words in the book.

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TRY THE SKILL

Use the table of contents, glossary, and index from *Heat Is Energy* to answer the questions.

1. What page and chapter would give information about insulators? ____________________

2. What page and chapter would give information about Erasto B. Mpemba? ____________________

3. What page and chapter would give information about convection? ____________________

4. What would be another good title for Chapter 2?

____

5. Where would you look to find out what the word *glacier* means? ____________________

Answer Key

Make Inferences

Inference:

Much larger things contain more heat energy than similar smaller things.

Facts:

- There are fewer particles in the tea than in the glacier.
- The motion of the particles in both the tea and the glacier generates heat.
- The particles in the glacier move much more slowly, but there are a lot more particles in the glacier.
- So, the glacier actually has more heat energy.

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Question and Answer

1. Answers will vary but should include using a good conductor like metals or glass.

2. Answers will vary.

Cause and Effect

Cause: The heat from the stove transfers to the bottom of the frying pan and then moves up the sides of the pan and into the handle.

Effect: The handle should get hot after a while.

Locating Information

1. Page 18, Chapter 3

2. Page 20, Chapter 4

3. Page 12, Chapter 2

4. Answers will vary but could include *Heat Transfer, Heat Movement,* or *Heat Energy Movement.*

5. Glossary