TOPIC 4

Expansion and Contraction

DidYouKnow?

Not everything we observe has the properties of matter. Light does not take up space or have mass; neither does sound. When you turn on a lamp or stereo, and fill a room with light or sound, the room does not become heavier. Light and sound are forms of energy, and like all forms of energy, they do not have mass or volume. With this in mind, make a prediction about whether the mass of an object changes when it warms or cools (that is, when its thermal energy changes).

Pause& Reflect

Write some ideas to answer the questions below. Do not worry about being "correct." You can change your ideas as you work through this Topic.

(a) Are the ice, liquid water, and water vapour in the illustrations made of the same kind of particle, or are they different types of matter?

(b) How does the motion of particles in solids, liquids, and gases differ?

As materials warm up, the particle model of matter says that their particles move faster and spread apart. We expect substances to **expand** (increase in volume) as their temperature rises. Falling temperature means that average particle motion is slowing down. It seems logical to expect substances to **contract** (decrease in volume) as they cool.

You can check those predictions by observing the behaviour of common pure substances. A pure substance is a type of matter that is made of only one kind of particle. On Earth, a pure substance may exist as a solid, liquid, or gas. These are the three states or phases of matter. Gold, oxygen, and water are examples of pure substances. Examine the illustrations to review the key characteristics of each state.

Figure 3.14 The three states of matter

In the solid state, materials keep their shape and size. Solids like ice have a definite shape and volume and cannot be compressed into a smaller space. In the liquid state, materials have a definite size (volume), but no fixed shape. Liquids like water settle to the bottom of their container and take its shape. Liquids cannot be compressed. Gases have no definite shape or volume. They expand to fill all parts of their container and can easily be compressed into a smaller space. Many gases cannot be seen. For example, the space just above a kettle's spout is filled with invisible water vapour (steam). As the water vapour (water in the gaseous state) rises and cools, it forms a cloud of tiny drops of liquid water.

Career CONNECT

Room to Grow

Civil engineers have to think about thermal expansion and contraction when planning roadways, sidewalks, and bridges.

Imagine that a builder or a civil engineer has been invited to speak to your class. Write five questions that you would like to ask this person about engineering as a profession. Make sure that your questions are clearly worded, and that they will help you find out what you want to know.

Expansion and Contraction of Solids

The lengths of solid bars of different materials can be measured at different temperatures using very precise equipment. Table 1 shows some of these measurements. You can see that the changes in a 100 cm long bar are very small. If the bar were twice as long, however, the changes would be twice as large. In a very long structure, such as a bridge or a train track, the small changes can add up and become very important.

Table 1 Expansion and Contraction of Solids

Material	Length at –100˚C (cm)	Length at 0˚C (cm)	Length at 100˚C (cm)
lead	99.71	100.00	100.29
steel	99.89	100.00	100.11
aluminum	99.77	100.00	100.23
brass	99.81	100.00	100.19
copper	99.83	100.00	100.17
glass	99.91	100.00	100.09
Pyrex™	99.97	100.00	100.03

Find Out ACTIVITY

Stretch and Shrink

Are there similarities in how substances expand when heated? Are there similarities in how they behave when cooled? This activity will help you to identify any patterns.

Procedure ✱ Performing and Recording

1. Examine Table 1 above, and use it to answer these questions.
   - **(a)** What similarity do you see in how all the materials react as they warm?
   - **(b)** In what way do the materials react differently as they warm?
   - **(c)** Which material expands the most as it warms?
   - **(d)** Which material expands the least as it warms?
2. Copy the list of materials in Table 1, but arrange them in order, starting with the material that expands the most and ending with the one that expands the least.

What Did You Find Out? ✱ Analyzing and Interpreting

1. What do you notice about your list when you examine how the materials cool and contract? Does the material that expands the most at a high temperature also contract the most at a low temperature?
2. **Apply** A baker places a paper cone into the centre of a fruit pie before putting the pie in the oven. Explain why this would keep juice from running out of the pie during baking.

INQUIRY

INVESTIGATION 3-D

SKILLCHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Expanding Solids

When substances are heated and cooled, changes in size can be small and easy to overlook. Make a prediction and then check it in this activity.

Question

What evidence can you observe of solid materials expanding as they are warmed, and contracting as they are cooled?

Hypothesis

1. Complete the following hypothesis statements. Particle theory suggests that
   - **(a)** when a material is heated it will …
   - **(b)** when a material is cooled it will …

Safety Precautions

You will be working with an open flame and hot objects. Be careful!

Apparatus

long copper or iron wire
small hooked mass (200 g or 500 g)
metre stick
ball-and-ring apparatus
laboratory burner
2 lab stands
2 C clamps

Materials

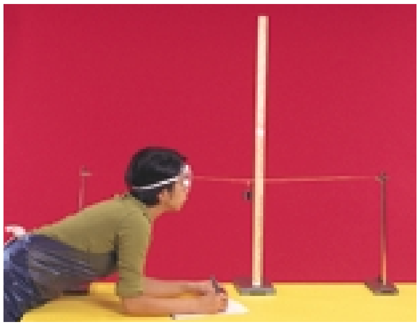
candles, matches, cold water

Skill FOCUS

For tips on making predictions, turn to Skill Focus 6.

Part 1

The Sagging Wire



Procedure

1. Study the procedure steps below. Then use your hypothesis to **write a specific prediction**. What will happen to the weight as the wire warms and cools?
2. Clamp two supports firmly to the table and stretch the wire tightly between them. Place the small mass in the middle of the wire. Put the metre stick behind the mass, and **record** its height.
3. Use lighted candles to warm the entire length of the wire for several minutes. **Observe** and carefully **record** the height of the mass after each 30 s of heating.
4. Stop warming the wire. **Observe** and **record** what happens to the height of the mass during the next 2 or 3 min.

Analyze

1. **(a)** If the wire sags, the mass moves down. Does this mean that the wire is getting longer or shorter?
   (b) What is happening to the length of the wire if the mass moves up?
2. Did you **observe** what you predicted would happen?
3. Did your observations **support your hypothesis**?

Part 2

Your teacher will do the heating in Part 2 as a demonstration.

The Ball and Ring

Procedure

1. **Observe** whether the brass ball fits through the brass ring when both the ball and the ring are at room temperature.

2. Study the procedure steps that follow. Then use your hypothesis to **write a specific prediction**. How will heating change whether the ball fits through the ring?

3. **Observe** whether the ball fits through the ring when your teacher warms only the ring in a hot flame for 30 s.

4. **Observe** what happens when your teacher warms both the ring and the ball.

5. As a class, brainstorm possible ways to make the ball fit through the ring. You or your teacher will test the ideas until one method works. With the ball through the ring, cool both the ball and ring. Try to pull the ball back through the ring. If you cannot, find a way to separate them by warming or cooling.

Analyze

1. How did the demonstration give evidence that solids can expand? Describe what your teacher did to cause the expansion and which part of the apparatus (the ball, the ring, or both) expanded.

2. How did the demonstration give evidence that solids can contract? Describe what you did to cause the contraction and which part of the apparatus (the ball, the ring, or both) contracted.

3. How well did your hypothesis help you predict the behaviour of the ball and ring? Was it a useful hypothesis, or would you like to modify it?

4. Use the particle model to **explain** why objects expand and contract when heated. Review page 210 for clues.

Conclude and Apply

5. **Predict** how the position of the electric transmission lines in the photograph below, taken in summer, would change as the temperature dropped in winter. Why would it be a bad idea to stretch the transmission lines more tightly between the towers so they would sag less in the summer?

Pause& Reflect

You have observed gases expanding, in your work in this unit and in everyday life. Think about the situations below, and answer the questions in your Science Log.

(a) A spray can, even when it is almost empty, contains compressed gases. Why does the safety warning on the label tell you not to dispose of the can by putting it in a fire?

(b) The tires on a car are filled with compressed air. In the winter, when the air temperature drops very low, the tires become slightly flat, even when they are not leaking. Why?

Expansion and Contraction in Gases

Because most common gases are colourless, they are difficult to observe. As well, gases have no fixed shape or size. (Remember that they always take the shape and size of their container.) If you put gases in a flexible container such as a balloon, however, you can see that they expand and contract much more than solids when the temperature changes. Warming a sample of helium from 0°C to 100°C, for example, increases its volume by about one third. Unlike the particles in solids, the particles in gases are far apart and moving fast and freely.

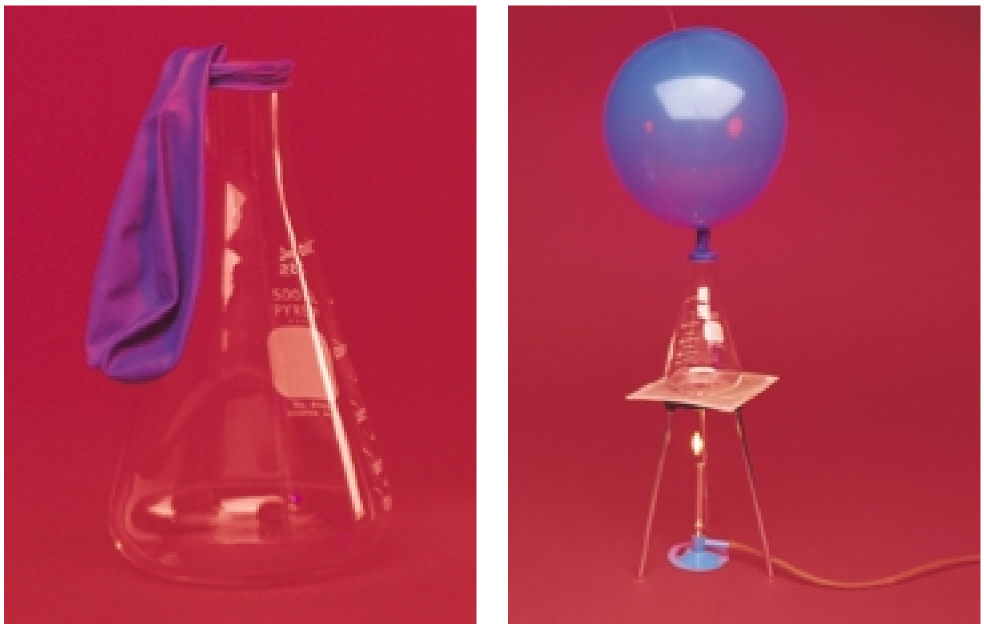
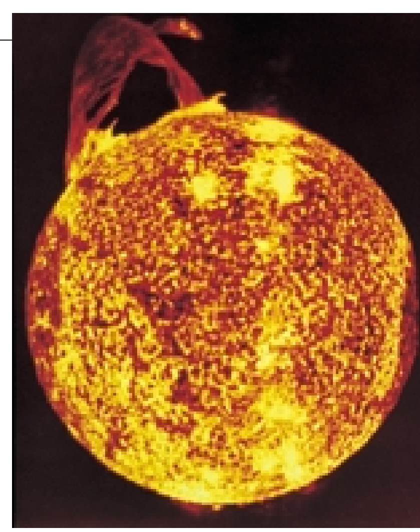


Figure 3.15 The particle model predicts that warming air will cause its particles to move faster and spread farther apart. When the air in the flask is warmed, the air expands and fills the balloon.

Off the Wall

You are familiar with three states of matter. There is a fourth state of matter, called *plasma*. To change a material into a plasma, extremely high temperatures are required, like those inside the Sun—millions of degrees Celsius! In a plasma, individual particles that make up the material start to break apart into tinier pieces called electrons and ions. Plasmas can be produced on Earth, but only under extreme conditions. Matter on Earth exists as a solid, liquid, or gas almost all of the time.



Find Out **ACTIVITY**

Bulging Balloons

In science, even ideas that seem like common sense are checked to see if they agree with observations and the rules for logical thinking. Can you find evidence to support the following statement, which you read earlier in this Topic?

If you put gases in a flexible container, such as a balloon, you can see that they expand and contract.

Materials ✷ Performing and Recording

2 identical balloons

refrigerator or freezer

hair dryer, electric heater, or toaster

Procedure

1. Blow up the balloons several times to stretch them. Then blow up both of them to the same size, and tie them so that no air can get in or out.
2. Put one balloon in the refrigerator or freezer to cool it. Leave the other balloon at room temperature. After an hour, compare the size of the two balloons.
3. Warm the cold balloon by blowing warm air from a hair dryer over it, or by holding it in warm air from a heater or above a toaster. Observe what happens as the air in the balloon warms. Continue until the balloon feels much warmer than room temperature.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Describe what you observed using the words "expand" and "contract."
2. How well do your observations support the statement you were testing: completely, partially, or not at all?
3. Describe any differences between what you expected to happen and what did happen.
4. In this activity, one balloon is called the *control* and the other is called the *test*. Which is which? Why?
5. At which point in this activity were air particles in one balloon farthest apart? When were they closest together?

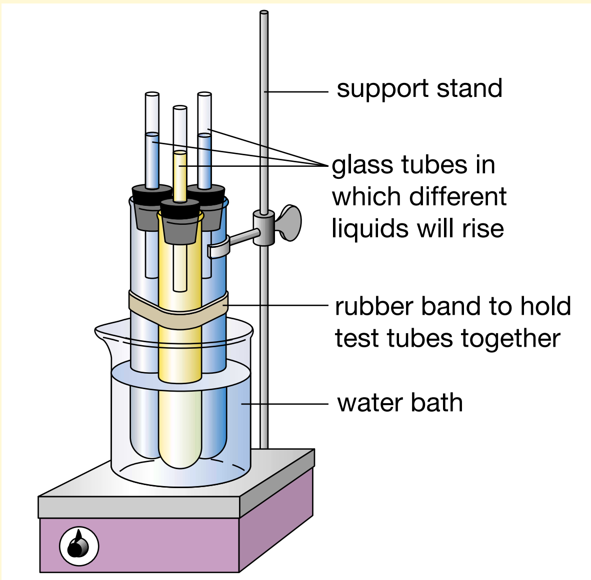
Expansion and Contraction in Liquids

Imagine watching a laboratory thermometer as its temperature changes. As the thermometer liquid moves up the glass tubing (the bore), it takes up more space. In other words, the liquid expands as it warms. As the thermometer cools, the liquid contracts, so it moves back down the tubing. The liquid must be contracting as it cools. Do all liquids expand and contract in this way? Do some liquids change volume more than others as they warm and cool? Follow the next activity carefully to find out.

Find Out ACTIVITY

Race for the Top

You have already observed a liquid in a thermometer expanding and contracting. Do all liquids behave the same way? Write a hypothesis, and explain why you think as you do. Check your hypothesis by observing the behaviour of liquids in this activity. (Your teacher may choose to demonstrate some or all of the steps for you.)



Materials

3 liquids (coloured water, ethyl alcohol, and cooking oil)

3 large test tubes

3 one-hole rubber stoppers, with 50 cm pieces of glass tubing inserted

laboratory stand and clamps

rubber bands

markers

2 large tin cans or 500 mL beakers

very hot water

ice-cold water

Procedure ✷ Performing and Recording

1. Completely fill one test tube with coloured water, the second with ethyl alcohol, and the third test tube with cooking oil. Insert a stopper in each test tube so there are no air bubbles and the liquid rises a few centimetres up the glass tubing. Hold the test tubes together with the rubber band so the liquids are at the same level in the glass tubing, and arrange the apparatus as shown in the diagram.
2. Use the markers to mark the starting height of each liquid on the glass tubing.
3. Pour the hot water into the beaker around the test tubes. Watch the height of the liquids closely as the liquids warm.
4. Before the liquids overflow the glass tubes, lift the apparatus out of the hot water and put it into the ice-cold water. Keep watching the height of the liquids as they cool.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Did all the liquids expand by the same amount as they warmed? If not, answer the following questions.
   - **(a)** Which liquid expanded more?
   - **(b)** Did the liquid that expanded more as it warmed also contract more as it cooled?
2. At the end of the activity, did the liquids return to their original heights in the tubes? Did you expect them to? Explain.
3. Was your hypothesis supported by your observations? If not, how might you modify it?
4. Explain which of the liquids you tested would be most suitable for making a thermometer that could be used to
   - **(a)** show small changes in temperature very clearly;
   - **(b)** measure large changes in temperature, without the thermometer being too large.

Off the Wall

Astrophysicists (scientists who study the way stars work) have found evidence that most stars, late in their lifetimes, go through a phase where they cool down and expand at the same time. A star that has expanded in this way is called a *red giant*. It usually becomes many, many times larger than its original diameter, and it may swallow up planets in orbit around it. Why do stars go through this strange behaviour? Is our own Sun expected to become a red giant, and if so, when? Do some research in a library or on the Internet to find answers to these questions.

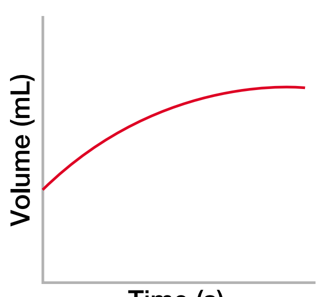
TOPIC 4 Review

1. Name the three states of matter. Give examples of three substances that are each in a different state at room temperature.

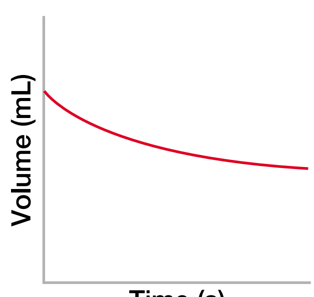
2. From your observations in this Topic, write a general description of what happens to solids, liquids, and gases as they are
   (a) warmed
   (b) cooled

3. Which state of matter shows the largest change in volume when warmed or cooled? Which state shows the smallest change?

4. The graphs below show the volume of mercury in a thermometer.
   (a) Which graph could be called a warming curve? Explain why.
   (b) Which graph could be called a cooling curve? Explain why.
   (c) Which graph shows what happens as soon as a thermometer is placed in hot soup?
   (d) Which graph shows what happens as soon as a thermometer is placed in ice cream?



Graph X



Graph Y

5. **Apply** Bridges are made from materials that contract and expand as the temperature changes, so they cannot be fastened firmly to the bank of a river or lake. The photographs below show an expansion joint at the end of a bridge in winter and in summer.
   (a) Which season is shown in each picture? Explain how you know.
   (b) Why do you suppose concrete roadways and sidewalks are laid in sections with grooves between them?

TOPIC 5

The Particle Model and Changes of State

Figure 3.16 The same hot Sun beats down on both sand and water at the beach. The sand warms up quickly. The temperature of the water changes much more slowly.

You have seen that different materials expand by different amounts as they warm up. Another difference in the way that materials respond when they are heated is the amount that their temperature rises when a certain amount of thermal energy is added. Some materials, such as sand, warm and cool quickly. Under identical conditions, other materials, such as water, warm and cool slowly.

Suppose you are studying the beach pictured above. Sunlight shines down equally on the sand and water. After some time, the thermal energy of both sand and water will increase by about the same amount. The temperature of the two materials will also change, but quite differently. Can you predict which one will warm up more? How do you know?

Exactly how fast does an object warm up? Scientists use two properties of an object to help answer this question. Examine the table to learn about these properties.

Table 2 Heat Capacity and Specific Heat Capacity

	Heat capacity	Specific heat capacity
Definition	amount of thermal energy that warms or cools the object by one degree Celsius	amount of thermal energy that warms or cools one gram of a material by one degree Celsius
Describes	a particular object	a particular material
Depends on	mass of the object and material the object is made of	material the object is made of

INVESTIGATION 3-E

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

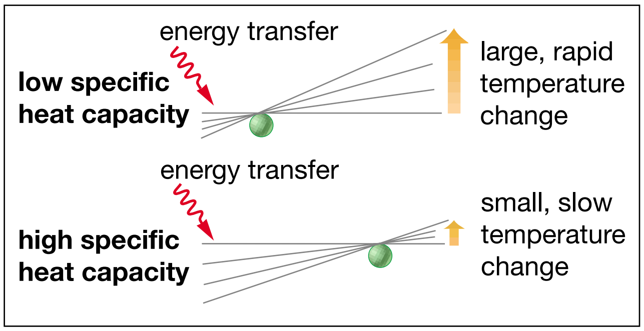
Hot Stuff!

Think About It

Scientists have measured the specific heat capacities of many common materials. In this investigation, you will study illustrations to learn one idea from each about specific heat capacity. This will help you to explore how the specific heat capacity of a material affects its behaviour.

Part 1

Rate of Temperature Change



1. Examine the illustration above. Copy the table below into your notebook. It shows speed of warming and cooling. Fill in the blanks in the Rate of temp. change column using complete sentences containing the words *more quickly* and *more slowly*.

Material	Rate of temp. change	Specific heat
sand on beach	warms ??	??
water in lake	warms ??	??

2. Fill in the blanks in the Specific heat capacity column using sentences containing the words *higher* and *lower*.

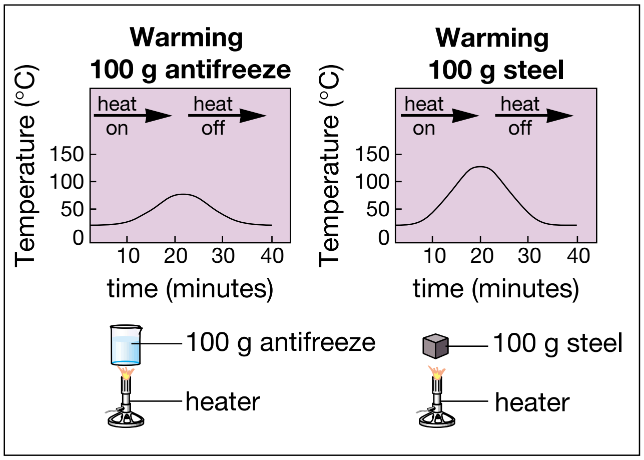
3. Decide if each object in the list that follows should be made from material that warms quickly or slowly. In your notebook make a three-column chart. Put the name of each object listed below in the first column, and your answer in the second column. Use the third column for your answers to question 4.

   (a) the bottom of a cooking pot
   (b) a cold pack for treating athletic injuries
   (c) solid glue in a glue gun

4. Decide if each object listed above should be made from a material with high specific heat capacity or low specific heat capacity.

Part 2

Size of Temperature Change



5. The graphs above show size of temperature change. According to the graphs, which material warmed faster? Which material cooled faster?

6. Which material had the higher specific heat capacity? *Hint: Use the ideas from Part 1.*

7. What is the best description of a material with a high specific heat capacity?
   (a) warms slowly
   (b) cools slowly
   (c) both warms and cools slowly

8. Write a sentence to describe *both* the warming and cooling of a material with low specific heat capacity. *Hint: make sure your answer agrees with your answer to question 7.*

Changes of State

Figure 3.17A At the top of the candle, solid wax melts into a liquid, which flows up the wick. There the liquid wax vaporizes and burns.

Figure 3.17B Imagine how much thermal energy would be required to cause fusion to occur throughout this icy landscape.

In a candle, the same substance — wax — changes between all three states of matter: solid, liquid, and gaseous states. You can observe the same phase changes or changes of state with another common substance — water. Everyday changes in temperature cause water to **melt** (turn from solid ice into liquid water) or **freeze** (turn from liquid water into ice). Temperature changes can also cause water to **evaporate** (turn into invisible water vapour, the gaseous form of water) and **condense** (turn back from a gas into liquid water). **Sublimation** occurs when a gas changes directly to a solid or a solid changes directly to a gas (see Figure 3.18).

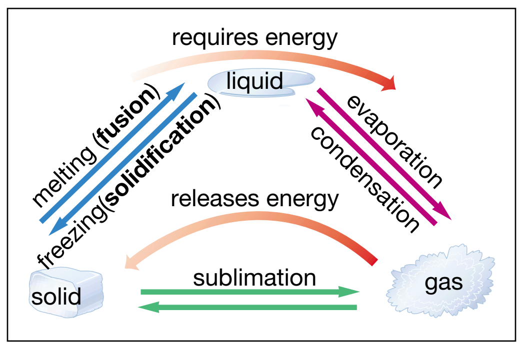


Figure 3.18 Changes of state

Most other substances are not so easy to study. Hydrogen, for example, is a gas, even at the coldest winter temperatures. If you want to make liquid hydrogen, you need to cool hydrogen gas to –253°C! To make solid hydrogen, you need even lower temperatures, as well as extremely high pressures.

Any pure substance can exist in all three states of matter. You can cause any substance to change state if you warm or cool and, possibly, change the pressure of the substance enough. Changes in temperature, however, are just a sign of changes in particle motion, which means changes in thermal energy. In this Topic, you will explore links among these three ideas: state of matter, temperature, and thermal energy. You will experiment with water, but your conclusions will apply to other substances as well.

DidYouKnow?

Scientists have found evidence to show that most of the giant planet Jupiter, just below its cloudy surface, is made up of a strange substance: liquid metallic hydrogen. At pressures of more than 4 000 000 times that of Earth's atmosphere, hydrogen not only flows like a liquid but also conducts electricity like a metal.

Melting and Boiling Points

The melting and boiling points of a substance are vitalpieces of information, and not only for scientists. You have already seen that water has an unusually high heat capacity. Another unusual feature of water as a substance, and one that is even more important for Earth's climate, is the temperature range at which water is a liquid. A glance at Table 3 will show you that most common substances are either gases or solids at everyday temperatures on Earth.

Table 3 Melting and Boiling Points of Pure Substances

Substance	Melting point (°C)	Boiling point (°C)
oxygen	–218	–183
mercury	–39	357
water	0	100
tin	232	2602
lead	328	1740
aluminum	660	2519
table salt (sodium chloride)	801	1413
silver	962	2162
gold	1064	2856
iron	1535	2861

What Happens When a Liquid Evaporates?

When you take part in an energetic activity, you sometimes become hot and start to perspire. That seems to cool you down. The particle model can explain this!

In a drop of liquid, particles are moving at many different speeds. At the surface of the drop, some of the faster-moving particles are able to escape into the air. Slower-moving particles stay in the liquid state. Slower motion means lower average energy, however, and this means lower temperature. As high-energy particles evaporate, the remaining liquid cools. The cool liquid then cools the surface on which it is resting. Scientists call this phenomenon **evaporative cooling**.

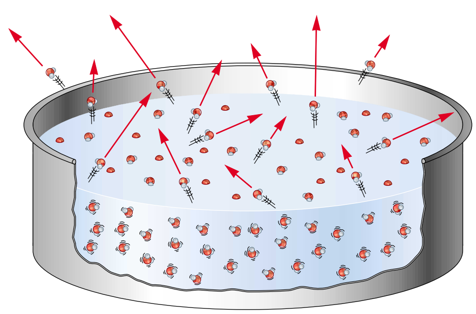


Figure 3.19 Evaporation cools a liquid, because the most energetic particles escape from its surface.

Evaporative cooling is common and can be very useful. Can you think of other examples besides the ones below?

- Joggers feel cold as their clothes dry out after getting soaked in a rainstorm.
- A home-owner sprays the roof of a house with water to cool the house on a hot summer day.
- A first-aid worker puts a wet cloth on the forehead of a person with a high fever.

Figure 3.20

INQUIRY

INVESTIGATION 3-F

SKILLCHECK

Initiating and Planning

Performing and Recording

Analyzing and Interpreting

Communication and Teamwork

The Plateau Problem

When water freezes or vaporizes, it takes time. What happens while the water is changing state?

Question

What happens to the temperature of water while it changes state?

Hypothesis

Form two hypotheses about familiar situations in which ice is melting or liquid water is boiling. In your notebook, complete the following two statements, with reasons.

(a) While solid ice changes to liquid water, the temperature will (drop/stay the same/increase), because …

(b) While liquid water boils into gas, the temperature will (drop/stay the same/increase), because …

Safety Precautions

- Use oven mitts, hot pads, or tongs to handle the beaker of boiling water.
- Unplug the hot plate at the end of the investigation, and let it cool before putting it away.

Apparatus

2 laboratory thermometers
stirring rod
hot plate
kettle
2 beakers (250 mL)
clock or watch

Materials

crushed ice
ice-cold water
hot water (almost boiling)

Procedure

1. **Make a data table** like the one shown here. You will need space for at least five observations.

2. Fill one beaker with hot water from the kettle, and put it on the hot plate to boil.

3. In the other beaker, make a slush of crushed ice and a little cold water.

Time (min)	Temperature of melting ice (°C)	Temperature of boiling water (°C)

Skill FOCUS

For some tips on the correct way to use a thermometer, turn to Skill Focus 5.

4. With a stirring rod, stir the contents of each beaker for several seconds, and then **measure** and **record** the temperature. Lift the thermometer off the bottom of the beaker to ensure that you are measuring the temperature of the contents, not the container.

5. Repeat the temperature measurements every 3 min. For a fair test, make sure that you stir and measure exactly the same way each time. **Record** each result.

6. Stop heating the boiling water *before* it all boils away. Unplug the hot plate, and carefully set aside the hot beaker to cool.

Skill FOCUS

For help in drawing your line graphs, turn to Skill Focus 10.

Analyze

1. In this activity, you measured time and temperature.

(a) What was your responding variable? (Which value was unknown until after you made an observation?)

(b) What was your manipulated variable? (What value did you select before making an observation?)

2. Draw two line graphs to show your temperature/time observations: one for the melting ice and one for the boiling water. Instead of joining the points, draw a smooth line or curve that passes through or between the points (a best-fit line).

3. On your hot-water graph, mark where

(a) the water was hot but not yet boiling

(b) the hot water was boiling vigorously

4. Label any plateaus (flat, horizontal segments).

5. Compare the temperature of your melting slush with the "official" temperature you learned in Topic 2.

(a) If the two temperatures are almost the same, any small difference might be caused by errors in your equipment or measurements. Suggest at least two specific errors of this sort that might occur.

(b) If the two temperatures are quite different, the conditions in your laboratory or your sample may be responsible. Suggest at least two specific conditions that might cause this type of error.

6. Imagine that you combined both parts of this investigation. **Sketch a third graph** that shows what would probably happen if you heated one sample from ice to water and then to water vapour.

7. On the temperature scale of your third graph, mark the melting point and the boiling point of your samples, according to your **observations**.

8. Combine all the results from your class to find the average melting point and the average boiling point for water. Compare these values to the "official" values. Are they closer than your individual group values? If they are closer, explain why.

Conclude and Apply

9. From your observations, write a clear answer to the question at the beginning of this investigation.

10. How well do your **observations** support your **hypotheses**?

11. (a) Identify any problems you had with apparatus, procedure, or the way you organized and worked together in your group.

(b) Describe one improvement your group could make the next time you work together.

Find Out **ACTIVITY**

How Low Can It Go?

Alcohol evaporates more rapidly than water. If you compare the temperature change when the two liquids evaporate, the results may surprise you.

Materials

lab thermometer or computer temperature sensor
electric fan
2 strips of cloth or paper towel
room-temperature water
room-temperature alcohol

Safety Precautions

Pure alcohols are harmful to the body. Do not taste these chemicals, and do not breathe their vapours. Do not use alcohols near open flames, as the alcohol vapours may catch fire or explode.

Procedure

Performing and Recording
Communication and Teamwork

1. Measure and record the temperature of the liquid water and alcohol.
2. Wrap the cloth strip around the thermometer bulb, and soak it in the water. Hold the thermometer near the fan to speed up evaporation from the wet cloth. Record the temperature every 30 s until it stops dropping.
3. Repeat step 2, using a second cloth strip and alcohol.
4. To compare your observations for the two liquids, draw a graph with temperature on the vertical axis and time on the horizontal axis. Plot both sets of data on the same graph.

What Did You Find Out?

Analyzing and Interpreting

1. In which liquid were the particles evaporating faster? How do you know?
2. Which of the two cloths would take longer to dry completely? What would happen to temperature of the cloth after all of the liquid had evaporated?

Skill FOCUS

To learn about graphing, turn to Skill Focus 10.

Why the Temperature Stays the Same

What, exactly, is happening to particles of a substance during a phase change? For example, what happens to water particles in ice crystals as the ice melts? Recall that, according to the particle model, the average speed of the particles cannot be changing because temperature stays constant during a phase change. If the speed of the particles changed, the temperature would have to change, too.

What does change, according to modern particle theory, is the *arrangement* of the particles. Study Figure 3.21 to visualize how this happens. Particles become *less* organized as their energy increases, so the substance changes from a solid to a liquid, and then to a gas. Particles become *more* organized as their energy drops, so a gas will change to a liquid and then to a solid.

During a phase change, the total energy of a substance increases or decreases. This occurs because the particles no longer increase or decrease their speed; the arrangement of the particles changes. The average energy of the particles, however, does *not* change. Therefore, the temperature of the substance stays constant. The energy change is hidden from thermometers, so it is called "hidden heat" or "latent heat."

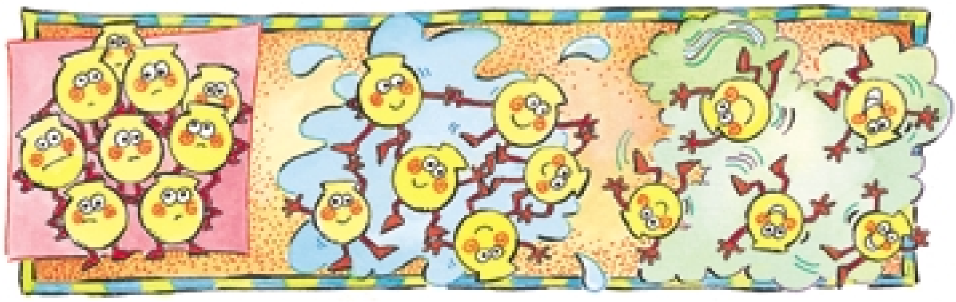


Figure 3.21A Particles in many solids have a regular arrangement. They move by vibrating in the same spot.

Figure 3.21B Particles in a liquid move freely, but they are still held loosely together. They can vibrate and rotate, but they can only move a short distance before colliding with a nearby particle.

Figure 3.21C Particles in gases move independently and are separated by large spaces. They can vibrate, rotate, and travel longer distances between collisions.

Pause & Reflect

When you take a shower, beads of water may form on the bathroom mirror and other cold surfaces far from the shower.

(a) Where did the water in the beads come from?

(b) In what state was the water that formed the beads as it travelled to the mirror?

(c) What change of state is occurring when the beads of water form?

TOPIC 5 Review

1. Name a change of state in which particles become
   (a) more organized
   (b) less organized
   (c) able to move more freely
2. Imagine that you can see the moving particles in a drop of liquid on your skin. Describe
   (a) the speed of the particles that are able to escape from the surface of the drop
   (b) the speed of the particles that are left behind in the drop
   (c) the temperature change of the drop as particles continue to escape
   (d) the change of state that is occurring
3. Use Table 3 on page 221 to find a temperature at which
   (a) oxygen is a liquid
   (b) table salt is a gas
   (c) tin is a liquid
4. From memory, list six changes of state, and give a name for each one.
5. **Apply** Anyone who falls into a lake fully clothed may develop hypothermia (dangerously low body temperature) after being rescued. No matter whether the water and the weather are warm or cold, first-aid experts say that the victim's wet clothing should be removed immediately. Use your knowledge of energy and change of state to explain why.

TOPIC 6

Transferring Energy

Imagine holding your hand near a light bulb or in front of a hot fire. You can feel the warmth. Your skin warms up because it receives thermal energy from the bulb. The light bulb is an **energy source**: an object or material that can transfer its energy to other objects. In this section, you will study three ways in which energy can be transferred: radiation, conduction, and convection.

Radiation Transfers Energy

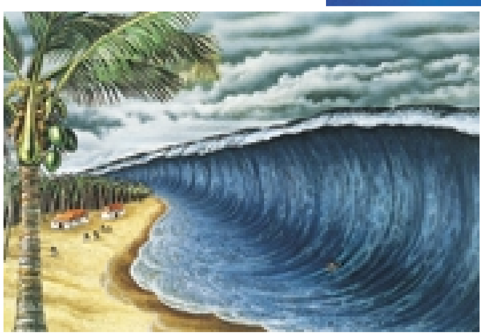


Figure 3.22 A tsunami carries enormous amounts of energy from its source, an underwater earthquake, across thousands of kilometres of ocean. When the wave hits land, the energy can devastate buildings and the natural environment, and can cost thousands of lives.

Figure 3.23 The ripples in this pond are evidence of energy transfer.

The Sun shines. Millions of kilometres away, sunshine may strike a solar cell that runs your calculator or a solar-powered radio or toy. Energy has been transferred, even though no material — no *thing* — has travelled from the Sun to the solar cell. Scientists call this form of energy transfer **radiation**. Radiation is the transfer of energy without any movement of matter. Energy that is transferred in this way is called **radiant energy** or **electromagnetic radiation** (EMR for short).

Exactly how does radiant energy travel through space? After many years of study, scientists found that radiant energy travels and behaves like a wave. Like the ripples and tsunami in the illustrations, electromagnetic radiation transfers energy. Unlike other waves, EMR can travel through empty space, as well as through air, glass, and many other materials.

There are many different forms of EMR, including radio waves, microwaves, visible light, and X-rays. If the energy source is a warm object, such as the Sun, some of its thermal energy is transferred as a type of EMR called infrared radiation (IR) or "heat radiation." All of the different forms of radiant energy share several characteristics:

- They behave like waves.
- They can be absorbed and reflected by objects.
- They travel across empty space at the same very high speed: 300 000 km/s.

Find Out ACTIVITY

Absorb That Energy

If an object absorbs radiant energy, what happens to its temperature?

Materials

2 empty pop cans
2 thermometers
light (at least 100 W)
ruler
dark- and light-coloured cloth, or black and white paint
aluminum foil
200 mL cooking oil
tape or rubber bands

Procedure ✷ Performing and Recording

1. Think of summer sunlight beating down on different materials. Use your own experience to write a prediction about which type of surface absorbs the radiant energy best:
   (a) dark or light
   (b) shiny or dull
2. Use an appropriate choice of materials to cover the pop cans so that you can test one of your predictions.
3. Pour 100 mL of cooking oil into each can. Place the cans an equal, short distance from the light. (Try 10 cm.)
4. For each can, record the initial temperature of the oil and the temperature of the oil every 5 min for 15 min.
5. Calculate the temperature change of the oil in each can by subtracting the initial temperature from the final temperature.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Compare the temperature change of the oil in the two cans. Do your observations support your prediction?
2. If several groups tested the same prediction, how well did their results agree?
3. What other factors, besides the one that you tested, may be affecting the temperature change in the oil?
4. According to scientific theory, the same materials that absorb radiant energy well should also radiate energy well. Suppose that you have pairs of similar objects with different surfaces, as listed below. You heat them to the same high temperature. Which type of surface radiates energy better and thus cools down more quickly?
   (a) a light-coloured surface or a dark surface
   (b) a dull surface or a shiny surface

You know, from your own predictions or from the activity above, that some materials absorb radiant energy well, and some materials reflect well. Do the same materials make good reflectors and bad absorbers of radiant energy? In the next investigation, you can think about this and similar questions, and infer some everyday-life consequences.

INVESTIGATION 3-G

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- ✸ Analyzing and Interpreting
- Communication and Teamwork

Comparing Surfaces

Think About It

From your own experience, can you think of examples of the following scientific observations?

- Dark-coloured surfaces absorb and radiate energy better than light-coloured ones.
- Dull surfaces absorb and radiate energy better than shiny ones.
- Shiny surfaces reflect radiant energy better than dull ones.
- Light-coloured surfaces reflect radiant energy better than dark-coloured ones.

How can you use this knowledge to make wise choices about materials you use?

Procedure

1. In your notebook, make a table like the one below. Give your table a title. Complete the table by writing "better" or "worse" to describe the behaviour of each surface compared to its opposite.

Surface	Ability to absorb	Ability to radiate	Ability to reflect
light-coloured			
dark-coloured			
shiny texture			
dull texture			

2. Identify the combination of colour and texture that would be
   (a) the best reflector
   (b) the worst reflector
   (c) the best absorber
   (d) the worst radiator

Off the Wall

People radiate energy. Have you ever been cool and comfortable at the start of a concert or school assembly and then, after an hour or so, found yourself getting unbearably hot? Thermal energy from the crowd of warm bodies was probably to blame. Each person acted like a miniature furnace, warming nearby air and furniture. Without air conditioning to transfer the thermal energy elsewhere, a crowded room can quickly become uncomfortable.

Analyze

1. Use your answers in steps 1 and 2 to:
   (a) recommend that a car owner cover black seats with light-coloured fabric in summer
   (b) suggest to a dairy truck manufacturer that the milk-holding tanks be shiny white or silver-coloured
   (c) explain why you carry your dog across a dark asphalt road in summer and let it walk on the concrete sidewalk
   (d) persuade tennis players to wear white or light-coloured clothing
2. The Russian government once experimented with a method to speed up the melting of snow on northern farmland, so that crops could be planted earlier in the spring. Black coal dust was dropped on the snow from low-flying aircraft.
   (a) Explain why the coal dust was expected to speed up snow melt.
   (b) The snow did melt sooner, but the method was never actually put into use. Think of some reasons why it would be impractical.
3. Write a brief statement explaining how these observations can lead to energy-saving actions.

Conducting Energy Through Solids

In solids, where particles are close together, thermal energy can be transferred directly from one particle to the next. **Thermal conduction** is the process of transferring thermal energy through direct collisions between particles. Study Figure 3.24 to see how conduction transfers energy.

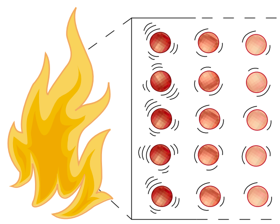


Figure 3.24A Particles near the heat source absorb energy from it and begin moving more rapidly.

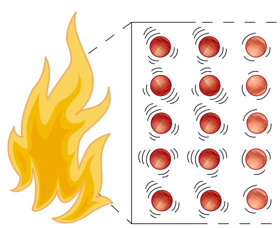


Figure 3.24B The fast-moving particles bump into neighbouring particles, increasing their energy and motion.

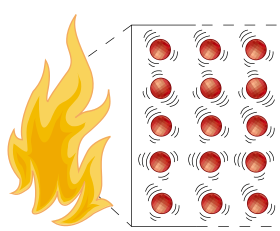


Figure 3.24C In this way, thermal energy is transferred throughout the material.

Most metals, especially gold and copper, are excellent heat conductors. A hot stove burner touching one part of a copper saucepan, for example, soon heats the entire pan. Other solids, such as glass and wood, are much less efficient at transferring thermal energy by conduction. Poor conductors are called **heat insulators**. When insulators are wrapped around an object, they slow down the transfer of thermal energy to or from the surroundings. The object stays warm or cold longer. Think of some good insulators!

Find Out ACTIVITY

The Super Stirrer

Can you predict how well a substance will conduct heat? Find the material that will make the best stir stick.

Materials

equal-length pieces of plastic from a pen, pieces of copper wire, long iron nails, wooden craft sticks or wooden pencils

plastic cup of very hot water **CAUTION** Handle the hot water with care.

Procedure

Performing and Recording

1. Predict which of your sample stir sticks will be the
   (a) best conductor **(c)** best insulator
   (b) worst conductor **(d)** worst insulator
2. Place one end of each sample in the hot water. Wait 1 min.
3. Touch the inside of your wrist to the top of each sample to identify the warmest one (the best conductor). Remove it from the cup and record which materials made the best conductor.
4. Wait another minute. Then repeat step 3 to find the second-best conductor. Continue to repeat step 3 until you have ranked all of the samples in order, from the best to the worst conductor.

What Did You Find Out?

Analyzing and Interpreting

1. Explain which of your samples would be the best for making
   (a) a stir stick
   (b) the bottom of a frying pan
   (c) the handle of a frying pan
   (d) a container for delivering hot pizza
2. How might the particles in your best insulator differ from the particles in a conducting material?

Convection, Energy on the Move

Thermal energy can be transferred in a third way by **fluids**: materials that can be poured or that flow from place to place. A hot fluid may force its way up through a colder fluid. In **convection**, the warm fluid, itself, moves from place to place, carrying the thermal energy with it. The moving fluid is called a **convection current**. Study Figure 3.25 to identify the different parts of a convection current. Then read on to learn the details of how a convection current operates.

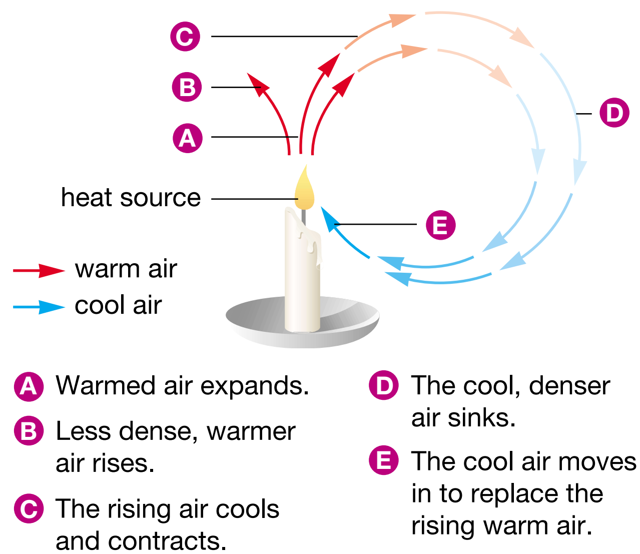


Figure 3.25 All convection currents display the features shown here.

Why do fluids, at different temperatures, rise, sink, and create convection currents? Remember that materials expand as they warm up. Their particles move farther apart. Each section of the warmed material is left with fewer particles than when it was cold, so each section is a bit lighter than it used to be. In other words, the warmed material becomes less dense. Colder, denser fluid sinks down and pushes nearby warmer fluid upward. Then this cold fluid, too, is warmed and pushed upward.

As warm fluid rises and moves away from the heat source, it cools. It contracts as its particles move closer together. It becomes denser and sinks back down toward the heat source, where it is warmed and forced upward. As the whole process repeats, a continuous movement — a convection current — forms.

Career CONNECT

Setting the Standard

Steve Reid

Steve Reid knows that convection currents cannot warm a house unless the heat source is working. Steve is a gas appliance technician. His job is to install and repair any type of furnace, boiler, stove, dryer, or other appliance that uses natural gas as its fuel.

A mistake could turn a safe appliance into a hazardous one, so Steve's work must be done with great care. To train for his work, Steve completed a college course in heating, refrigeration, and air conditioning. Then he passed a government test in order to receive a gas fitter's licence. Without this licence, Steve could not legally work on gas appliances.

To ensure everyone's safety, the government has set standards that must be met by people who want to work in occupations that are potentially dangerous to the worker or the public. In some other occupations, an organization of people who already work in the occupation create a test that others must pass to become a registered or certified member. This process ensures that everyone who works in the occupation is well qualified.

With a partner, brainstorm at least three occupations that may require people to be licensed, registered, or certified. Start by thinking about occupations that could involve danger to the worker or the public. You and your partner could each choose one of the occupations and, after checking with your teacher, contact someone in that field of work for comments on how licensing is done and its importance to the occupation.

Find Out ACTIVITY

Displaced Drops

You can create a small-scale model of parts of a convection current. Observe what happens in this activity, and compare it with the explanation you have just read.

Materials

dropper
250 mL beaker of room-temperature water
100 mL beaker of coloured, ice-cold water
100 mL beaker of coloured, very hot water

CAUTION Handle the hot water with care.

Procedure ✷ Performing and Recording

1. Make sure that the beaker of room-temperature water is completely still.
2. Fill the dropper with ice-cold water, and hold it just above the surface of the room-temperature water. Gently squeeze out one drop of cold water. Watch to see if it can force its way to the bottom of the beaker.
3. Repeat step 2 several times. Then make a careful diagram showing what usually happens to the drop of cold water.
4. Repeat steps 2 and 3 using very hot water in the dropper.

What Did You Find Out? ✷ Analyzing and Interpreting

1. Did the drops of very hot water appear to be more or less dense than the room-temperature water around them? How do you know?
2. How did the density of the drops of ice-cold water compare with the density of the room-temperature water? How do you know?
3. In what way do your observations agree or disagree with the text description of what happens to warm and cold fluid in a convection current?
4. Why did the drops of hot or cold water not move in a complete convection current?

Analyzing Energy Transfer Systems

A volleyball rockets across the net. This fast movement means a large amount of energy. The source of the energy was Carrie's hard-swinging fist. The impact of her fist on the ball transferred energy to the ball.

Most of the energy of Carrie's fist ended up as the energy of the ball — most, but not all. The other players heard the smack of Carrie's spike and the thud of the ball hitting the floor. If you asked Carrie, she would report that her fist stung and felt warmer after her shot. The part of the ball that she hit also warmed up a bit. When the ball hit the floor, the ball warmed up a bit more. So did the spot on the floor where the ball landed. A few moments later, the floor nearby and even the air above it was a tiny bit warmer.

Can you explain what is going on in this energy transfer system? Examine Figure 3.26 below without reading the information below it. Try to explain what is happening at each letter, in terms of energy, particle movement, and temperature. Then check to see if your explanation included everything in the caption.

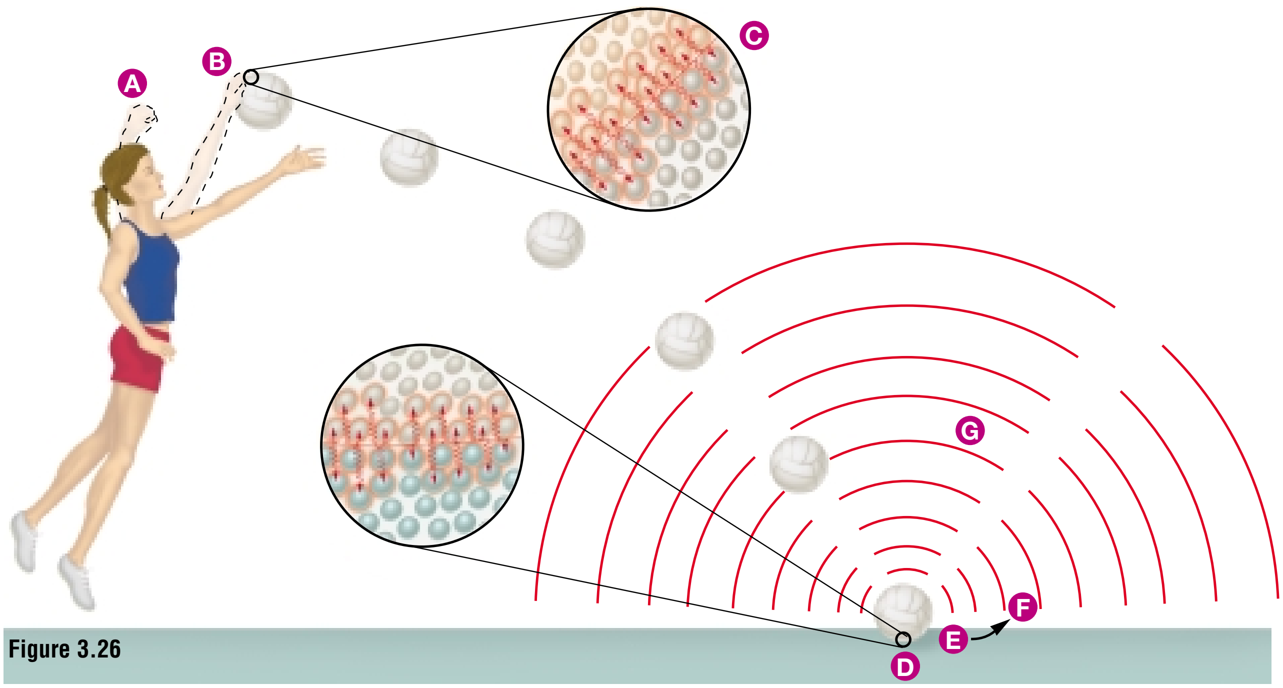


Figure 3.26

A The moving fist (energy source) has a large amount of energy.

B Most of the energy is transferred to the entire volleyball, which moves away rapidly.

C Some energy is transferred to individual particles in the skin and the volleyball, which vibrate more rapidly, producing a temperature increase.

D Energy is transferred from the ball to the floor. Particles that make up the floor vibrate more rapidly, producing a temperature increase.

E Energy is transferred by conduction to nearby particles in the floor.

F Convection currents transfer energy through the air.

G Energy is also transferred to air particles by compressing them and starting a sound wave. The sound wave distributes this energy throughout.

Features of Energy Transfer Systems

All energy transfer systems have similar features. Hair dryers, bicycle brakes, weather systems, and ocean currents — like Carrie's volleyball spike, they all have five things in common. As you study each point below, find an example of it from Figure 3.26.

- *Energy Source* Some part of the system acts as an energy source, supplying energy to the rest of the system. Some systems have *mechanical* energy sources, such as a tightly wound spring in a toy. Cars, trains, and even humans and animals depend on *chemical* energy sources, such as gasoline, diesel fuel, or food. Stars, atomic bombs, and nuclear power plants use *nuclear* energy sources: substances whose smallest particles can fuse together or break apart, releasing large amounts of energy. Radios, power tools, and plug-in appliances use *electrical* energy sources: batteries or generators in a power station. (You will find out more about sources of energy in Topic 7.)

- *What is the energy source for Carrie's volleyball spike?*
- *Direction of Energy Transfer* Energy is always transferred *away* from concentrated sources. Changes in non-living systems always spread energy around more evenly.
- *At which point in Figure 3.26 is energy most concentrated?*
- *Name three things that end up sharing part of Carrie's original energy.*
- *Transformations* Energy does not necessarily keep the same form as it is transferred from place to place. When Carrie hit the volleyball, only part of the original energy of her fist became energy of the ball.

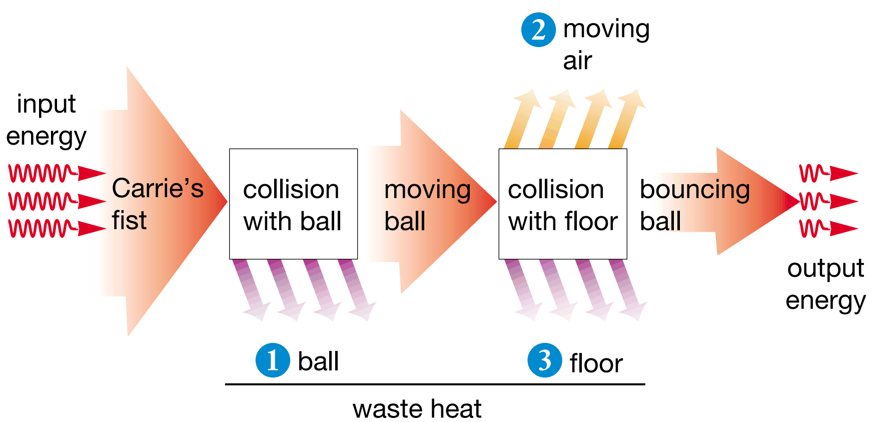


Figure 3.27 These are the energy transformations that take place when a volleyball is spiked.

- *Waste Heat* Almost all energy systems transfer at least a little thermal energy into the surroundings. Some of this can be prevented by using a thermal break. For example, the two outer metal sections of a door or window frame are separated by a layer of solid wood or plastic. This thermal break is a poor conductor, so it prevents heat transfer through the metal.
- *Identify two things which were warmed by waste heat from Carrie's volleyball spike.*
- *Control Systems* The furnace in your home transfers thermal energy to the air, but it does not run all the time. A thermostat controls the energy transfer by turning the furnace on and off. Many other systems include some way of adjusting energy transfers. Warm-blooded animals, for example, are able to warm themselves in winter and keep cool in the summer. Their body temperature stays almost the same despite changing weather conditions.
- *Which item in Figure 3.26 includes an energy control system?*

Word CONNECT

Recall from Topic 3 that in science and engineering, the word "heat" has a very precise meaning: thermal energy transferred as a result of temperature differences. Heat is not a substance or a thing. It is the name of a particular kind of energy transfer. What do you suppose the scientific meaning of "cold" might be? Use a good dictionary to check your idea.

Pause& Reflect

In your Science Log, draw a concept map or a tree diagram to summarize the five features of all energy transfer systems, as discussed in this section. Add important vocabulary, details, or examples for each main idea. Colour-code your diagram so that you can quickly pick out each type of information. For example, use black ink for main ideas and blue ink for vocabulary words.

PROBLEM-SOLVING

INVESTIGATION 3-H

SKILLCHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Making a Transfer

You know more about energy than most people who have ever lived! Almost all of the ideas you have been studying were developed in the last 200 years. Can you apply all this new knowledge in a practical way?

Challenge

Design and build a simple but efficient device to harness and transform energy: a candle-powered water heater.

Safety Precautions

- All nonflammable materials must be approved by your teacher.
- During and after heating, handle the apparatus with care. It may be hot enough to burn you.
- Candle flame soot is hard to wash off clothing. Wear an apron, and wash your hands immediately with soap and hot water if you get soot on them.
- Have water or a fire extinguisher nearby.

Materials

thermometer
birthday candle
100 mL room-temperature water
nonflammable containers, fasteners, and insulation
matches

Specifications

A. Your goal is to raise the temperature of the water as much as possible.

B. The water may be heated directly with the candle or indirectly using the candle to heat something else, which will then heat the water.

C. Your energy transfer device must be nonflammable and movable so that it can be safely placed over the candle after the candle is lit.

D. The candle will be allowed to burn for only 3 min during your demonstration.

Plan and Construct

1. Brainstorm ideas about how to build the most efficient heater. Think about
   - energy transfer by convection, conduction, and radiation
   - prevention of heat loss to the surroundings
   - specific heat capacity (you will need to make sure that the heater itself does not absorb too much energy)
   - possible materials to use (remember that paints, plastics, glues, and tape are flammable, so they do not meet the design criteria)

2. Choose the most practical ideas, and write a design proposal for your teacher that includes
   - a list of materials
   - a labelled sketch of your device
   - a task list and a time line to show how each group member will contribute to the project

3. Assemble the materials, and build your device. You may test and modify it, but the candle can be burned for only 1 min during a test. Keep a written record of any design changes you make.

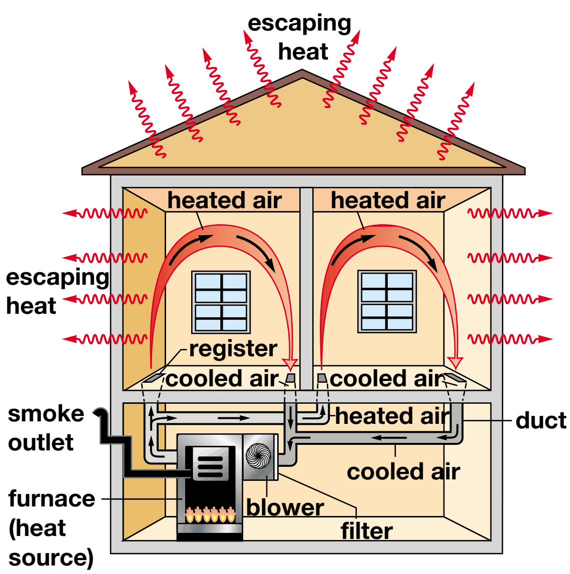
4. For the demonstration, be ready to give a brief explanation of the design features of your device. Then show how it works!

Evaluate

1. What knowledge from this unit did you use when designing your device?
2. How could your device be improved if you had more time to work on it?
3. What extra resources would have helped you to do a better job on this project?
4. What could your group do differently in the next design project to be more efficient?

Keeping in the Warmth

In a home, some of the thermal energy produced by a furnace is lost to the outside air through chimneys, walls, windows, etc. (see the diagram). We can reduce this loss by using high-quality insulation in new houses that are built.



Fuel is burned in a furnace.

- It heats air that then travels through ducts to various rooms. The air circulates from heat registers throughout the room.
- A fan helps to pull air back into the furnace.
- A filter helps clean the air of dust and other particles before the air returns to the furnace.

Insulation materials that are used in building construction are rated by their RSI value. This value describes the resistance of a 1 cm thickness of a material to heat conduction. Materials with higher values are better insulators. Some typical values are given in the table below.

Material	RSI per cm
blue plastic foam panels	0.35
white plastic foam panels	0.29
fibreglass	0.24
vermiculite	0.16
plywood	0.087
glass	0.017

Find Out ACTIVITY

Extra thickness increases the RSI value. For example, a 3 cm thickness of fibreglass would have an RSI value of 3 x 0.24 = 0.72. Only 2 cm of blue plastic foam would provide about the same resistance to heat conduction (2 x 0.35 = 0.70).

Procedure

Performing and Recording

List each type of insulation material used in your home and how thick it is. Then calculate its total RSI value. If the material is not listed in the table, check with a building materials store, in the library, or on the Internet to find its RSI value.

Extension

You have probably noticed that the area around windows and doors feels cooler in winter than other parts of the room. Windows and doors allow heat to escape, reducing the efficiency of a home's heating system. How could you reduce the heat loss through windows? With your group, think about this question. Brainstorm some methods of cutting heat loss through windows, and design an investigation to test at least one of your methods. State the question your experiment is intended to answer. Describe your variables and how you will control them. List the materials your experiment will require and the steps you will follow. Have your investigation approved by your teacher, and if possible, carry out the experiment.

Fibreglass building insulation

Stretch Your Mind

In the 1970s, the price of fuels rose suddenly. People and governments became very concerned about conserving energy and using fuels efficiently. The auto industry started making vehicles that travelled much farther on each litre of gasoline. Architects designed buildings with more insulation and better seals around windows and doors. Today there is less emphasis on energy conservation. Few headlines or television newscasts focus on this topic. Do you think people should still be concerned about energy conservation? Why? Find out about the United Nations Earth Summits, held every five years.

TOPIC 6 Review

1. Define the term "energy source," and list four common types of energy sources. Give an example of each type.

2. List five features of all energy transfer systems.

3. **Apply** 100 mL of hot water (50°C) is mixed with 100 mL of cold water (10°C).

(a) Predict the temperature of the mixture after it is well stirred.

(b) In which direction was energy transferred?

4. **Apply** In the winter, pioneer families spent much of their waking time in the kitchen because it was the warmest room in the house. A wood box beside the large cast-iron stove held the fuel for the stove. The stove pipe passed through a hole in the ceiling and went up through the upstairs hallway and out through the roof.

(a) What was the source of heat for the house?

(b) How was thermal energy released from the source?

(c) Explain how thermal energy was transferred to
- the iron stove
- the kitchen
- the bedrooms
- the rest of the rooms in the house

(d) How did this heating system release waste heat to the surroundings?

(e) How is this heating system an example of thermal energy spreading out?

Did You Know?

About 85 percent of the energy from the fuel burned in a furnace is transformed into useful thermal energy. In other words, the system is highly efficient.

In the case of an incandescent light bulb, only 5 percent of the electrical energy of the bulb is transformed into light energy. The remaining 95 percent is transformed into thermal energy. Creating thermal energy is not the purpose of a light bulb, so this is a very inefficient energy system.

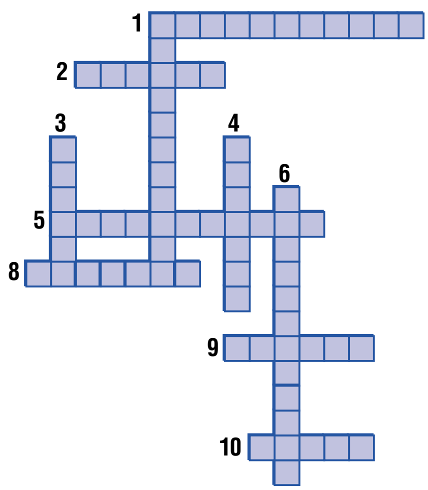
If you need to check an item, Topic numbers are provided in brackets below.

Key Terms

expand	freezing	sublimation	fusion	radiation	heat insulators
contract	condensation	boiling	evaporative cooling	radiant energy	fluids
melting	solidification	evaporation	energy source	thermal conduction	convection current

Reviewing Key Terms

1. Copy and complete the crossword puzzle below using new terms you learned in these Topics.



Across

1. cooling caused by a wet blanket (6)
2. increase in size (4)
5. phase change involving no liquid (5)
8. energy from the Sun (6)
9. another word for melting (5)
10. cannot be compressed (4)

Down

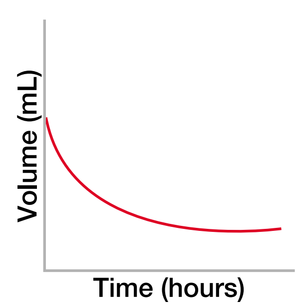
1. a drying puddle (5)
3. state not found on Earth (4)
4. happens when ice is heated (5)
6. opposite of evaporation (5)

Understanding Key Concepts

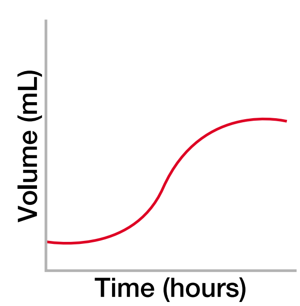
2. Carbon dioxide gas sublimes at –78.5°C.
   (a) If you cool carbon dioxide below –78.5°C, in what state will it be?
   (b) Could you produce liquid carbon dioxide by cooling the gas or by warming the solid? (Hint: What does *sublimation* mean?) (5)

3. You pour 100 mL of hot water at 50°C into 200 mL of cold water at 10°C. (6)
   (a) In which direction is thermal energy transferred?
   (b) Which methods of energy transfer occur?
   (c) What happens to the temperature of the hot water and the temperature of the cold water?
   (d) If you leave the water mixture in a glass beaker for 24 h in a room with a temperature of 20°C, what will happen? What general feature of energy transfer does this illustrate?

4. The two graphs below show the volume of liquid in a laboratory thermometer during a temperature measurement. (4)
   (a) Which graph is a warming curve, and which is a cooling curve? Explain how you know.
   (b) Which graph shows what happens when the thermometer is placed in water in a pot on a stove and the burner is turned on? Which shows what happens when the thermometer is placed in a jug of water that was just put in a refrigerator?



Graph A



Graph B