CHAPTER

6 Controlling Heat

This fire-walker crosses red-hot coals without scorching his feet. He does this more with good science than good luck or magic.

Getting Ready...

- How are fire-walkers and the beads of water related?
- How is knowledge of heat transfer used when insulating houses?
- Why do oceans moderate climate so well?

Science Log

Your work in Chapter 5 will help you start to answer some of the Getting Ready questions. Write what you think now in your Science Log.

Fire-walkers amaze tourists. They aim to convince audiences that they have mystic powers. There is a trick to their ability, of course. Fire-walkers have learned to reduce the transfer of thermal energy from the red-hot coals to their feet. How is this done?

The second visual provides a hint. One secret to the fire-walker's trick is suggested by the dancing beads of water on the chef's frying pan. The chef is using this method to check the amount of heat transfer.

We control heat transfer every day. In this chapter, you will study scientific principles involved in controlling the transfer of thermal energy. You will measure rates of heat transfer for several substances. You will also examine factors that affect heat absorption and heat loss.

Knowledge of differences in heat absorption is used in many ways. You will investigate some of these. As you learn more about the principles of heat transfer, you will discover the secret of walking on fire.

Transfer

Cooks use this test for correct temperature. If the pan is hot enough, drops of water will dance across the surface of the skillet.

What You Will Learn

In this chapter you will learn:

- how buildings keep the heat in
- how firefighters are protected from extreme temperatures
- how heat loss is measured
- how different materials absorb heat at different rates

Why It Is Important

- From running large machines to wearing clothes that keep you warm, controlling heat transfer is important. If you control heat transfer well, you will not be left sitting in the cold.

Skills You Will Use

In this chapter you will:

- compare the rate of heat absorption
- manipulate variables affecting the rate of heat transfer
- investigate ways of slowing heat transfer
- design a device to control the transfer of heat

Starting Point ACTIVITY

Survivor

Think About It

You are the only survivor of a shipwreck. You are stranded on a tropical beach wearing only shorts and sweatshirt. A duffel bag has washed ashore with you.

What You Have

sweatshirt

duffel bag with the following contents:

– several sandwiches wrapped in aluminum foil
– two large plastic containers of water
– a pocket knife
– notebook and a pencil

materials around you, including:

– bark
– large banana leaves

What to Do

1. Sketch a shoe design for yourself.
2. In the sketch use only materials that you have on hand. Do not waste any.

6.1 Absorbing and Losing Heat

In Chapter 5, you learned that water moderates the temperature of the land around it. In this section, you will learn another reason why that happens. The following activities investigate how different materials absorb heat at different rates. This is referred to as **heat absorption**.

CONDUCT AN

INVESTIGATION 6-A

SKILL CHECK

Initiating and Planning

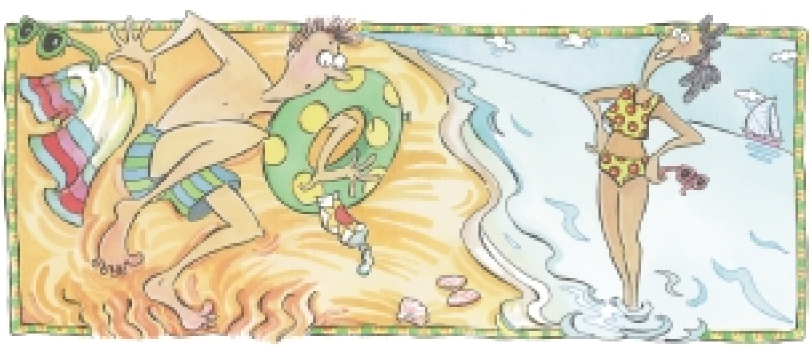
✹ Performing and Recording

✹ Analyzing and Interpreting

Communication and Teamwork

Keeping It Cool

You do not have to be stranded on a tropical island to know that a sunny beach can be uncomfortably hot. This investigation will help you find out why you can burn your feet on the sand but keep cool in the water.



To get an accurate reading, the thermometer should be away from the side of the beaker.

Problem

Part 1: Do liquids absorb thermal energy at the same rate?

Part 2: Do solids absorb thermal energy at the same rate?

Safety Precautions

- Handle containers of hot materials with care.
- If hot oil or water touches your skin, hold the burned skin under a stream of cold water for several minutes. Have a fellow student inform your teacher at once.
- Wash your hands thoroughly at the end of the investigation.

Apparatus

hot plate
500 mL beaker
graduated cylinder
thermometer
retort stand with thermometer clamp
oven mitts
stopwatch
stirring stick
balance and masses

Materials

water
oil such as paraffin oil, mineral oil, or motor oil
vegetable oil
glass marbles
sand
steel shot

Procedure

Part 1

1 Pour 200 mL of water into a beaker. Place the beaker on the hot plate.

2 Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water but not touching the side or bottom of the beaker.

3 **(a)** Record the initial water temperature.

(b) You want to raise the water temperature by 30°C. What will the temperature be then?

Turn the hot plate to medium high. Time how long it takes to reach the temperature you calculated in 3(b). Record the time.

5 Turn off the hot plate. Use oven mitts to remove the beaker from the hot plate. Allow time for the hot plate to cool.

Repeat Steps 1 to 5 using vegetable oil and the other oil. **CAUTION:** If droplets of oil fall on the hot plate, they can ignite.

Part 2

1 Pour 100 mL of water into a beaker.

2 Add about 100 g of glass marbles to the water in the beaker. Place the beaker on the hot plate.

3 Using the clamp and retort stand, fasten a thermometer so that its bulb is in the water.

(a) Record the initial water temperature.

(b) You want to raise the water temperature by 30°C. What will the temperature be then?

5 Turn the hot plate to medium high. Time how long it takes to reach the temperature you calculated in 4(b). Record the time.

Use oven mitts to remove the beaker from the hot plate. Turn off the hot plate and allow it to cool.

7 Repeat Steps 1 to 6 using approximately 100 g of sand and of steel shot. (**Hint:** To be sure that the sand is heated evenly, you need to stir it with the stirring stick.)

Analyze

Part 1

1. Which liquid(s) took the longest time to increase in temperature by 30ºC?
2. Which liquid(s) took about the same time to warm 30ºC? Can you suggest a reason for this?

Part 2

3. Which solid(s) took the longest time to raise its temperature by 30ºC?
4. Which solid(s) took about the same time to warm 30ºC? Can you suggest a reason for this?

Conclude and Apply

5. Compare the times taken to heat the materials in Parts 1 and 2.

   (a) Does the kind of material being heated affect the amount of heat needed to change its temperature?

   (b) What piece of information shows you this?

Extend Your Knowledge

6. Look at your results for sand and gravel, and for water. Explain why the young man in the illustration is dancing the "hot foot jig" and the young woman is cool and comfortable.

Find Out **ACTIVITY**

Does Double the Water Take Double the Time to Boil?

Watched pots never boil. But does a full kettle take twice as long to boil as a kettle that is half full?

Does it take the same amount of thermal energy to heat water from cool to warm as it does to heat it from warm to hot?

Safety Precautions

What You Need

500 mL beaker
water
thermometer
clamp and stand
hot plate

SKILLCHECK

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

What to Do

1. Repeat Steps 1 to 5 from Conduct an Investigation 6–A, Part 1, using 400 mL of water at room temperature, and record the time it takes.
2. Repeat Step 1. This time, start with water at 40°C.
3. Clean up any spills and wash your hands thoroughly.

What Did You Find Out?

1. When you double the volume of water, does it take twice as long to heat to 30°C?
2. Do your findings change or stay the same when the starting temperature of water changes?

Specific Heat Capacity

READING Check

What unit is used to report specific heat capacity?

In Investigation 6–A, you found that different substances require different amounts of thermal energy to raise their temperature the same amount. This is true for all substances. Each substance requires a unique amount of heat gain or loss to change its temperature.

Specific heat capacity measures a substance's ability to absorb or lose heat. Specific heat capacity is measured in joules per gram degrees Celsius. This is often written as $\frac{J}{g \bullet °C}$ or J/g•°C

The specific heat capacity for water is 4.19 J/g•°C. This means that:

- One gram of water absorbs 4.19 joules of heat to raise its temperature 1°C.
- One gram of water loses 4.19 joules of heat to lower its temperature 1°C.

In the Find Out activity, you confirmed that the amount of heat needed to change the temperature of a specific amount of water does not change, regardless of the starting temperature of the water.

The specific heat capacity of sand is 0.66 J/g•°C. To increase the temperature of 1 gram of sand by 1°C would require 0.66 J of energy.

Look at these two numbers:

Specific heat capacity of water = 4.19 J/g•°C
Specific heat capacity of sand = 0.66 J/g•°C

As you can see from the numbers, the specific heat capacity of water is a lot higher than that of sand. It takes more energy to increase the temperature of water than it does to increase the temperature of sand. No wonder sand on a sunny beach is much warmer than the shallow water nearby.

Try This!

Take another look at your results from Investigation 6–A.

1. List the liquids in the order of the time it took for them to increase in temperature in Part 1. Start with the liquid that took the longest time. Does this list agree with the order of the specific heat capacities of the liquids in the table?
2. List the solids in order of the time it took for them to increase in temperature in Part 2. Start with the solid that took the longest time. Does this list agree with the order of the specific heat capacities of those solids in the table?

Table 6.1 Some Common Specific Heat Capacities

Substance	Specific Heat Capacity (J/g•˚C)
water	4.19
motor oil	2.00
vegetable oil	1.97
air	0.995
glass	0.84
sand	0.66
iron	0.45
copper	0.38

Warming Up and Cooling Down with Oceans

In Chapter 5, you learned that oceans moderate shore areas. In this chapter, you learned that water has a high specific heat capacity. Oceans store more heat energy or thermal energy than you might expect!

Add this new knowledge to what you know about sea breezes and land breezes. With its large specific heat capacity, water can absorb, store, or release much more thermal energy than land. That is another reason for land heating and cooling quicker than lakes and oceans.

Specific heat capacity affects climate in other ways.

- On a hot day, water will absorb heat. This slows the rise of temperatures in the surrounding area.
- At night, water will release heat. This slows cooling in the surrounding area.

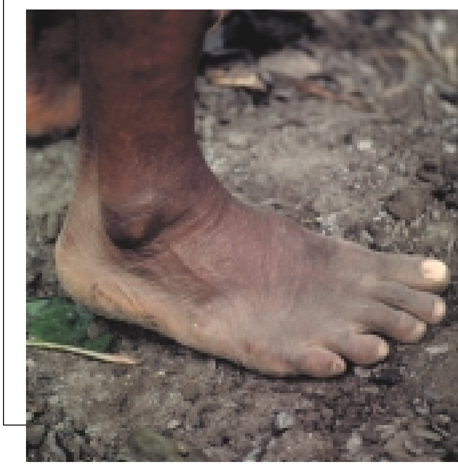
Figure 6.1 Warm water releases a large amount of heat as it cools. Many houses have hot water heating systems that use this feature. Water is used in hot water bottles because it stays hot for a long time.

Figure 6.2 In winter, Vancouver is warmed by the North Pacific Drift. This ocean current is warmed many thousands of kilometres away, across the Pacific. Even after travelling that distance, the ocean releases heat that keeps Vancouver warm during the winter.

Did You Know?

Figure 6.3 One secret of the fire-walker is knowledge of specific heat capacity. Before they walk on hot ashes, fire-walkers wear a thick pair of socks. The socks make their feet sweat. How might having a layer of water (sweat) on the soles of their feet protect fire-walkers from burns?

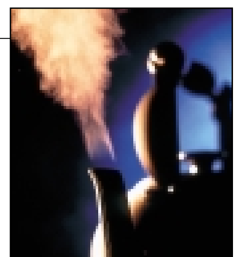
CAUTION: This is a dangerous stunt. Even if you have wet feet, *do not* try this yourself.



SCIENCE Myths

When water boils in a kettle you may notice a white "cloud" streaming from the spout. This is *not* water vapour. Water in gas form is invisible.

The cloud is condensed water droplets. To find water vapour, look closely at the spout. You will see a short, clear space between the spout and the cloud. That is water vapour.



Key Terms

heat absorption

specific heat capacity

Check Your Understanding

1. Which beaker in each of the following requires a greater input of thermal energy? Explain each answer.
   - **(a)** Beaker A with 250 mL and Beaker B with 500 mL of water are warmed from 10°C to 20°C.
   - **(b)** Beaker A with 250 mL of water is heated from 10°C to 20°C. Beaker B with 250 mL of water is heated from 10°C to 30°C.
   - **(c)** Beaker A with 250 mL of water and Beaker B with 250 mL of vegetable oil are heated from 10°C to 20°C.
2. Which of the following beakers would need a greater amount of heat to raise its temperature 10°C? Explain your answer.
   - Beaker A with 500 mL of water
   - Beaker B with 500 mL of sand
3. Why does water at a beach feel cooler than beach sand during the day and warmer at night?
4. Use your knowledge of specific heat capacity to explain why water is a better coolant than vegetable oil. Relate your knowledge of specific heat capacity to coolant in a car radiator.
5. You plan to make French fries. It's best to use very hot oil. Is oil with a higher or a lower specific heat capacity better? Explain your answer.

6.2 Keeping Heat at Home

Heat moves from hot toward cold all too well during Canadian winters. Heat leaks through windows, doors, walls, and roofs. Proper **insulation** can help this problem. Insulation slows heat transfer.

With insulation you get two benefits for the price of one. The same insulation that keeps heat *in* during the winter keeps heat *out* on a hot summer day. Knowledge of heat transfer teaches you how to keep your home warm in the winter and cool in the summer. But what makes a good insulator?

READING Check

Describe the purpose of an insulator.

R-value

Air transfers heat when it is moved by convection currents. Air is an excellent insulator when it is held still. Take a look at the insulating materials in Table 6.2. Which of the materials have pockets of air? Which have a high R-value?

R-value is a measure of how well an insulating material slows heat transfer. Materials with high R-values are better insulators than those with low R-values. An insulation of R-12 loses heat faster than one with R-16.

When materials are used together, the total R-value is the sum of the R-values of each material used.

Example:

The walls in your home have 25 mm of expanded polystyrene and 25 mm of rigid urethane foam. What is the R-value of your insulation?

- Check the R-value of 25 mm of expanded polystyrene.
- Check the R-value of 25 mm of rigid urethane foam.

The total R-value of these two materials would be: $3.96 + 7.50 = R\ 11.46$.

Figure 6.4 Heat will escape from your house no matter what you do. There are ways to make it escape slowly.

Table 6.2 R-values of Common Building Materials

Thickness of Insulating Material	Approximate R-value
25 mm of air space in a wall cavity	2.04
25 mm of air space with reflective surface on inside of wall cavity	5.54
25 mm of expanded polystyrene	3.96
25 mm of rigid urethane foam	7.50
25 mm of fibreglass	4.25
25 mm of solid wood	1.25
25 mm of wood shavings	2.42
25 mm of clay brick	0.11
25 mm of concrete	0.19
one thickness of glass	1.00
thermal glass (2 thicknesses with air space)	1.80

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

Ice Sculptures

It's your job to transport blocks of ice to a winter carnival. It is a warm sunny day for February. How will you keep the ice from melting on its way to the carnival site?

Problem

Which insulating material will save the most ice for carving?

Prediction

Consider the following types of insulation: foam pellets, aluminum foil, sheets of plastic bubble wrap, wood shavings. List these types, in order, from best insulator to the poorest.

Safety Precaution

- Use care when handling the coffee cans.

Apparatus

scale or balance
6 identical, empty, metal coffee cans with plastic lids
large basin
thermometer

Materials

ice cubes
paper towels
foam pellets about the size of peanuts
poured insulation
sheets of plastic bubble wrap
wood shavings
aluminum foil
sealable plastic bags

Procedure

1 In the large basin, prepare a warm water bath of about 60°C.

2 Prepare the coffee cans as follows:
- Half fill one can with wood shavings.
- Half fill one with foam pellets.
- Place the bubble wrap so it will fit, rolled, in another can.
- Cover the inside of another can with poured insulation.
- Line the fifth with aluminum foil.
- Do nothing with the sixth.

3 Choose six ice cubes that are approximately the same size.

Place each ice cube into a sealed plastic bag. Measure the mass of each one and record this data on a table similar to the one on the next page.

5 Put the ice cubes and bags into the cans as follows:
- One onto the wood shavings. Add enough shavings to fill the can.
- One onto the foam pellets. Add enough foam pellets to fill the can.
- One into the centre of the plastic bubble wrap.
- One onto the poured insulation. Cover it with insulation.
- One into the can lined with aluminum foil. Wrap aluminum foil around it.
- One onto the bottom of the empty can.

Put the lids on the cans.

7 Place the six coffee cans into a warm water bath for 30 minutes.

You have packed the ice cubes. While you are waiting, consider and revise your predictions.

After 30 minutes, quickly remove all ice cubes from their cans. Take each ice cube out of its bag. Pour out the water.

1 Place the cubes back into the plastic bags. Record the mass of each ice cube.

11 Clean up all materials and wash your hands thoroughly.

Insulation Material	Ice Cube Initial Mass (g)	Ice Cube Final Mass (g)	Ice Cube Mass Lost (g)
A wood shavings			
B foam pellets			
C bubble wrap			
D poured insulation			
E aluminum foil			
F empty can			

Analyze

1. In which container did the ice melt most? which least?
2. Which container had the best insulation?
3. Which container had the poorest insulation?
4. Did you conduct a fair test?
   (a) Which factors did you control the best?
   (b) Which factors did you control the poorest?

Conclude and Apply

5. Which would be the best material(s) to use to get the ice to the carnival?
6. There is another consideration. How would you insulate around the ice blocks to get them to the carnival? Would you be able to use the best insulator or would you have to switch to a second best? Explain.

Extend Your Knowledge

7. What else could you do to keep the ice from melting on the way to the carnival?
8. Would the best insulating material for ice blocks also be the best for keeping soup hot? Explain your answer.

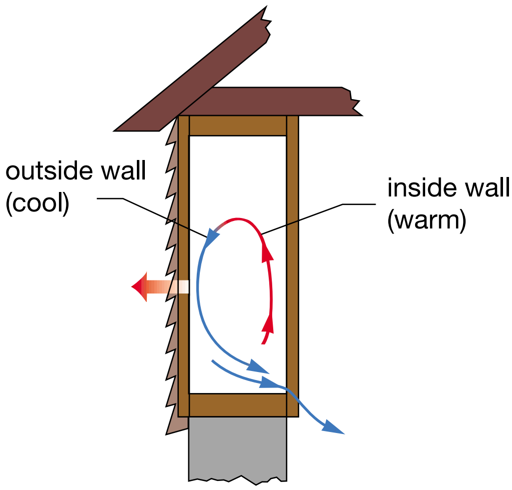


Figure 6.5 If a wall cavity is left empty, convection currents transfer heat across the space. How can these currents be stopped?

Other Ways to Keep the Heat in Your House

The empty space between the inside and outside wall of a house is called a wall cavity. Filling the cavity with insulation stops convection currents.

When insulation fills a wall cavity, there are many pockets of trapped, still air. In Conduct an Investigation 6–B, you likely noticed that materials that trap air helped prevent the ice cube from melting. Foam pellets and poured insulation work in this way.

The activity below provides other ideas that may help keep you warm. In doing this activity, you might experiment with which way to place the aluminum foil. Should the shiny surface face in or out?

SKILLCHECK

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

Find Out ACTIVITY

Will Aluminum Foil Keep You Warm?

Safety Precautions

What You Need

2 beakers (500 mL)

aluminum foil

thermometer

What to Do

1. Cover the sides and bottom of one beaker with aluminum foil.
2. Pour 500 mL of hot water into each beaker. Record the temperatures of the water.
3. Let the beakers stand undisturbed for 30 minutes. Record the temperatures of the water.
4. Make up a chart to show your observations.

What Did You Find Out?

1. Which beaker lost the most heat in 30 minutes?
2. What is the difference in temperature between the two beakers?
3. What effect does covering a beaker with foil have on heat transfer?

Conclude and Apply

4. Examine Table 6.2 on page 111.
   - What is the R-value for air space in a wall cavity?
   - What is the R-value for air space with a reflective surface on the inside of the wall cavity?
   - How does foil affect heat transfer?
   - Did the results of this activity agree with the information in the table?

Windows and Doors That Keep Heat In

Windows and doors are two weak points when you try to keep a house warm. A single pane of glass is a poor insulator. Heat escapes quickly through glass. To make matters worse, leaks develop around the panes and around the edge of the windows.

Older houses use double windows and doors — called storm windows and storm doors — to keep heat in. Today's exterior doors and windows use double glazing. This provides a space of still air. Insulation value of this still air is improved when air is mixed with a gas such as argon.

Exterior doors used to be solid wood. Modern doors are cavities filled with insulation. Some are metal covered. To prevent heat transfer, there is a break in the metal between inside and outside.

Take a look around your school and home. What else is done to keep heat leaking from windows and doors?

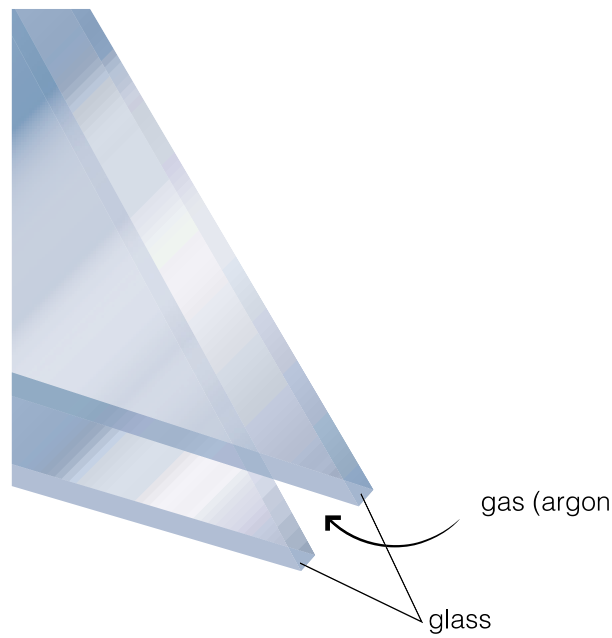


Figure 6.6 Windows in modern houses have double or triple glazing. They are constructed with two or three panes of glass spaced a few millimetres apart. The space between the panes of glass is filled with a mixture of air and a gas called argon. This slows the transfer of heat.

READING Check

List the ways that modern homes keep heat in.

Did You Know?

Check the size of one and a half millimetres. If you have a crack this wide around the outside of one window, your furnace may burn an extra litre of fuel per day.

Career CONNECT

Learning about today's technology for insulating houses demands on-the-job training as well as class time. You can apprentice yourself to a builder and take courses in building trades at an institute of technology. While you learn to build houses — from the footings to the roof — you will also study how to insulate them.

Try This!

Tie a piece of recording tape to a short stick. Hold this breeze detector near the crack of a window. If the tape moves in a draft, heat is leaking out of your house.

INVESTIGATION 6-C

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

Energy Efficiency

Think About It

What can be done to minimize the amount of heat that leaves your school building?

Public buildings have many places where heat loss can occur.

What to Do

1. With a small group, tour the school looking for places where heat might be lost from the school. (**Note:** As you move around the school, be careful to leave other groups undisturbed.)

2. Record your information on a table similar to the one here. Add more rows as needed.

Site of Heat Loss	Insulating Material	Approximate R-value

3. Suggest insulators you would use to minimize heat loss for the areas that you identified.
   (a) Identify the R-value of your suggested improvements.
   (b) Explain the reasons for your choices.

Analyze

1. Choose any two of your improvements. Estimate the R-value before and after your suggestion.

2. Compare your list with that of one other group. Working with that group, list your suggested trouble spots in order. Your list should go from areas of most to least heat loss.

3. List your suggested changes from the least to the most expensive to implement.

4. Write a brief report of your findings and present it to the administration of your school.

Extend Your Skills

5. Are there places in your home where heat loss can be minimized by adding insulation? List these places and state what you could do.

Off the Wall

R-values are fractions. R-4 insulating material lets one quarter of the heat pass through it in a given time. An insulator of R-8 lets one eighth pass through it. What fraction of heat would R-30 insulation allow to escape?

Controlling Heat Transfer

Knowledge of heat transfer is also used to keep things in your house warm.

Pizza parlours keep pizza warm by transporting it in insulated containers. As well as limiting heat transfer, the envelope must be washable. This limitation prevents the use of some of the materials you used in Investigation 6–B.

What material would you use if you were designing a pizza envelope? Would foil be a good choice? Explain.

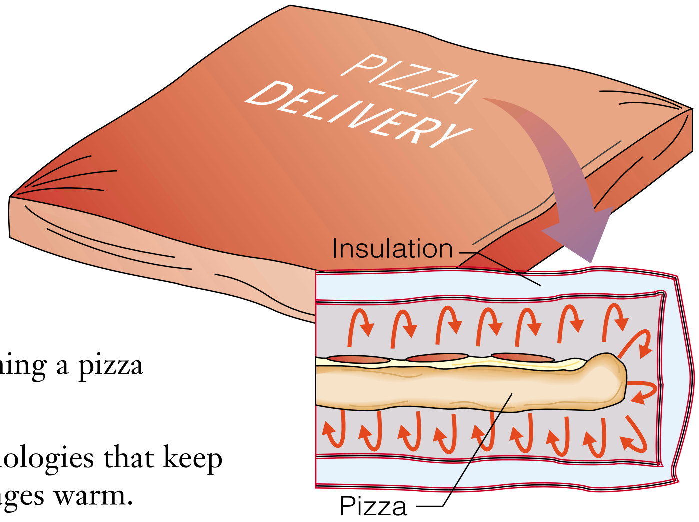


Figure 6.7 During delivery, take-out pizzas are insulated to keep them hot. The pizza is placed in a cardboard box. The box goes into an insulated envelope.

A **vacuum bottle** uses several of the same technologies that keep your house warm in order to keep food and beverages warm.

- Inside is a double glass jar. One jar is fitted inside the other — similar to windows with a double pane.
- Some air is removed from between the two jars. That is where the name comes from. The space is a partial vacuum.
- The jars are painted with a silver reflective coating.
- Rubber or plastic keeps the glass away from the outer case.
- The cap is insulated.

Can you point to where the vacuum bottle prevents the following types of heat transfer?

(a) conduction
(b) convection
(c) radiation

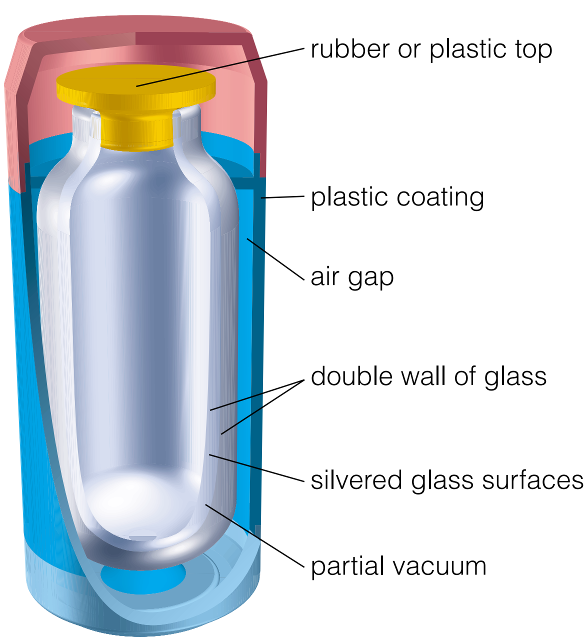


Figure 6.8 By blocking each of the three methods of heat transfer, vacuum bottles keep a drink hot all day.

READING Check

Explain how foil or silver controls heat transfer.

Try This!

Check around your home. Where are foil and reflective surfaces used to slow heat transfer?

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

When You're Hot ...

A vacuum bottle is just what you need if you want to keep a drink hot or cold. It does have one big fault. If you drop it once, you get to buy another. Perhaps you can improve that design.

Challenge

Construct a container that will keep water hot for four hours.

Safety Precautions

- Be careful when working with very hot liquids.

Apparatus

2 glass jars with metal lids
foam chips
thermometer

Materials

plastic bags
wool blankets or scarves
aluminum foil
newspapers
styrofoam pellets
duct or electrician's tape
string

Design Criteria

A. Insulate one jar. Use the other as a control. Compare the results with the two jars to see how well your insulation works.

B. Even with the insulation in place, the top of the insulated jar must be easy to reach and easy to unscrew.

Plan and Construct

1. With a group, consider and record the advantages and disadvantages of each insulating material provided.

Insulation Material	Advantages	Disadvantages

2. Decide the best insulator for this job. Sketch and label a design using these materials. Get your teacher's approval.

3. Build your insulated jar.

Fill both jars with hot water from the tap. Record the temperature of the water in each container. Put tops on the jars. Set them aside for four hours.

5. After four hours, open both jars. Measure and record the temperature of water in each jar.

Evaluate

1. Would you be able to keep hot chocolate warm with your insulated jar?

2. How might you improve your plan? Consider the following:

   (a) ability to insulate

   (b) ease of carrying

Extend Your Skills

3. Compare the results from your design with those from your classmates' designs. Which insulating material is best for this job?

Kitchen and Workshop

Like your house, large appliances — stoves, refrigerators, freezers, even dishwashers — are insulated. Insulation slows heat transfer, keeping ovens hot and freezers cold.

In Chapter 5, you found that non-metals are good insulators. Wooden and plastic handles on pots and pans allow you to pick them up from a hot element. Toasters are often encased in plastic or have plastic handles for the same reason. Soldering irons and torches use plastic or wood to protect your hands from the heat.

Aprons and mitts are worn in both shop and kitchen to protect the body and hands from heat transfer. You would no more imagine taking a pizza from the oven barehanded than you would consider arc welding without gloves, apron, and mask.

Figure 6.9 Many household appliances become hot when in use. They are fitted with protective coverings or handles to guard against burns to the skin. Plastic is a common material because it is a poor conductor of heat.

READING Check

List three ways that heat transfer is controlled in a kitchen or shop.

Check Your Understanding

1. Use Table 6.2 on page 111 to help you calculate the R-values of the following insulation materials. Show your calculations.
   - **(a)** 25 mm of air space + 25 mm of expanded polystyrene
   - **(b)** 25 mm of rigid urethane foam + 25 mm of solid wood
   - **(c)** 25 mm of air space + 25 mm of concrete
2. Examine Table 6.2. Explain the difference in R-value between solid wood and wood shavings.
3. Why do builders put more insulation in an attic than in walls?
4. Why is aluminum foil a good insulating material?
5. **(a)** Why does so much heat escape from windows and doors?
   (b) How can heat transfer be slowed?
6. Why are the handles of pots and pans usually made of non-metals?

Key Terms

insulation
R-value
vacuum bottle

6.3 Keeping Yourself Warm

The same techniques that keep a house warm also keep our bodies warm. On cold days, wear several layers — underwear, shirt, sweater, pants, and jacket. Choose inner layers for their open weave and thickness. Air trapped in the material serves as insulation. A windproof outer layer keeps warm air from escaping.

Some of the warmest winter clothes contain down. Birds grow fluffy, down feathers under the feathers you see. These feathers keep birds warm. Down is often quilted between the outer shell and inner lining of a vest or jacket. When down is fluffed, it holds air in place. The jacket material keeps air from blowing through the down and changing cold air for warm.

Reading Check

Using a diagram, show how down vests keep people warm.

Remember that a dry body is a warm body. Vigorous activity causes sweat. In Chapter 5, you were reminded how water causes cooling as it evaporates. When working or playing outside, you want to protect yourself from getting and staying damp. When you start to sweat, remove one layer, possibly another. This allows heat to transfer out and your body to stay at the right temperature.

Try This!

Examine wool and synthetic yarn under a 4x or 5x magnifying glass. Is yarn smooth or rough? How might this help to keep you warm?

As soon as you stop moving, replace those layers of clothing.

Reading Check

Explain why wool is a good insulator.

Figure 6.10 How does each piece of clothing keep these skiers warm?

People of the North

Traditionally, Caribou Inuit wear clothes like the ones in this photograph. On cold days, two complete suits are worn. The inner set is worn with fur next to the body. Body moisture is transferred through the fur and through the leather skin.

Caribou fur is dense; individual hairs are hollow. Air trapped between and inside the hair provides insulation.

The outer parka is worn with the fur outside. This is particularly important on very cold days. The parka hood traps air in front of the wearer's face. Frigid air is warmed before being breathed. This protects the wearer's lungs.

During extreme cold, water vapour from the lungs can condense and freeze on people's faces and clothing. Inuit hoods are designed to prevent condensation. The edge of the hood, where ice might form, is trimmed with fur. Ice does not stick to wolverine, wolf, or some dog fur.

Caribou and Copper Inuit wear up to four layers on their feet in winter. Seal skin is preferred for boots because it is waterproof.

Inuit parkas are much larger than you might expect. The large size allows wearers to bring their arms inside this warm space!

Figure 6.11 In the extreme cold of the Canada's North, Inuit designed the warmest clothing.

READING Check

Explain how Inuit clothing keeps the wearer warm.

DidYouKnow?

Some motorcyclists are now wearing clothes with built-in heaters. Heating elements sewn into the clothing warm areas — such as the torso — that can lose a lot of body heat. The clothing runs off a motorcycle battery and uses less power than a headlight. The amount of heat can be controlled using a palm-size computer.

DidYouKnow?

People outside in winter protect themselves from frostbite. Frostbite usually freezes hands, feet, and face. One way to warm a cold hand is to tuck it into your armpit for a few minutes.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect1

Clothing is designed to prevent you from losing body heat to the cold environment during the winter. To compare modern winter clothing with traditional Inuit clothing, go to the above web site. Go to Internet Connects, Unit B, Chapter 6, and then to Surviving in the Arctic. Write a note in your Science Log telling how these clothes work so well in extreme cold.

INVESTIGATION 6–E

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

A Winter Survival Car Kit

This driver might be here for a long time. What should he do to increase his chances of survival?

When a winter storm hits Alberta, snowploughs have trouble keeping up. Even in a city, you can be stuck far from help. Off main roads, you can be stuck for a day or even overnight. Wise drivers keep an emergency survival kit in their cars.

Challenge

Plan and assemble an emergency survival kit for your car. Include items necessary for hot and cold temperature extremes.

Design Criteria

A. Clothes in your kit should fit into a small overnight bag.

B. This unit emphasizes insulation. Choose clothes for their insulation value.

C. A container for other materials should be no bigger than a loaf of bread.

Plan and Construct

1. List what you will put in the kit in three columns: clothes, food, equipment.
2. Discuss alternative choices for each item.
3. Plan to collect, display, and justify the contents of your emergency kit.

Evaluate

1. In a snowstorm things get wet. Did you include extras of items you *must* have?
2. People dress lightly because their vehicles are warm. Did you pack layers of extra clothes — just in case?
3. Did you consider clothes that are insulators and those that are wind proof?
4. Many canned foods are bad after they have been frozen. Will you be able to heat and eat the food in your kit?
5. Eating snow is a poor idea. How will you get water?

Try This!

A simple plastic sheet can keep you warm. Sit outside. Wrap yourself until only your face is exposed. Note the amount of heat that builds up inside the plastic. List three situations in which you could use this knowledge.

Internet CONNECT

www.mcgrawhill.ca/links/science.connect1

When people drive away from their homes, do they expect to slide off the road, run out of gas, or have an accident? Most do not. But every day, hundreds of drivers do each of these things. That is why it is important to carry an emergency survival kit in your vehicle. To learn more about emergency survival kits, go to the above web site. Go to Internet Connects, Unit B, Chapter 6, and then to Emergency Survival Kit.

Keeping Cool

Are you surprised to see that people in hot areas wear so many clothes? They do this to minimize heat transfer. Long, thick robes protect bodies from the Sun's rays. Light-coloured clothes reflect heat from the environment, and allow body heat to escape.

Oven mitts work in a similar manner. Their quilted material reduces heat transfer. Some include reflective material that also reduces heat transfer.

READING Check

Explain how oven mitts work.

Figure 6.12 When Canadian summer arrives, we trade our winter coats and pants for T-shirts and shorts. People who live in hot, dry areas cover up.

Find Out ACTIVITY

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

Is Heat Transfer a Black and White Issue?

Safety Precaution

- Handle the thermometer with care.

What You Need

2 thermometers

2 socks of same thickness: one black, one white

tray

What to Do

1. Wait for the thermometers to get to room temperature.
2. Place the thermometers into the socks, one per sock.
3. Put the socks on the tray. Place the tray outside in the Sun. Be sure that sunlight hits both socks equally.
4. Wait 15 minutes and then record the temperatures.

What Did You Find Out?

1. After 15 minutes, were the temperatures the same?
2. Which sock absorbed heat faster?
3. Which sock would be hotter if worn on a hot, sunny day?
4. Would you be better to wear black or white on a hot sunny day?
5. Why do people who live in hot deserts prefer light-coloured robes?

Dressing for Intense Heat — or Cold

Firefighters and deep-sea divers have to deal with major changes in temperature. How do they do it?

Firefighters' suits are made of a special material. Many contain flame-retardant chemicals. When flames or sparks come into contact with the suit, the fabric chars but does not burn. The charred material produces a layer of insulation that protects the firefighter from too much heat.

READING Check

Explain how firefighters are protected from intense heat.

Firefighters can suffer from heat stroke if their body temperatures increase too much. Material on the inside of their fire suit absorbs body moisture. This helps to keep the firefighter cool.

Like people who work outside in intense cold, firefighters must carefully monitor their own bodies. If they get too hot, they could suffer from heat stroke, even at a winter fire!

The fabrics used in firefighters' suits are tested to determine their fire resistant qualities. Scientists test whether clothes are safe enough for firefighters to wear. They do this by dressing a mannequin such as Harry in fire gear and setting it on fire.

Figure 6.13 Fighting fires is hot work. Firefighters' bodies must be protected from the fire. Their clothing must also protect them from heat stroke caused by too much body heat.

Figure 6.14 Harry is a mannequin at the University of Alberta. His 110 sensors measure the rate and the amount of heat transfer from fires.

Off the Wall

A forest fire can cause its own wind. Look back to land and sea breezes in Chapter 5. Can you see how this might happen? And how the wind might be quite strong?

Even in hot climates, temperatures deep under water can be as cold as winter. A diver's suit should fit snugly. Tight diving suits prevent cold water next to the skin from causing cooling by conduction. If cold ocean water moved in and out of the suit, a diver would soon be cold. Water would pick up heat from the diver's body and carry it off into the ocean.

Dive suits are neoprene with bubbles of nitrogen trapped in the fabric. The more gas trapped in the fabric, the higher the thermal value. This means that neoprene suits are well insulated to keep body heat inside.

Dive suits have hoods for the same reason that winter parkas have hoods. Under water, a great amount of heat can be lost from a diver's head.

Figure 6.15 Even on hot summer days, a diver's body must be protected from cold ocean temperatures. If too much of the diver's body heat escapes, hypothermia could result.

DidYouKnow?

Some dive suits have titanium added to the side of the fabric that is next to the skin. The shiny titanium reflects heat back to the body.

Check Your Understanding

1. You plan to walk five kilometres on a day when it is –30°C outside. Describe the clothing that you will choose to keep your body warm. Give reasons for your choices.
2. Describe the protective clothing that a diver should wear when submerged in the cold ocean.
3. Name and describe three materials that could protect you on a cold day.
4. Describe three ways Inuit clothes are designed to keep the heat in.
5. Why do people in hot deserts and people in the cold North both wear head coverings?
6. How would a summer emergency car kit differ from the winter kit you planned?

CHAPTER
6 Review

Key Terms

heat absorption
specific heat capacity
insulation
R-value
vacuum bottle

Reviewing Key Terms

If you need to review, the section numbers show you where these terms were introduced.

1. You place a cold metal spoon in a foam cup of hot chocolate. Keep this scenario in mind. Write sentences that correctly use the following terms.
   (a) heat absorption (6.1)
   (b) specific heat capacity (6.1)
   (c) insulation (6.2)
   (d) R-value (6.2)
   (e) vacuum bottle (6.2)

Understanding Key Ideas

Section numbers are provided if you need to review. Use this Table of Specific Heat Capacities to answer questions 2 and 3:

Substance	Specific Heat Capacity (J/g•°C)
water	4.19
motor oil	2.00
vegetable oil	1.97
air	0.99
sand	0.66
iron	0.45
copper	0.38

2. A student performs an investigation to determine the specific heat capacity of three new substances. Where would you place each of the following new substances — near the top or near the bottom of the table? (6.1).
   (a) Substance X requires a large amount of thermal energy to increase the temperature of 1 gram of mass by 1°C.
   (b) Substance Y requires a small amount of heat energy to increase the temperature of 1 gram of mass by 1°C.
3. You heat a copper and an iron pot using the same method. Which pot heats more quickly? Explain your answer. (6.1)
4. Some animals have hollow tubular hair. Others have solid core hair. Which type of hair would best help the animal survive very cold climates? Explain your answer. (6.3)
5. Is it better to wear gloves or mittens on a very cold day? Explain. (6.3)

Developing Skills

6. A student wants to determine the specific heat capacity of water. The mass and the initial temperature of a sample of water have been taken. As the water is poured into another container to heat, some of the water is spilled. Would this affect the accuracy of the investigation? Justify your answer. (6.1)
7. Two cups contain hot chocolate from the same pot. One cup is half full. The other cup is one quarter full. Which cup will remain hot longer? Explain. (6.1)

Problem Solving/Applying

8. Two cups of hot chocolate are at the same temperature. One cup also has a metal spoon in it. Which cup will cool faster? Explain why. (6.1)
9. Two different objects are heated for the same length of time over a Bunsen burner. List three reasons why their final temperatures might not be the same.

10. You are told to pack fibreglass insulation tightly into a wall cavity because more insulation is better. Is this correct? Explain. (6.2)

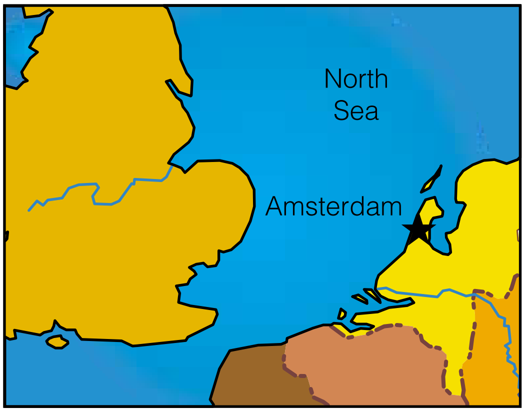
11. Have you noticed that birds fluff their feathers on a cold day? How does this help keep them warm? (6.3)

Critical Thinking

12. Mercury is the liquid in some thermometers. Mercury has a low specific heat capacity. Thermometers should adjust to change quickly. Is low specific heat capacity a disadvantage or an advantage? Explain. (6.1)

13. Hydrogen gas has the highest specific heat capacity of all substances. Would hydrogen be a good cooling agent? Explain. (6.1)

14. Edmonton and Amsterdam, the Netherlands (Holland) are about the same distance north of the equator. Their climates are very different. What might account for this? (6.1)



15. Fruit and vegetable growers will protect their crops by spraying them with water or by covering them with blankets when the outside temperature is expected to drop below freezing. What is the purpose of the layer of water and the blankets? (6.2, 6.3)

16. Research the protective clothing worn to protect one of the following groups from intense heat. (6.3)
    - race-car drivers
    - people who fight oil-well fires
    - people who work near volcanoes

    (a) What special materials are used in their clothing?
    (b) How do these protect the wearer?

Pause & Reflect

1. Check your original answers to the Getting Ready questions on page 104 at the beginning of this chapter. Would you answer the questions the same way now? What changes would you make?
2. How would your winter clothing selections change if you were dressing solely for warmth?