# 3 Investigating heat

## Planning page

**Getting started**

**3.1 Heat and temperature page 47**
- Investigate 6 Heat and temperature
- Skillbuilder page 50 Using maths equations
- Animation What affects the rate?

**3.2 Heat transfer page 53**
- Activity page 53
- Investigate 7 Which absorbs more radiation?
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- Animation Enzyme action

**3.3 Heat in everyday life page 62**
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- Assessment task 3 Methods of cooking

**Main ideas**
- Chapter 3 crossword

**Review**
- Chapter 3 test

# Essential Learnings for Chapter 3

| *Essential Learnings* | *References* | | |
|---|---|---|---|
| | ***Student book (page number)*** | ***Workbook (page number)*** | ***Teacher Edition CD (Assessment task)*** |
| **Knowledge and understanding**<br>***Energy and change***<br>Energy can be transferred from one medium to another | pp. 53–56 | pp. 20, 24 | |
| Transfer of energy can vary according to the medium in which it travels | pp. 53–54 | | Assessment task 3<br>Methods of cooking |
| **Ways of working**<br>Identify problems and issues, formulate scientific questions and design investigations | Investigate 6 pp. 49–50<br>Investigate 7 p. 57<br>Experiments pp. 59, 64–65 | | |
| Select and use scientific equipment and technologies to enhance the reliability and accuracy of data collected in investigations | Investigate 6 pp. 49–50<br>Investigate 7 p. 57<br>Experiment p. 59 | | |
| Evaluate data, information and evidence to identify connections, construct arguments and link results to theory | Investigate 6 pp. 49–50<br>Investigate 7 p. 57<br>Experiment p. 59 | | |

*QSA Science Essential Learnings by the end of Year 9*

## Vocabulary

absorbed
Celsius
conduction
conductor
convection
datalogger
infra-red
insulator
radiation
reflected
refrigerator
thermometer
thermos
transferred
transmitted
vacuum

## Focus for learning

Analyse a photo of a glassmaker in terms of heat transfer (page 46).

## Equipment and chemicals (per group)

| | |
|---|---|
| **Investigate 6 pages 49–50** | hotplate or burner, tripod and gauze, 250 mL beaker, thermometer, measuring cylinder (100 mL), stopwatch, olive oil, paper towel |
| **Activity page 53** | glass and metal rods about 20 cm long and same thickness, 2 paperclips, wax or grease, tripod, Bunsen burner and heatproof mat |
| **Activity page 55** | large beaker, used tea leaves, tripod and gauze mat, Bunsen burner and heatproof mat |
| **Investigate 7 page 57** | 2 thermometers or datalogger and 2 temperature probes, portable spotlight or electric radiator, 2 metal cans (one shiny and one dull black) |
| **Experiment page 59*** | identical metal cans, various materials to wrap cans (eg wool, cotton, nylon, polyester, flannelette), thermometers or datalogger and temperature probes |
| **Activity 3 page 64*** | same as for Investigate 7 |
| **Activity 4 page 64*** | coffee, milk, coffee cup, 2 thermometers or datalogger and 2 temperature probes, digital watch, graph paper |
| **Activity 5 page 65*** | saucepan and lid, hotplate or stove, digital watch, thermometer or datalogger and temperature probe |
| **Activity 6 page 65*** | cardboard boxes for students to construct model house |

* Students to list equipment they will need, which may be different from what is listed here.

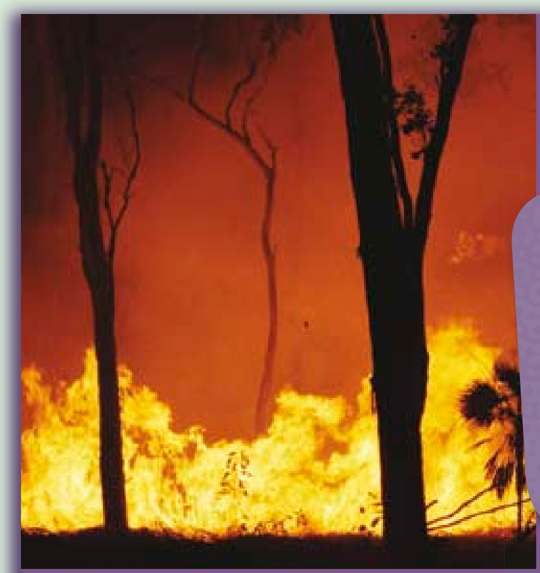
## Starting point

1 List some words relating to heat on the board and ask the students to construct a concept map with information about each word. They may like to perform this task in pairs. Make sure they do not use the glossary at the back of the text. You could use the map as a pre-test to help identify the facts they already know about heat.

2 After discussing the Getting Started points, you could ask the students to choose another point of interest relating to heat to discuss in small groups (about three students per group). Encourage each student in the group to share what they already know before formulating their group's final answer. What does each student believe the answer is, and why? How does it help the group to reach a final conclusion?

3 Ask questions like:
- Why do you sometimes feel a draught?
- Why do polar bears have black skin and white fur?
- How are clouds formed?
- On hot days, why do we perspire and dogs pant?
- In cold weather, why does a bird fluff up its feathers?
- Is it better to wear light- or dark-coloured clothing in hot weather and why?

4 The students could draw a simplified illustration of the Getting Started photo and write their answers to the questions in the relevant positions on their picture. Throughout the chapter, they could refer back to their illustration and continue to add explanatory information.

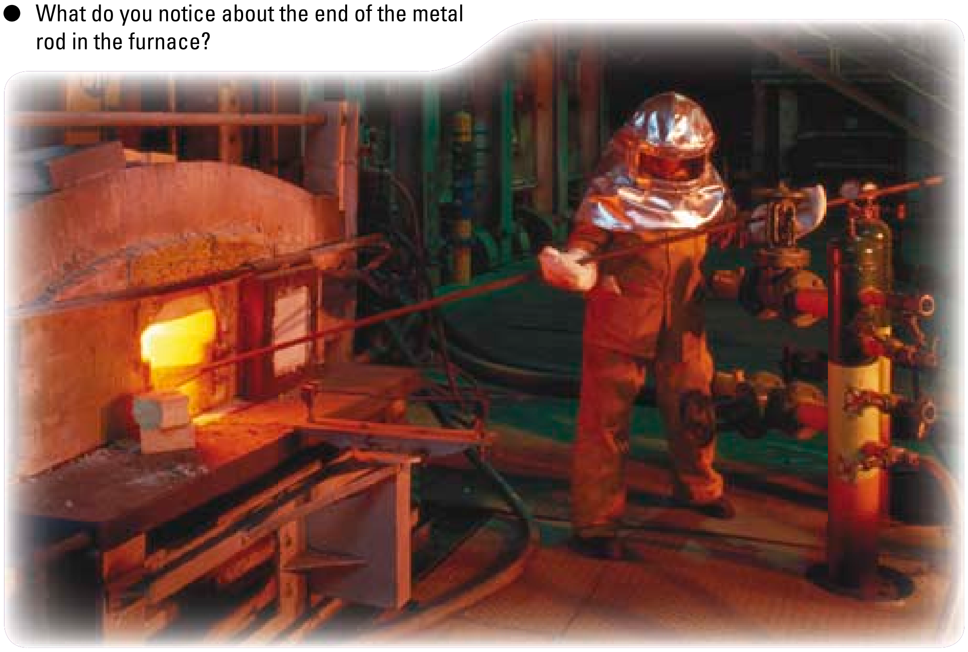


# 3 Investigating heat

## Getting Started

The photo shows a glassworker. The molten glass inside the furnace is at a temperature of more than 1000°C. The furnace and glass give off a huge amount of heat.

- What do you notice about the end of the metal rod in the furnace?
- List the items of protective clothing the worker is wearing.
- Suggest why the glassworker's clothing is silver-coloured.
- Describe two ways in which the heat moves from the furnace to the glassworker.



## 3.1 Heat and temperature

Heat is very important in our lives. Our body functions best at a temperature of about 37°C. If we get too hot or too cold we feel uncomfortable. If our body temperature rises too far above normal or too far below normal we can die.

We use fans, heaters and air conditioners to keep us comfortable. The walls and ceilings of our homes are insulated to keep heat in during winter and out during summer. We use heat for cooking food and for heating water. Heat is used by industries to make new materials such as glass, steel and plastics. Our cars produce heat when they burn petrol. Heat from burning coal is used to generate electricity. But what is heat? And how is it different from temperature?

Several hundred years ago, people thought of heat as a special fluid called *caloric* which flowed in and out of objects as they were heated or cooled. An American named Benjamin Thompson, who later moved to Germany and became Count Rumford, showed that this caloric idea was incorrect. He observed that when holes were drilled in brass to make cannons, so much heat was produced that water had to be poured over the cannons to cool them. From this

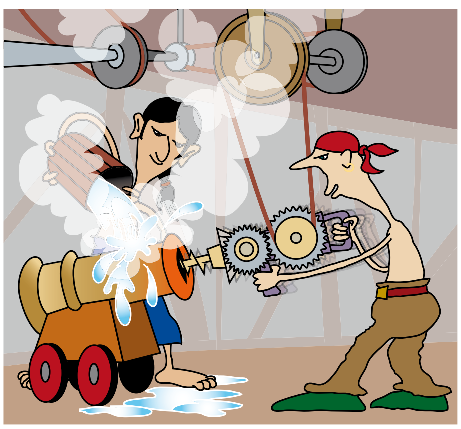


**Fig 2** Drilling brass cannons produced considerable heat. From this, Count Rumford inferred that heat is a form of energy.

Rumford inferred that it was the movement of the drills that made the cannons hot. The kinetic energy of the drill had been converted into heat energy. People soon realised that some heat is always produced when energy changes from one form to another. In other words, **heat** is a form of energy. For this reason it is measured in joules (J).

Heat and temperature are not the same, but there is a connection. **Temperature** is a measure of how hot or cold something is. It is measured in degrees Celsius (°C) using a thermometer.

You have probably used 'sparklers'. Each spark is actually a tiny piece of white-hot metal, and its temperature may be as high as 800°C. (The temperature of boiling water is only 100°C.) However, if a spark falls on your hand you don't even feel it. This is because each spark contains only a small amount of heat energy. Some of this heat energy is transferred to your skin, but the resulting temperature rise is so small that you usually cannot detect it.

**Fig 3** Each tiny spark has a high temperature but contains very little heat.

### Hints and tips

- Students often hold the misconception that *heat* and *temperature* are the same. In everyday life, *heating*, *cooling* and *temperature* are frequently used in ways that are inconsistent with their scientific definitions. Make sure to give the students very clear definitions of each.
- It may also be necessary to revise the concept of *energy* (*ScienceWorld 1* Chapter 12) and to ask the students to explain heat in the context of being a form of thermal energy.
- Temperature is a measure of how hot or cold something is and is often estimated subjectively. How hot it is outside to one person may be different for another person. Thermometers provide an objective measure of temperature, and degrees Celsius (°C) is commonly used. (The Celsius scale of temperature is based on the freezing point and boiling point of water.) For a thermometer to work, it needs to be made of a material which is affected by a change in temperature. Types of thermometers include glass-tubed thermometers (expansion and contraction of mercury or alcohol), liquid crystal thermometers (colour change) and electrical thermometers (change in electrical resistance).
- 'Stress cards' are novelty cards often found in showbags. They are activated by pressing your fingers onto a strip on the card which is sensitive to heat. If your hands are cold the card is likely to indicate that you are calm and relaxed. See if you can obtain some for the class to experience.

### Learning experience

Ask the students to investigate the subjective nature of temperature. They should work in pairs.

1. Have three bowls of water: hot (not enough to burn skin), ice-cold and warm.
2. Ask one student in the pair to place their left hand in the hot water and right hand in the ice-cold water for a few minutes.
3. While they have their hands in the water, the other student should measure and record the temperatures of each bowl of water.
4. The student with their hands in the water should take them out and quickly place them both into the bowl of warm water.

How does each hand feel now it is in the warm water? Ask the students to explain their feelings using words like *heat*, *hot*, *warm*, *cold* and *temperature*.

## Hints and tips

Ask the students to write down what they can recall about the particle theory of matter and how it applies to the context of heat (see *ScienceWorld 1* page 215). It is probably worth revising the theory with the class and to add any points you think necessary about heat.

*Particle theory*

- All matter is made up of small particles.
- There are spaces between the particles and each particle is attracted to other particles. The further the particles are from each other, the weaker the attractive forces.
- Each particle is moving (has kinetic energy).
- At high temperatures the particles move faster than at low temperatures.

*Consider adding:*

- The more energy the particles have, the faster they move.

## Homework

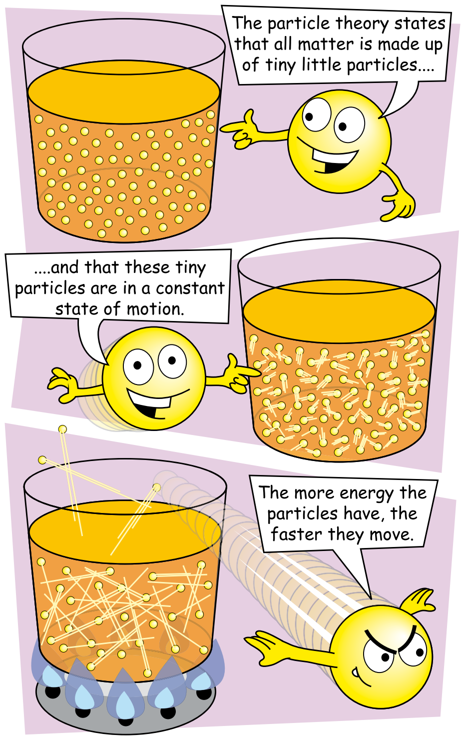
Ask students to investigate the Kelvin temperature scale and convert some temperatures from degrees Celsius to Kelvin (eg –273°C, 0°C, 20°C, 100°C, 300°C). They could construct a table listing the freezing, melting and boiling points of different substances, converting them from the Celsius scale to the Kelvin scale.



## Heat and the particle theory

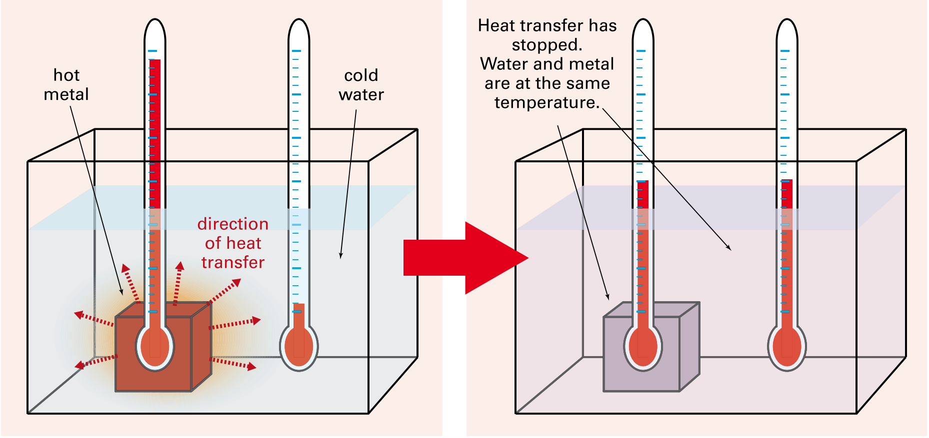
We can use the particle theory to explain heat. When you heat an object, the particles in it move more rapidly and therefore have more energy. This is why the temperature is higher. When the particles lose energy and move more slowly, the temperature is lower.

Look at the diagram below. When a hot object comes into contact with a cold object, heat flows from hot to cold until both objects are at the same temperature. The rapidly moving particles in the hot object transfer some of their energy to the particles in the colder object. The larger the temperature difference, the faster the transfer. Cool objects in warm places take in energy from their surroundings. For example, an ice block melts quickly on a hot day. Warm objects such as a cup of hot coffee lose heat energy to their cooler surroundings.




### Did you know?

If the temperature of a substance was lowered to –273°C, its particles would have no energy at all and would therefore be completely still. This temperature is called *absolute zero*, and scientists have come close to this in some experiments.




## Learning experience

Present to the class some interesting facts about heat and temperature. Alternatively, the students could compile their own list of facts, especially if they have access to computers. The students could be set a challenge to see who can find the most interesting or quirky points. Some interesting facts include: helium gas liquefies at –272°C and iron boils at 750°C; steam burns are more serious than burns from boiling water; the heating effect of radiant energy is one of the greatest dangers in a bushfire; sources of radiant heat can be identified from space using infra-red technology.

Investigate

# 6 HEAT AND TEMPERATURE

### Aim

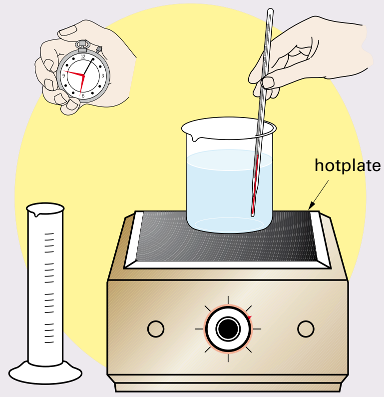
To find answers to these questions:

**A** Does the mass of a substance influence how much its temperature rises?

**B** Does the type of substance influence how much its temperature rises?

### Materials

- hotplate or burner, tripod and gauze
- 250 mL beaker
- thermometer
- measuring cylinder, 100 mL
- stopwatch
- **olive oil** **Flammable**
- paper towel




### Planning and Safety Check

Read through both parts of the investigation.

- Discuss with your teacher the safest way to handle the hot beaker.
- How is Part B different from Part A?
- Suggest why a hotplate is used in this experiment instead of a Bunsen burner.

Draw up a data table like the one below.

| | Temperature of the liquid (°C) before heating | Temperature of the liquid (°C) after heating | Rise in temperature (°C) |
|---|---|---|---|
| 50 mL water | | | |
| 100 mL water | | | |
| 60 mL olive oil | | | |
| 120 mL olive oil | | | |

## PART A

### Method

1 Use the measuring cylinder to add exactly 50 mL of water to the beaker.

Use the thermometer to measure the temperature of the water, to the nearest degree. Record this in the data table.

2 Adjust the hotplate or the burner to medium heat. *Leave it at the same setting throughout the experiment.* This is to make sure that the heater supplies heat at a constant rate.

3 Place the beaker of water on the hotplate for exactly *2 minutes*. Then remove the beaker from the hotplate, stir the water *gently* with the thermometer and read the temperature.

Record this temperature in the data table.

Calculate and record the rise in temperature.

4 Empty the beaker, cool it under running water, and dry it.

5 Add 100 mL of water to the same beaker and measure the temperature before and after heating for 2 minutes.

Record your results in the data table.

### Discussion

1 Which variable did you change in this investigation?

2 Which variables did you keep the same?

### Conclusion

Write an answer to the question *How does the mass of a substance influence how much its temperature rises?*

## Lab notes

- Hotplates are sometimes much safer to use than open flames, but the danger is that students can't see that they are hot and it is easy to get quite serious burns.
- Warn students about handling hot beakers and the possibility of injury or breakage.
- It is important to go through the safety procedures for using olive oil, especially if for any reason the oil catches alight.
- Instead of using olive oil, cooking oil could be used as a cheaper alternative. The specific heat capacity of cooking oil is about 2.2 J/g/°C, compared to 2.0 J/g/°C for olive oil.

## Hints and tips

- Most solids and a lot of metals have a low specific heat capacity, while most liquids have a higher specific heat capacity. This means that solids and metals heat up or cool down more quickly than liquids, and less energy is needed to raise the temperature of solids and metals.
- Did you know it takes more energy to increase or decrease the temperature of water by 1°C than any other common substance? This means that water retains its heat well and takes longer to heat up or cool down than other substances. Hot-water bottles used in bed in winter are an application of this principle.
- Ask students if they have ever bitten into a hot fruit pie, only to burn their tongue on the filling. The pastry and fruit filling are the same temperature, as equilibrium has been reached, so why is it the filling that burns your tongue rather than the pastry?
  - — The fruit filling contains a lot of water, while the pastry contains a lot of air.
  - — When you bite into the pie, the energy is transferred from the pie to your mouth.
  - — Each gram of air in the pastry gives out only about 1 joule of heat into your mouth for every 1°C lost. Each gram of water in the filling gives out about 4 joules (4.2 J) of heat into your mouth for every 1°C lost.
  - — This means the fruit filling transfers about four times as much heat into your mouth as the pastry does.

## Skillbuilder notes

Students who are less mathematically able are likely to need calculators to work out the solutions. It is worth doing the task as a class exercise. Allow the students a set amount of time to try the questions by themselves before going through the solutions together.

### PART B

**Method**

Repeat Part A, but this time use olive oil—60 mL and 120 mL. (Sixty millilitres of olive oil has the same mass as 50 mL of water.)

Record all results in the data table.

**Discussion**

Which variable did you change going from Part A to Part B? Which variables did you keep the same?

**Conclusion**

Write an answer to the question *How does the type of substance influence how much its temperature rises?*

From Investigate 6 you can conclude that—

**A** The same amount of heat will raise the temperature of 50 mL of water twice as much as it raises the temperature of 100 mL of water.

**B** The same amount of heat will raise the temperature of olive oil more than it raises the temperature of an equal mass of water. In other words, olive oil heats up more quickly than water does. The bar graph below shows the amounts of heat needed to warm 1 gram of various materials by 1°C.

You could also predict that if you supply twice as much heat to water or olive oil you raise the temperature twice as much.

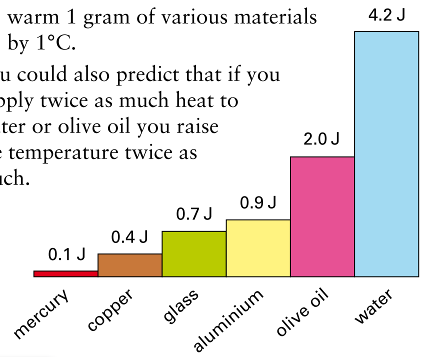



**Fig 7** The heat needed to raise the temperature of 1 gram by 1°C. You will notice that solids generally heat up more easily than liquids.

To summarise, the amount of heat gained or lost by an object depends on three variables:
- its mass
- the temperature change
- what it is made of.

You can calculate the amount of heat that is transferred if you know these three variables.

## Skillbuilder

### Using maths equations

The amount of heat energy needed to raise the temperature of 1 gram of a substance by 1°C is called its **specific heat capacity**. For example, the specific heat capacity of water is 4.2 joules per gram per °C. To calculate the heat needed to change the temperature of something, you can use this mathematical formula:

**heat (J) = mass (g) x specific heat capacity x change in temperature (°C)**

So, the heat needed to raise the temperature of 50 mL (50 g) of water by 10°C can be calculated as follows:

heat = 50 g x 4.2 x 10°C
= 2100 joules

Use the specific heat capacities from the bar graph on the left to answer these questions.

1. How much heat is required to:
   a. raise the temperature of 100 mL of water by 10°C?
   b. raise the temperature of 60 mL of olive oil by 10°C?
2. A 5 gram block of aluminium was heated from 30°C to 100°C. How much heat energy was needed?
3. How much heat is given out when 60 g of copper cools from 100°C to 20°C?
4. Using your results from Investigate 12, calculate the amount of heat transferred to 50 mL water, 100 mL water, 60 mL olive oil and 120 mL olive oil. Are they all the same?

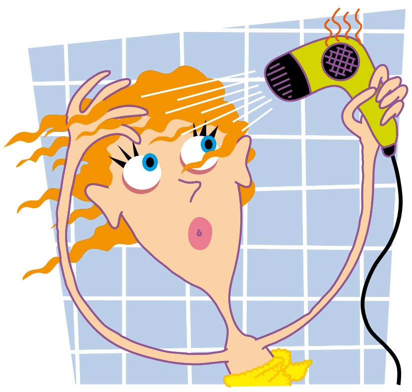
## Learning experiences

1. An interesting application of heat is to bake a tray of biscuits. When they are cooked, you take the metal tray with biscuits on it out of the oven and put it down to cool. Why is it that in a few minutes the tray is cool enough to touch but the biscuits are still hot? If hot objects transfer some of their heat to cooler objects, and both the metal tray and biscuits were originally the same temperature when they came out of the oven, why has the tray cooled down more rapidly than the biscuits? What is going on scientifically?
2. Turn this into a higher-order thinking task and allow students enough time to work through their ideas. You might like to set this scenario at the beginning of the lesson, and say that you will give them more time at the end of class to review their response if new concepts have been covered.

## Check!

1 Decide which of the following statements are true and which are false. Rewrite the false ones to make them true.
  a Heat is a form of energy.
  b When you strike a match, you convert kinetic energy into heat energy.
  c When an energy change occurs, some heat energy is always produced.
  d A block of ice contains no heat energy.
  e Heat is measured in degrees Celsius.
  f As an object becomes hotter, its particles move more rapidly.
  g Heat travels from cold objects to hot objects.

2 When Faith used an electric hair dryer to dry her hair, the hair dryer became quite hot. What energy change has occurred?



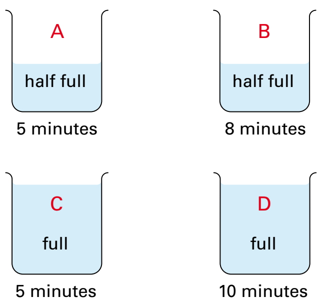
3 a Which is hotter—a cup of water at 50°C or a bathtub full of water at 50°C?
  b Which contains more heat energy?

4 A cold saucepan is put into a sink containing hot dishwashing water.
  a What will happen to the temperature of the saucepan?
  b What will happen to the temperature of the water?
  c Does heat flow from the water into the saucepan, or from the saucepan into the water?

5 Josh heats two identical iron nails together until they are red hot. He drops one into 50 mL (50 g) of water and the other into 60 mL (50 g) of olive oil. If both liquids are at the same temperature to start with, predict which will be hotter one minute after the nails are dropped in? Explain your answer.

6 Explain why heat energy can be considered a form of kinetic energy.

7 Eva had four identical beakers containing different amounts of water, as shown. She heated them for different lengths of time and none of them boiled.




  a Which beaker of water received the most heat?
  b Which beaker would you predict had the highest temperature after heating?
  c Which beaker would have the lowest temperature after heating?

8 Samples of 50 g of aluminium, copper, glass and water all initially at 20°C are heated for 5 minutes on a hotplate with a constant setting. Predict the order (from highest to lowest) of the final temperatures of each sample. See the bar graph on the previous page.

9 Suggest why mercury is used in thermometers. (Hint: see the bar graph on the previous page.)

10 On a hot summer's day the dry sand at the beach can be almost unbearable to stand on, while the water is cool. Try to explain this temperature difference.

### Check! solutions

1 a True.
  b True.
  c True.
  d False. Ice will contain some energy but not as much as the same amount of water.
  e False. Heat energy is measured in joules and temperature is measured in °C.
  f True.
  g False. Heat travels from hot objects to cold objects.

2 The hair dryer is changing electrical energy to heat and kinetic energy. Some of this heat will cause parts of the dryer to heat up.

3 a 'Hotness' (temperature) is measured by a thermometer and they are both the same (50°C).
  b The bath contains more heat energy because it has more water at this temperature.

4 a The temperature of the saucepan will increase.
  b The temperature of the water will decrease.
  c The heat flows from the saucepan to the water.

5 The olive oil will be hotter because it takes about half the heat energy to raise the temperature of olive oil by 1°C compared with an equal mass of water.

6 Kinetic energy is energy of motion. As an object is heated, the particles gain energy and move more quickly.

7 a Beaker D received the most heat because it was heated for the longest time.
  b You would predict that beaker B would have the highest temperature because it is heated longer than A and C and has only half the water compared to D.
  c You would predict that beaker C would have the lowest temperature because it is heated less than B and D and has twice the water compared to A.

8 You would predict that the order from the highest temperature to the lowest would be copper, glass, aluminium and water.

9 Mercury has been used in thermometers because it has a very low specific heat capacity and expands a lot, making the temperature easier to read. It is also a silver colour, which is easier to see, and has a high boiling point and low freezing point, which means that it will not change to a gas or solid at normal temperatures.

10 The main reason is that water has a high specific heat capacity and will heat up more slowly than sand.

## challenge

1 Ramone was making some ice blocks from fruit juice, and decided to investigate their temperature as they cooled in the freezer. He put a thermometer in one of them and measured the temperature every 10 minutes. His results are in the table below.

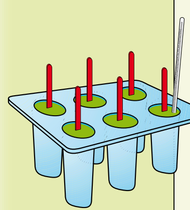
a Was heat being added to the ice blocks during Ramone's experiment, or being taken away from them?

b Plot Ramone's results on a line graph.

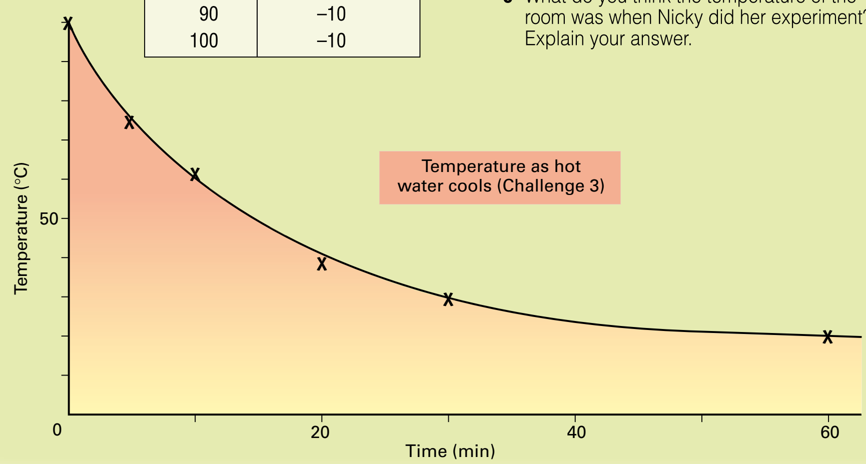
c Suggest a reason for the flat part of the graph between 40 min and 60 min.

d Suggest a reason for the flat part between 90 min and 100 min.

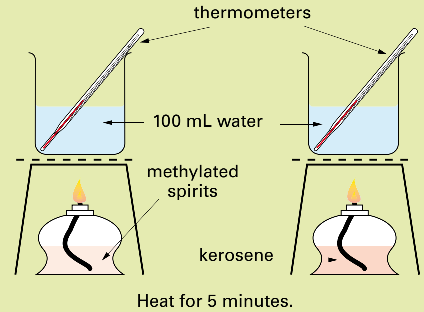
e At what temperature did the ice blocks freeze?



| Time (min) | Temperature (ºC) |
|---|---|
| 0 | 25 |
| 10 | 15 |
| 20 | 8 |
| 30 | 1 |
| 40 | –1 |
| 50 | –1 |
| 60 | –1 |
| 70 | –4 |
| 80 | –8 |
| 90 | –10 |
| 100 | –10 |




2 Harry did an experiment and drew these diagrams to show his method.




a Which variables did Harry control in this experiment?

b Which variable did he purposely change?

c Which variable did he measure?

d What do you think was the aim of Harry's experiment?

3 Nicky measured the temperature of a saucepan of hot water as it cooled. She plotted her results as shown in the graph.

a What was the temperature of the water after 10 minutes? After 40 minutes?

b Why is Nicky's graph steep to start with but flatter near the end?

c What do you think the temperature of the room was when Nicky did her experiment? Explain your answer.

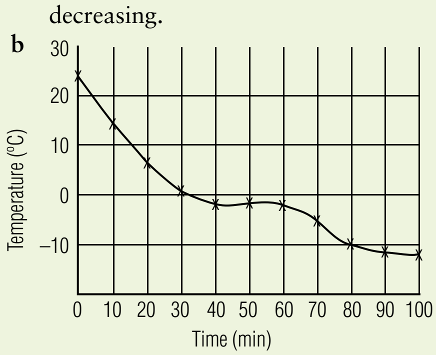
### Learning experience

If it is a nice day outside and there is a place on the school grounds that has grass butting up to a concrete path, take the class outside to investigate heat transfer through conduction. Get the students to place one bare foot on the concrete and the other foot on the grass. The students should notice a difference. The temperature outside is the same, so why do you feel a difference? Alternatively, use carpet and a tiled floor.

### Challenge solutions

1 a Heat was being taken away from the blocks because the temperature was decreasing.

b




c The reason that there is a 'flat part' on the graph is that a lot of heat energy is removed to change the ice blocks from liquid to solid.

d The most likely reason is that the temperature of the freezer is about –10°C.

e The ice blocks froze at –1°C.

2 a The variables that Harry controlled were the apparatus, the volume of water and the time he heated both beakers.

b The variable that he purposely changed was the type of fuel in the burner.

c The variable that he measured was the increase in the temperature.

d The aim of this experiment was to see which fuel (methylated spirits or kerosene) produced more heat when burned.

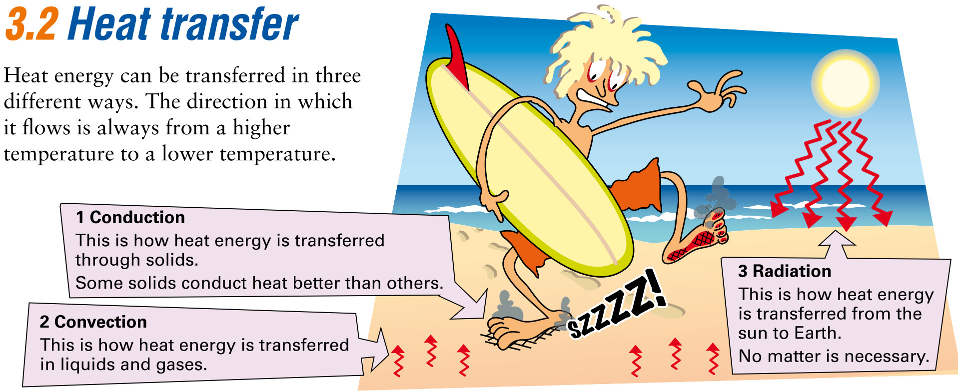
3 a After 10 minutes the temperature was about 60°C. After 40 minutes the temperature was about 25°C.

b The water cools quickly at first because there is a big difference between the temperature of the water and the temperature of the air.

c The water will not cool down any more after it reaches the same temperature as the room, which is about 20°C.

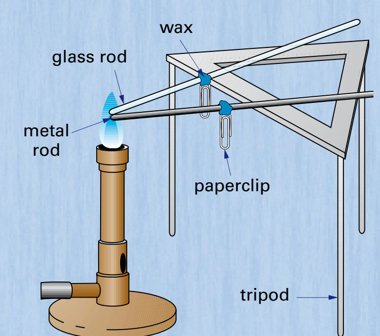
## 3.2 Heat transfer

Heat energy can be transferred in three different ways. The direction in which it flows is always from a higher temperature to a lower temperature.



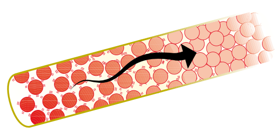

### Activity

1. You will need a glass rod about 20 cm long, and a metal rod the same length and thickness as the glass one.
2. Use wax or grease to stick a paperclip about 5 cm from the end of each rod. Then lay the rods across a tripod so that the paperclips hang down as shown.
3. Heat the end of both rods equally.
   Which paperclip falls off first? What does this mean?




### Conduction

A metal rod in contact with a hot flame quickly becomes hot. The heat is transferred along the rod by the process of **conduction**. The particles in the end of the rod gain energy from the flame. This causes them to vibrate faster and collide more energetically with each other. This process continues like a chain reaction from particle to particle along the rod. As a result, heat energy is transferred from the hot end of the rod to the cooler end.




To see how meat is cooked by conduction, open the **Cooking** animation on the CD. *Working with technology*

As you saw in the activity, some solids conduct heat better than others. Substances that conduct heat well are called good **conductors**, and most metals are good conductors. Substances like glass, which are poor conductors of heat, are called **insulators**. Most plastics are poor conductors of heat, so those that do not melt easily are used to make handles for saucepans, kettles, frying pans and irons.

### Hints and tips

- Discuss with the class how fragile the human body is, how easily we can damage it from burns, and preventative measures we can take to avoid damage. In terms of heat transfer, how can we burn ourselves? Discuss the cartoon of the surfer at the beach and ask the students if they can think of any other forms of heat damage they may have experienced.
- A burn caused by steam at 100°C is more serious than a burn caused by the same mass of boiling water. Each gram of steam transfers energy to your skin as it condenses to water at 100°C. The condensed water then transfers more energy to your skin as it drops in temperature, cooling to your body temperature. Boiling water does not have to condense, and so only transfers energy to your skin as the water cools to body temperature.
- Solids are better conductors of heat than fluids (liquids and gases). This is because the particles are more tightly bound together so the kinetic energy (heat) is more quickly transferred. Heat is transferred through the material via collisions between neighbouring particles. As the particles collide, they transfer some of their energy and this energy is then transferred to other particles. Make sure you remind the students that there is no net movement of particles during heat conduction.

### Learning experience

You may like to get the students to investigate cooling curves of some substances (links with Challenge 1, page 52). Paraffin wax is commonly used.

1. Place some small pieces of solid wax into a large test tube.
2. Place the test tube into a water bath.
3. Assemble the heating apparatus (Bunsen burner, tripod, heatproof mat, gauze mat) and a retort stand and clamp to hold the test tube upright in the water bath.
4. Place a thermometer in the test tube and heat until the paraffin has reached about 80°C.
5. Remove the test tube from the water bath and record the temperature of the paraffin every minute until the temperature has fallen to about 30°C.
6. Gently stir the paraffin with the thermometer while the liquid paraffin is cooling. (Stirring the wax stops the thermometer from setting in the wax.)
7. Construct and analyse the graph (cooling curve).

Note: if some paraffin solidifies on the thermometer, it can easily be removed by dipping it into boiling water, but do not get the students to do this.

Although students need an understanding of latent heat of fusion to fully understand the graph, this activity is great for extending students' thinking skills. Gifted students will readily analyse and be able to accurately interpret the data.

## Hints and tips

Explain why you often feel warmer in winter if you wear many thinner layers of clothing rather than one thick jumper. Furred or feathered animals fluff themselves up when it is cold to trap air between their fur or feathers and their skin. Why do you often find lizards or snakes lazing on a sunny rock early in the morning or late in the day?

## Research

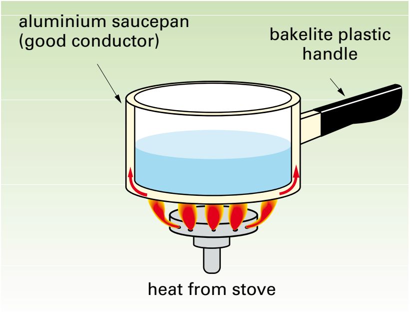
Students could investigate different types of housing insulation and produce a booklet detailing the pros and cons of each type in the context of heat. Three to five different types should be researched.

## Homework

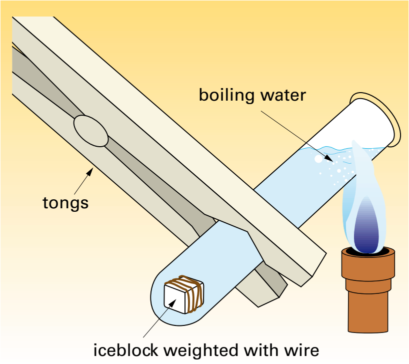
Ask students to investigate what heat principles are at work when making the dessert bombe alaska. The students may even wish to try making it themselves. (The sponge and meringue are good insulators and thus reduce the rate of heat transfer from the oven to the ice-cream centre.)

### Examples of conduction

Insulating handles allow you to pick up hot objects without the heat being conducted to your hand. Plastic foam is a good insulator, and is used in the walls of refrigerators to keep heat out.



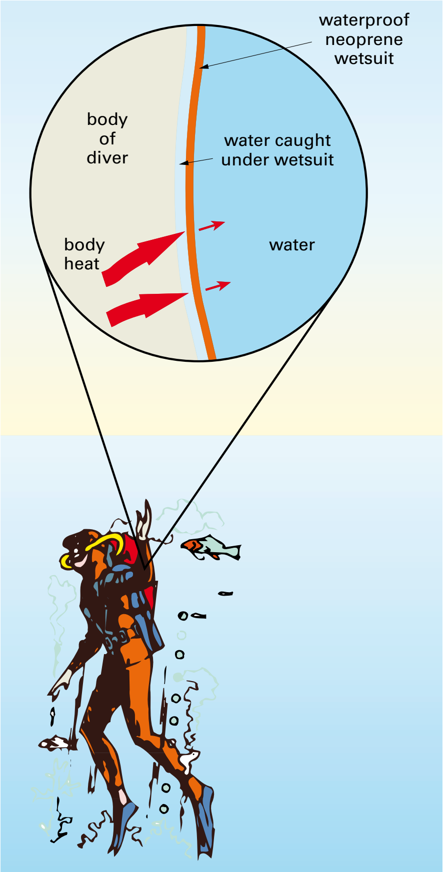

Liquids do not conduct heat very well. The set-up below shows that water is a poor conductor of heat. Even though the water boils at the top of the test tube, the ice at the bottom melts only slowly. If water was a good conductor of heat, the ice would melt quickly.




Gases are also poor conductors of heat. You can demonstrate this by holding your hand beside a burner flame. If air was a good conductor of heat, your hand would quickly be burnt, but it isn't.

You may have seen birds fluffing up their feathers on cold days. This is to trap air between their feathers. Because air is an insulator, it slows down the loss of heat from the bird's skin to the surrounding cooler air. Woollen jumpers, sleeping bags and the batts used to insulate houses also work by trapping air.

The wetsuits worn by surfers and divers are made of foam rubber. A thin layer of water warmed by body heat is trapped between the suit and the diver's skin. Being a poor conductor, this water helps to prevent the diver's body heat from escaping.



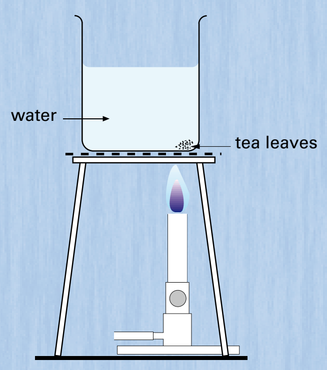

## Learning experience

Students can construct a chart listing as many heat conductors and insulators as they can think of. A good starting point for them is to use the examples given in the text.

Demonstrate to the class, or ask them to perform the investigation illustrated above of the weighted ice-cube and boiling water, to show that liquids are poor conductors of heat.

## Activity

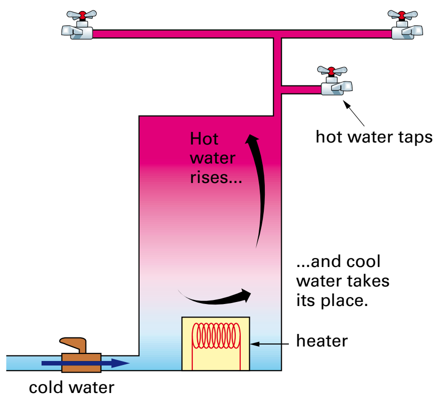
1 Fill a large beaker with water and allow it to stand until the water is completely still.
2 Carefully drop half a teaspoon of used tea leaves down one side of the beaker, making sure not to disturb the water.
3 Heat underneath the tea leaves as shown.
Suggest why the tea leaves rise.
Draw a diagram showing the movement of the tea leaves.




## Convection

The movement of the tea leaves in the activity above demonstrates the movement of heat energy by the process of **convection**. This process can be explained using the particle theory. When water particles at the bottom of the beaker are heated, they gain more energy and move more rapidly. Because of this, they move further apart than the particles above them. Hence the warm water near the bottom is less dense than the water above it. This warmer water therefore rises, and colder water moves in to take its place. This movement of particles is called a *convection current*. It continues until all the water in the beaker is at the same temperature.

Hot water systems work by convection. The heater at the bottom warms the water which moves upwards as the cool water takes its place, setting up convection currents. The hot water is drawn off from the top. When a hot water tap is turned on, more cold water flows in at the bottom.




Convection currents also occur in air. When you turn on a heater in winter, the warm air rises above the heater. A convection current is then set up as the cooler air sinks. The same thing happens on a larger scale to form a sea breeze. During the day the land is warmer than the sea, because the sea takes a long time to warm up. Warm air rises above the land, and cooler air blows in from the sea to take its place.

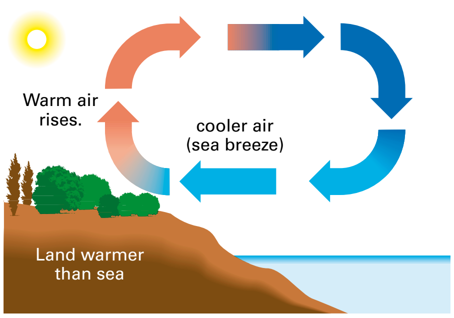



Fig 21 How a sea breeze is caused by convection

### Activity notes

- Remind students where to position the flame of the burner (under the tea leaves).
- It is important to review how to safely use a Bunsen burner.

### Hints and tips

As an example of convection currents, explain how the Daintree rainforest north of Cairns receives a large amount of rain each year. The forest is close to the sea and as the warm air rises it is pushed upward because of the nearby mountains and condenses forming rain.

### Research

For cricket-mad students, ask them to find out what the Fremantle Doctor is. (It is a sea breeze that blows in from the Indian Ocean towards Perth, reaching the WACA Ground during mid-afternoon on hot summer days. It comes from the direction of Fremantle and is just what the doctor ordered—a sea breeze!)

### Learning experience

Get the students to make their own spiral spinner to observe convection.

1 On a piece of paper, cut out a large circle, then draw a spiral in the circle. Cut along the spiral.
2 At the centre of the spiral, attach a piece of cotton thread, and tie the other end to a ruler or pencil.
3 Light a candle, reminding students not to leave their lit candle unattended. Carefully hold the paper spiral above the flame (not too close) so it doesn't catch alight, and watch as it starts rotating.

The candle flame produces a current of hot air, and as the air rises it causes the spiral to spin.

### Learning experience

Set up some temperature sensors around the room (ground level, ceiling, near a window, etc) for the students to read. They should notice a difference in temperatures, particularly between the ground level and ceiling readings. If it is possible, turn a fan heater on for a few minutes and check the sensors again. (Thermometers need to be used with care.)

### Learning experience

An alternative investigation to the one using tea leaves is place a few crystals of potassium permanganate in the beaker. You could do this as a demonstration using a large beaker for the whole class to view. When the water particles heat up, it is possible to see purple swirls due to convection currents.

## Hints and tips

- Give the class a quick quiz based on the material they have already learnt in this chapter. Ask the students to write the answers only (no need for the questions).
- Some students may not have seen a radiator heater (Fig 22) before. If the school does not have one for the students to see, you could find some photos on the internet. Explain how they work.
- One of the greatest dangers in a bushfire is the heating effect of radiant energy. Have a class discussion about why. You could also discuss why firefighters wear special reflective suits when combating some fires, and ask students what types of fabrics do they think firefighters' uniforms are made from.
- A vacuum is a space devoid of matter (a space containing no particles). A perfect vacuum is actually not possible to achieve. A vacuum is therefore considered to be a space containing a gas at very low pressure.

## Homework

Ask students to design an informative leaflet about the hazards in a bushfire in the context of heat. They should include diagrams and explain, in simple terms, safety measures which should be employed.

## Radiation

The Sun's rays heat the Earth. However, the space between the Sun and the Earth does not contain matter, so heat energy cannot be transferred by the processes of conduction or convection. Instead, the Sun transfers heat energy by the process of **radiation**.

All objects transfer some heat by radiation. The hotter the object, the more heat it radiates. The radiation itself is not hot, but when it is absorbed by an object it causes the particles in the object to move more rapidly, thus heating it.

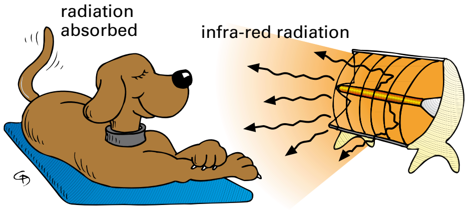



**Fig 22** The curved silver mirror at the back of an electric radiator reflects the radiation.

Warm objects radiate heat mainly in the form of *infra-red radiation*, which we cannot see but which can be detected by special infra-red scanners. People are usually warmer than their surroundings and give off more infra-red radiation. This is why infra-red scanners are used at night by air–sea rescue helicopters to help find people who are lost.

If a metal object becomes hot enough it will glow, giving off visible light as well as infra-red radiation.

Light, infra-red and other forms of radiation all travel as extremely high-speed waves which can pass through a vacuum, such as the vacuum of space. In a vacuum the speed of radiation is 300 million metres per second or $3 \times 10^8$ m/s. Different types of radiation have different wavelengths. The waves travel in straight lines, and they can be *reflected*, *absorbed* or *transmitted* by matter.

All of these properties of radiation are applied in microwave cooking. Microwaves are *reflected* off metals, so they reflect from the inside of the oven onto the food being cooked. The microwaves penetrate the food to a depth of between two and four centimetres, where they are *absorbed*. This causes the molecules in the food (mainly water molecules) to move more rapidly, and hence the food heats up. The heat is then transferred to other parts of the food by conduction. This process may continue for a short time after the food is removed from the oven. The microwaves are *transmitted* through the glass dish, which remains relatively cool because it absorbs very little radiation. (Microwaves will also pass through paper and most plastics.)

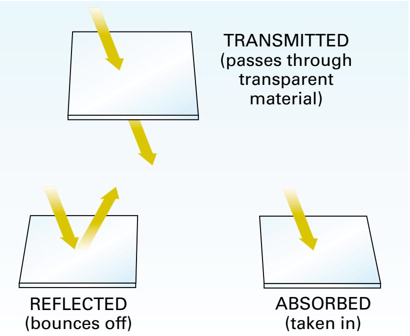



**Fig 23** Heat and light can be transmitted, reflected or absorbed.

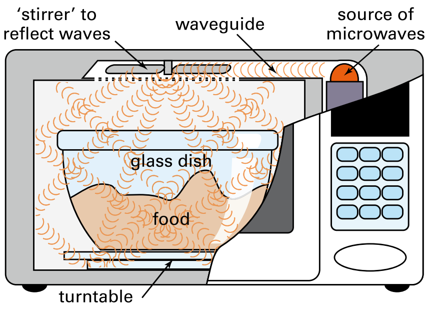



**Fig 24** How a microwave oven works. You can see through the glass door, but the microwaves cannot pass through the metal lattice behind the glass.

## Learning experience

The students could draw their own illustrations/cartoons depicting an everyday situation involving the three different types of heat transfer. They should provide annotated notes to accompany their illustration. Alternatively, the students could take a series of digital photos. They may like to compile a multimedia presentation.

## Learning experience

Ask the students how reflection of heat is similar to the reflection of light (*ScienceWorld 3* Chapter 3). It is important for the students to see how science concepts link together. Can they come up with their own links between heat and other science topics? Examples include heat and energy; conduction of heat and conduction of electricity; heat and chemical reaction rate; and heat and global warming.

Investigate

# 7 WHICH ABSORBS MORE RADIATION?

**Aim**

To compare the amount of radiation absorbed by a shiny silver can and a dull black can.

**Materials**

- 2 thermometers or datalogger and 2 temperature probes
- portable spotlight or electric radiator
- 2 metal cans—one shiny silver and one dull black

**NOTES**

1 Instead of using a spotlight, you could use a microscope lamp, or you could put the cans in direct sunlight.
2 If you use empty food cans, you could blacken one by holding it in the smoke from a burning candle. Painted soft drink cans work well.
3 To cut down on heat loss by convection, you need lids.

**Planning and Safety Check**

Read the Method carefully and discuss with your teacher what equipment you will use.

- What safety precautions will be necessary?
- Which can do you predict will absorb more radiation? Why?

In your notebook design a data table in which to record the temperature of each can every minute for 15 minutes.

**Method**

1 Add equal volumes of cold water to both cans.

2 Position the spotlight or radiator at an equal distance from each can.

3 Record the initial temperature of the water in each can. (These should be the same.)

4 Turn on the lamp and at the same time start timing.

Record the temperature in each can every minute for 15 minutes.

5 Plot the temperature for both cans on a single graph. (A datalogger will do this for you.) You could use a different colour for each can, but make sure you label the two curves.

**Discussion and conclusion**

1 Which was the independent variable, and which was the dependent variable?

2 Which variables did you control?

3 Which can absorbed more radiation? How do you know? Was your prediction correct?

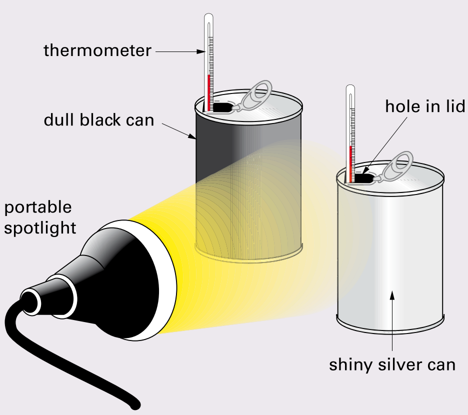
4 Look at your graph. What does the slope of each line tell you about the warming rate of the can?

5 Based on the results of this experiment, write a generalisation saying how the amount of heat absorbed by an object depends on the type of surface.

6 Could the experiment be improved? If so, how?

**try this**

Design a similar experiment to find out which can *cools* more quickly.




## Lab notes

- Ask the lab technician to prepare some painted black and silver cans (white paint can be used instead of silver) and put them aside for these classes.
- This investigation lends itself very well to the use of dataloggers (temperature sensors).
- If there are enough similar lamps available, it is far more effective to use one lamp per can.
- Since the lamps can get very hot, it is a good idea to place them on heatproof mats. Care should be taken when putting the lamps away to prevent burns to hands.

## Hints and tips

- Something which is red-hot is not as hot as the same item that is white-hot. If you observe the heating element in an oven or toaster, you will notice that as it heats up, its colour changes from dark red to a bright light orange.

## Learning experience

Set the class a challenge to design a solar cooker which toasts the tastiest marshmallow. The main materials you will need are aluminium foil, black paper and cardboard boxes.

1. Students should design their cooker by implementing ideas they have learnt from the investigation of heat. This activity could take anywhere from two to five lessons, depending on how much detail you incorporate into the task. It also lends itself well to project work. Groups of about three members work best.
2. Ask the students to draw a scientific diagram of their final design, then annotate it with notes which explain the use of materials, design shape and heat principles it uses. On a sunny day, it takes about half an hour until the marshmallow is liquefied inside. Surprisingly, a well-designed cooker still works on a rainy day.
3. Don't forget to remind the students to place their cooker facing towards the sun.

## Learning experience

As each student enters the room, give them a printed word card (some words may need to be doubled up). Ask students to write a definition for the word contained on their card. Choose students to read aloud their definitions, and make sure all the words are done. Suggested words: *heat, temperature, insulator, conduction, convection, radiation, reflected, absorbed, heat transfer, transmitted*.

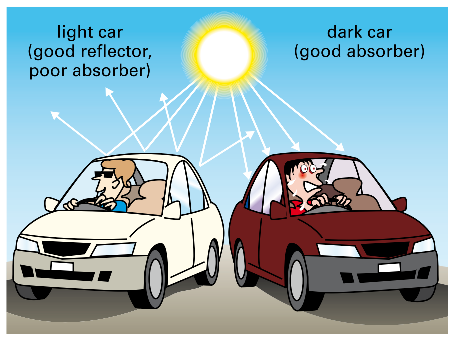
## Learning experience

Get students to compile a dot-point summary of the chapter so far. This can be added to later and used as a revision tool for tests or examinations.



### Absorbing and emitting radiation

Dark-coloured surfaces are better absorbers of radiation than light-coloured ones. This is because light-coloured surfaces reflect more of the radiation. Bright shiny surfaces are the best reflectors and the poorest absorbers. This is why aluminium foil is used in ceilings and walls of houses to reflect heat. On the other hand, the absorbing panels of solar water heaters are painted black so that the copper pipes inside them absorb as much of the sun's radiation as possible. Dark-coloured cars become much hotter than light-coloured cars when left in the sun. And dark-coloured clothes are hotter in summer than light-coloured clothes.




All objects emit (give out) infra-red radiation if they are at a higher temperature than their surroundings, but some radiate heat more readily than others. Dark-coloured objects radiate heat more effectively than light-coloured objects. Rough surfaces also radiate heat more effectively, due to their greater surface area.

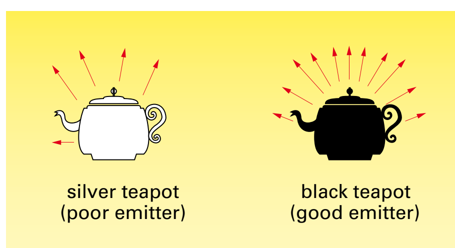


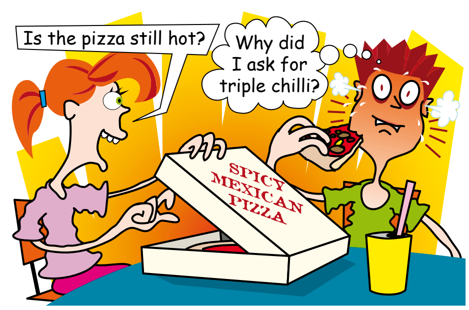


**Fig 28** The cooling fins on an air-cooled motorcycle engine have a large surface area to increase radiation of heat.

### Controlling heat transfer

An object that is warmer than its surroundings will lose heat until it is the same temperature as its surroundings. Similarly, an object that is cooler than its surroundings will gain heat from its surroundings. We use insulators to control this transfer of heat.

Eskys and thermos flasks (see page 63) are insulated containers to keep food and drink at the temperature we want it—either hot or cold. Pizza delivery people put their pizzas in special insulated boxes to keep them warm.




We insulate the walls and ceilings of our homes. This keeps them cool in summer by preventing heat from coming in from outside. It also keeps them warm in winter by preventing heat from escaping. (See page 65.)

## Learning experience

Number the students 1 to 5. Write five different thinking questions on the board and the students numbered 1 should answer question 1, and so on, up to 5. Ask questions such as:

- Why do elephants have big ears and polar bears have small ears?
- Why do some tea drinkers warm the teapot before filling it?
- What is the 'wind chill factor'?
- Why do small crowded rooms get so hot?
- How do tinted windows work?
- Why is damp clothing sometimes more hazardous than no clothing at all in cold conditions?

## Experiment
# WHICH IS THE BEST INSULATOR?

### The problem to be solved

Your task is to design an experiment to solve the problem *Which type of material keeps you warmest in winter?*

### Designing your experiment

The design of the experiment is up to you, but here are some questions to guide you.

- What will you use as a model for a human body? One idea is to use a can filled with hot water.
- How will you clothe your model bodies? What materials will you use? Some possibilities are wool, cotton, nylon, polyester, flannelette. How many model bodies will you need?
- How will you measure the temperature? How often will you do this, and how long will you continue the experiment?
- How will you make your test fair (as in Chapter 1)? You are varying the type of clothing, but what other variables are there? How will you keep these other variables constant?
- It would be a good idea to use an *experimental control*—a model body with no clothes. You can then compare the clothed bodies with it to see how effective the different types of clothes are.
- If possible, repeat your experiment to improve the accuracy of your measurements. If you get the same results, then you can be more confident your conclusion is correct. If *someone else* repeats your experiment and gets the same results you can be even more confident. Results like this are said to be *reliable*.

### Results

How will you record and display your results? If a datalogger is available you could use it. Would a graph be useful?

**Working with technology**

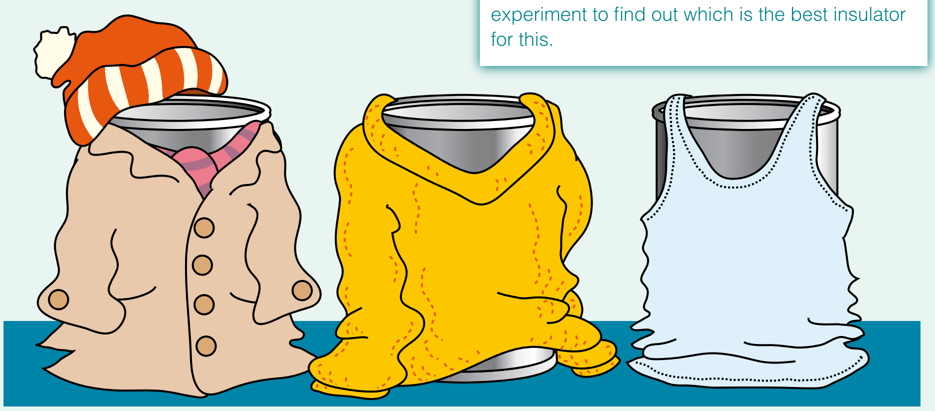
Computer programs such as Excel can be used for drawing graphs. Open the ICT skillsheet on the CD to see how this can be done.

### Writing your report

Look carefully at your results and write a report of your findings, giving your answer to the problem. You could take a digital photo of your set-up to include in your report. Could you improve your design? How?

**try this**

Instead of keeping something warm you often want to keep something *cold*. Design an experiment to find out which is the best insulator for this.



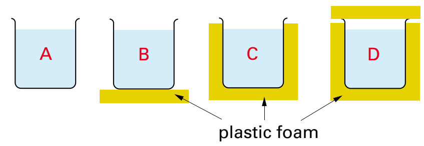
## Lab notes

- Revise how to design a fair test (see Chapter 1 pages 6–7 and 14).
- Fabrics can be cut to size by the lab technician before the lesson. Make sure to have a wide selection of different types of fabrics including natural and synthetic, open-weave and closed-weave.
- You will need a large collection of cans of the same size and material. Aluminium soft drink cans (375 mL) are ideal.
- This investigation also lends itself very well to the use of dataloggers.

## Check!

1 What is the advantage of a copper bottom on a saucepan?

2 The four beakers shown are identical and contain the same volume of water at 80°C. After 10 minutes the temperature of each is measured again.




a Which beaker do you think will be the hottest after 10 minutes? Why?
b Explain why the water in B will probably be a little warmer than that in A.
c What happens to the heat energy lost from the beakers?

3 An ordinary gas or electric oven is more correctly called a convection oven. Why? Draw a diagram showing how it works by convection.

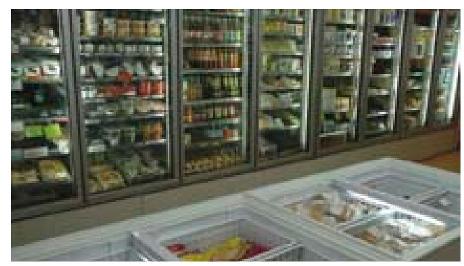

4 You put a can and a glass bottle of ginger beer into the refrigerator at the same time. They both contain 375 mL and are both at room temperature. Predict which one will cool more quickly. Why?

5 Refrigerators and freezers are painted white. Yet the coils at the back are painted black. Why is this?

6 Predict the effect that a chocolate coating would have on the rate at which an ice-cream melts. How could you test your prediction?

7 Polar bears have white fur and black skin. In winter their fur is fluffed up, and in summer it sits down flat. Suggest how these adaptations allow the bears to control their temperature.

8 In a supermarket the doors of vertical refrigerators must be kept shut, yet the freezer unit in the foreground of the photo has no lid. How can you explain this?



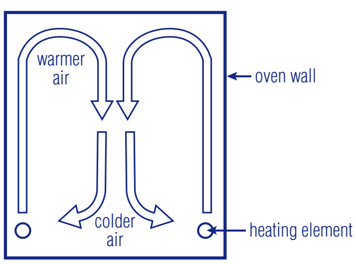
9 There are similarities and differences in the way light, heat and sound are transmitted, reflected and absorbed.
a Can heat travel through space where there is no air? What about light and sound?
b Can heat, light and sound be reflected? Give examples.
c Can heat, light and sound be absorbed? Give examples.

## Check! solutions

1 The advantage of a copper bottom on the saucepan is that it is a good conductor and will spread the heat more quickly and evenly.

2 a The beaker which will be hottest is D because the foam surrounding the beaker will reduce heat loss.
b The water in B will be a little warmer than A because the plastic foam will reduce the heat lost through the base of the beaker.
c The heat lost from the beakers goes to the air particles and eventually is radiated from the planet into outer space.

3 These ovens are called convection ovens because the heat is produced at the bottom and then the warm air circulates from the bottom to the top. This is shown in the diagram below.




4 You would expect the can of drink to cool more quickly because metal is a better conductor of heat than glass.

5 Refrigerators are designed to remain cool and are painted white so that they lose less heat by radiation. However, the coils at the back become hot and are painted black so that heat can be radiated more easily.

6 You would predict the chocolate coating on the ice-cream would speed up the rate of heating and melting. A simple way to test this would be to take two identical ice-creams and cover one with chocolate. You would then place them in the same conditions and observe how much ice-cream has dripped after a certain time.

7 In winter the fur is fluffed up to trap a layer of air next to the polar bear's skin. This air acts as an insulator and reduces the loss of heat. The black skin absorbs more heat than white skin and helps keep the body warm. In summer the hair lays down flat and less heat is retained in the hair.

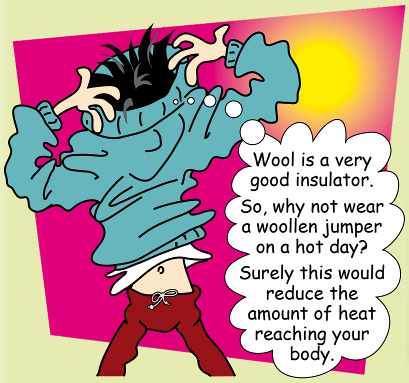
8 Cold air is more dense and will fall to the lowest point. In vertical refrigerators the doors must be kept shut whereas in the 'chest' freezers the air will not fall out and therefore lids are not used.

9 a Yes, the heat from the sun travels through space because it is a form of radiation similar to light, but sound must travel through matter such as air.
b Yes, all of these types of energy can be reflected. Light and heat can be reflected by a mirror, whether flat or curved. Sound can be reflected by a cliff or a large building. This is sometimes called an *echo*.
c Yes, all of these types of energy can be absorbed. Light and heat are readily absorbed by rough, dark surfaces such as black matting. Sound can be absorbed by soft, uneven surfaces such as curtains and carpets.

## challenge

1 What colour would you paint large petrol storage tanks? Why?

2 Look at the cartoon showing Jason thinking about how heat travels. Is he right? How would you answer him?




3 Ansa and Tammy filled two paper cups, one with water and the other with soil. They placed them in the refrigerator overnight. The next morning they took both cups, put them in the sun, and measured their temperature every 15 minutes. Here are their results.

| Time | Water | Soil |
|---|---|---|
| 9.00 am | 10°C | 10°C |
| 9.15 am | 10°C | 11°C |
| 9.30 am | 12°C | 13°C |
| 9.45 am | 13°C | 16°C |
| 10.00 am | 14°C | 20°C |
| 10.15 am | 15°C | 25°C |
| 10.30 am | 15°C | 30°C |

**a** Plot these results on a graph.

**b** Which absorbs heat more readily—water or soil?

**c** During the day, which becomes hotter—the land or the sea?

**d** Where would a glider pilot look for thermals (rising air)—above land or above a lake?

4 Hot-air balloons work by using a burner that heats the air below the balloon. How does this make the balloon rise?

5 Use the particle theory to explain the following.

**a** Conduction occurs much more rapidly in solids than in gases.

**b** Convection currents can occur in liquids and gases, but not in solids.

6 Design an experiment to compare the insulating properties of four different house bricks. Try it if you have time.

7 One end of a long glass rod is heated to 100°C and the other end is cooled to 0°C.

**a** What will happen to the temperature at each end if the rod is left at room temperature?

**b** Sketch graphs to illustrate the temperature changes at the two ends of the rod.

8 Using what you have learnt in this chapter suggest:

**a** four ways of preventing heat loss from your house in winter

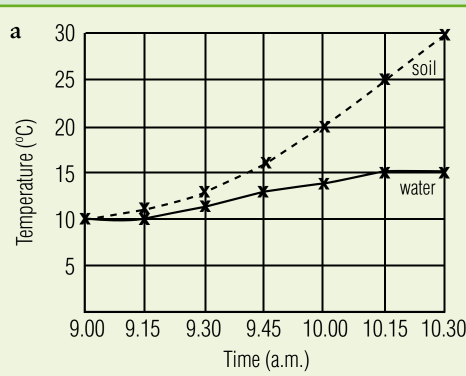
**b** four ways of preventing your house from getting hot in summer.

## Challenge solutions

1 It is important to keep petrol as cool as possible. It is a therefore a good idea to paint the tanks white to reflect heat from the sun.

2 Jason is wrong because he does not understand that heat is transferred in several different ways. A woollen jumper will trap a layer of air and reduce conduction and convection, but heat from the sun travels by radiation and passes through the jumper and the layer of air quite easily. Because the wool has trapped the layer of air, the heat will not be able to escape easily.

3 a




b Soil absorbs heat more readily.

c During the day you would expect the land to become hotter.

d A pilot would look for thermals above land rather than above a lake.

4 When the air inside the balloon is heated it expands. When it expands it becomes less dense and is pushed upward by the cooler, denser air around it. This explains why the balloon floats in the air.

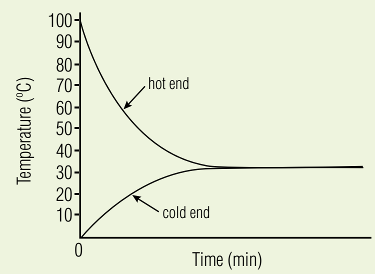
5 a When heat is transmitted by conduction, the particles bump into each other to transfer the energy. In solids, the particles are closer together than in gases and conduction occurs much more easily.

b When heat is transmitted by convection, the particles actually have to move from place to place. This can occur in gases and liquids but not in solids.

6 A very simple experiment to test insulating properties would be to drill a small hole in each brick and place a thermometer in each. You could then place the four different bricks in the sun and check the temperatures every 15 minutes. Then record the data in a table and possibly draw a graph.

7 a If the glass rod is left at room temperature, the temperatures at each end will slowly return to room temperature.

b




8 a Four ways of preventing loss of heat from your house in winter are to install:

- insulating 'batts' in the ceiling and possibly the walls
- good quality curtains and drapes to cover windows
- seals underneath and around doors to restrict air currents
- good-quality carpet and underlay to reduce heat loss through the floor.

b Four ways of preventing your house getting hot in summer are to:

- have insulation in the ceiling and possibly the walls
- have a light-coloured or shiny roof to reflect heat from the sun
- have lawns and gardens around the house rather than brick or concrete paths
- have pergolas or verandas to provide shade for outside windows.

### Hints and tips

Firewalking pits are usually around four metres long, which means the average person will take about four steps to walk from one end to the other. Normal walking speed allows for the foot to make contact with the ground for about half a second. If the foot is in contact with the coals for more than about one second, it will burn. Interestingly, there will be a trail of black footprints left behind the firewalker, lasting only for a few seconds. Why is this?

# 3.3 Heat in everyday life

This section is different from other sections of the book. Instead of working through it page by page, you can select any of the six activities on the following pages. You will need to apply what you have learnt in the first two sections and work things out for yourself. In some of the activities you will be designing your own experiments to solve a problem. If you need help with this, see Chapter 1.

## 1 Firewalking


You may have seen firewalking on TV, where people walk barefoot across a pit of red-hot coals. Some people think that this shows how the mind can influence the body. But it can be explained in terms of heat transfer.

Even when you walk barefoot on a hot bitumen road your feet can be burned as heat is transferred to them by conduction. So how can you walk on red-hot coals at about 800°C?

The coals are charcoal—formed by the partial combustion of wood. Only the outer layer of each coal is actually burning. When a firewalker's foot touches a burning coal, a small amount of heat is transferred to the foot by conduction. This loss of heat is enough to temporarily reduce the surface temperature of the coal below ignition temperature, causing it to stop burning.

The secret to firewalking is that charcoal is a poor conductor of heat, and it takes about a second before enough heat is transferred through the dead outer layer of skin on the foot to the living tissue beneath, thereby causing a burn. So, provided that the foot is in contact with any one hot coal for less than a second, it will not be burned.

Despite all this, firewalking is still dangerous, and you should not try it yourself! Firstly, burns can occur where the skin is thinnest; for example, under the arch and between the toes. Secondly, if there is any burning wood mixed with the coals it may produce hot gas jets capable of burning. Thirdly, small bits of coals can sometimes stick to the firewalker's feet. When this occurs the coal is in contact with the foot for longer than a second and a burn will result.

### Exercises

1 What is the temperature of red-hot coals?

2 What are coals made of?

3 Are coals good conductors of heat or poor conductors?

4 What is the main way heat is transferred in firewalking?

5 What is meant by the term 'ignition temperature'?

6 About how long does it take before living tissue beneath dead skin is burned?

7 Why is it a problem if small bits of coals stick to the firewalker's feet?

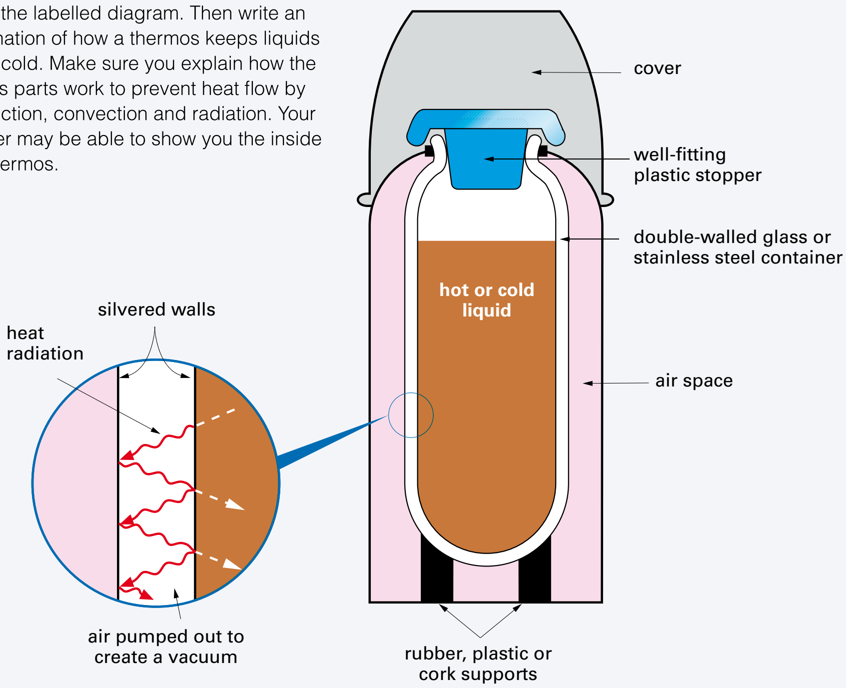
8 Given the maximum contact time of one second, is it safe to walk across the coals at normal walking pace? Explain.

9 Suggest why the maximum contact time is slightly different for different people.

10 How does firewalking illustrate the difference between temperature and heat?

## 2 How does a thermos work?

Study the labelled diagram. Then write an explanation of how a thermos keeps liquids hot or cold. Make sure you explain how the various parts work to prevent heat flow by conduction, convection and radiation. Your teacher may be able to show you the inside of a thermos.




### Hints and tips

The thermos or vacuum flask was invented in 1892 by the British chemist Sir James Dewar. The design of the flask reduces heat transfer by conduction, convection and radiation. The double-walled glass or stainless steel container reduces heat transfer by conduction. The vacuumed chamber reduces heat transfer by conduction and convection. The silvered (facing) walls reduce heat transfer by radiation.

## Hints and tips

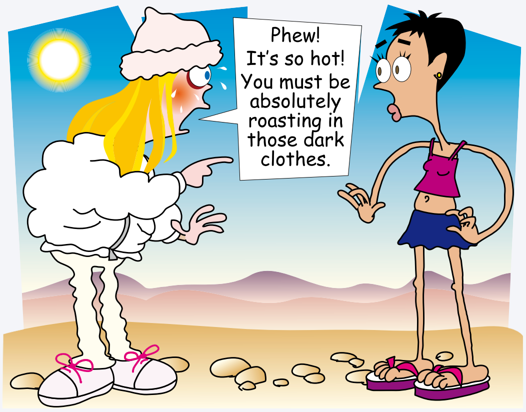
- Heat transfer, whether by conduction, convection or radiation, depends on the temperature difference between the object and its surroundings, and the surface area of the object.
- In Activity 3, light colours reflect radiant heat and dark colours absorb radiant heat. It is better to wear loose-fitting, light-coloured clothing in summer than tight-fitting, dark-coloured clothing.
- In Activity 4, it is important to keep the dimension of the cup constant (a short, wide cup exposing greater surface area cools faster than a tall, narrow cup). Students will need to take very accurate measurements to find any significant difference. Whenever you add the milk it will, of course, cool the coffee. However, the hot coffee with no milk added will cool faster than the coffee with milk added, because there is a greater difference between its temperature and room temperature. So it is better to add the milk first.
- Activities 3, 4 and 5 (pages 64–65) lend themselves well to the use of dataloggers.

## 3 Which is the coolest colour to wear?

*Which is the coolest colour to wear in summer?*

Design an experiment to find out. You could use a method similar to that in Investigate 7 on page 57, or you could work out your own design. A datalogger with several temperature probes would be very useful here.

Write your report, giving your conclusion and commenting on the accuracy and reliability of your method and results. Include a recommendation to people wanting to keep cool in summer.




## 4 Does white coffee cool faster than black coffee?

One evening as Mahdi was making coffee for Kyle and herself the telephone rang. Mahdi was just about to add the milk to Kyle's coffee when he said, 'The coffee will probably stay hotter if you add the milk after I've finished on the phone.' Mahdi knew Kyle would be on the phone for ages, so she said, 'Wouldn't it be better if I added the milk now? I learnt at school that dark-coloured things like coffee give off more heat and cool faster than light-coloured things like milk.'

Who is right? Write a hypothesis about the cooling of coffee. Then design and carry out an experiment to test your hypothesis.

You will need to make careful measurements and record your results on a graph. (You may be able to use a datalogger with temperature probes.)

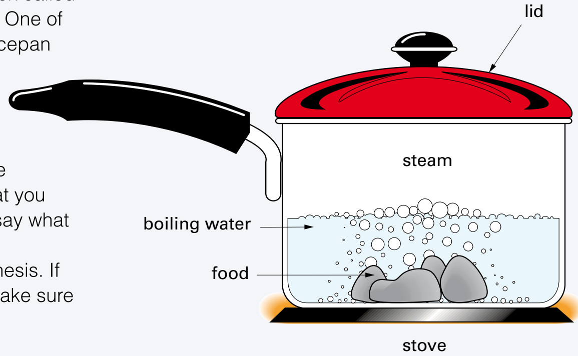
Is Mahdi's explanation correct? Is it to do with colour, or is it to do with the relative temperatures of the coffee and milk? How could you find out?

## 5 Why use a lid?

You have been glancing through a book called *101 ways to save energy in the home*. One of the tips is to always put a lid on a saucepan when cooking. You wonder whether this is in fact true.

Based on what you have learnt in this chapter, write a hypothesis that you think is correct. Make sure that the hypothesis is written in such a way that you can test it. For example, you need to say what will be measured.

Now go ahead and test your hypothesis. If possible, repeat your experiment to make sure your conclusion is reliable.




## 6 Designing a house

Your task is to design a house for your area that is cool in summer and warm in winter, using what you have learnt in this chapter about heat transfer.

Take into account how heat is gained and lost by an average house, as shown in the diagram. In your design you should consider:

- the position of the house
- the type of building materials used for the floor, walls and roof
- design features such as a flat or sloping roof, types of windows (eg single- or double-glazed) and ventilation
- the surrounds of the house, including the types of trees

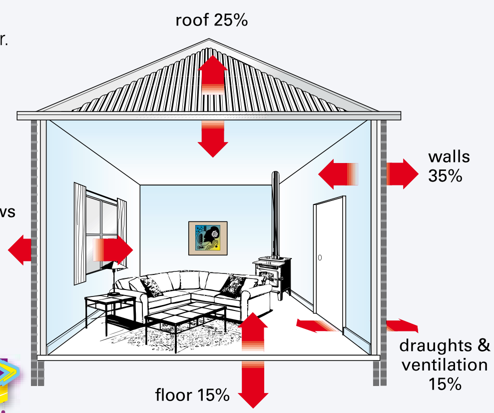



**Fig 43** The percentages of the total heat transfer in various parts of an average house

**WEBwatch**

To find out more about energy-efficient house designs, go to www.scienceworld.net.au and follow the links to **Sustainable energy info** (fact sheets on building) and **Energy Smart house design**.

### Hints and tips

- In Activity 5, it is safer for the students to use a hotplate rather than an open flame.
- In Activity 6, each group can work on a model house using cardboard boxes (computer boxes, photocopy paper boxes and boxes from the school canteen are ideal).
- The students choosing Activity 6 would benefit from doing the Webwatch. Allow them to use computers in the class if they have access to them, otherwise they can do it as a homework exercise.

### Assessment task

This would be a good place to set *Assessment task 3: Methods of cooking*, found on the CD.

## Main ideas solutions

1 energy, temperature
2 particles
3 mass, change
4 conduction, insulators
5 high, low, transfer
6 convection
7 radiation
8 absorb



## MAIN IDEAS

**Copy and complete these statements to make a summary of this chapter. The missing words are on the right.**

1 Heat is a form of _____ which can raise the _____ of an object.
2 The temperature of an object depends on how fast its _____ are moving. The faster they move, the higher the temperature.
3 The amount of heat gained or lost by an object depends on its _____, the temperature _____ and what it is made from.
4 _____ is the transfer of heat through a material by the collision of particles. Metals are the best conductors of heat. Poor conductors are called _____.
5 Heat energy flows from places where the temperature is _____ to where it is _____. Insulators are used to reduce the amount of heat _____.
6 _____ is where heat is transferred by circulating currents in liquids or gases.
7 Heat energy can be transferred across empty space by means of _____.
8 Dark-coloured surfaces _____ and emit radiation better than light-coloured surfaces.

absorb
change
conduction
convection
energy
high
insulators
low
mass
particles
radiation
temperature
transfer

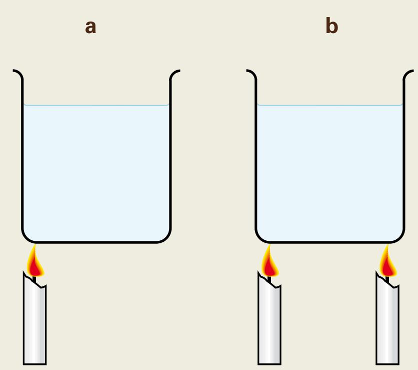
Try doing the Chapter 3 crossword on the CD. Working with technology

## REVIEW

1 If one end of a copper rod is held in a burner flame, heat travels quickly along the rod to the other end. Substances like copper which behave in this way are called good:
**A** absorbers
**B** insulators
**C** radiators
**D** conductors

2 A building is heated by running hot water through a number of radiators. The most efficient colour for these radiators would be:
**A** silver
**B** white
**C** black
**D** red

3 Copy and complete the diagrams below to show the convection currents you would expect to form in the water.

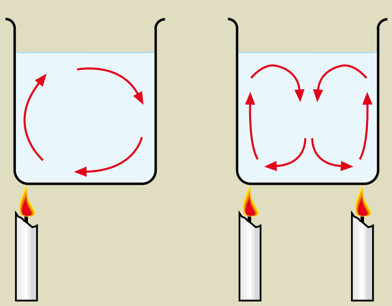



## Review solutions

1 D

2 C—see page 58

3

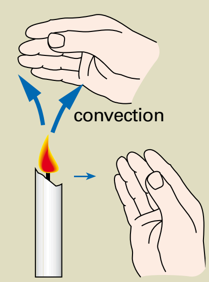


4 **a** true
**b** false—conduction is fast in *conductors* (or *slow* in insulators)
**c** true
**d** false—the Sun transfers heat energy to the Earth by the process of *radiation*
**e** false—the hotter an object is, the *more* radiation it emits
**f** true
**g** true

5 According to the particle theory (page 48) the particles in a hot object move more rapidly than the particles in a cooler object.

6 The amount of heat in an object depends on its mass, its temperature and what it is made of. So a bucket of water has more heat energy than a teaspoon of water at the same temperature.

7 When your hand is above the candle, heat rises through the air by *convection*. When your hand is beside the flame, some heat travels to your hand by *conduction*, but air is a poor



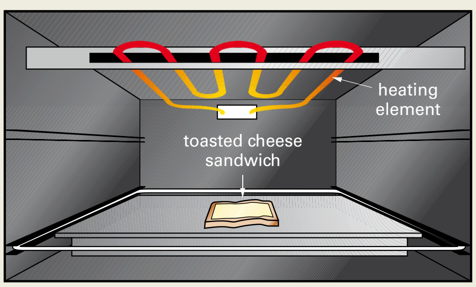
4 Which of the following statements are true, and which are false? Rewrite the false ones to make them correct.
  - **a** A cold object eventually heats up to the same temperature as its surroundings.
  - **b** Conduction is fast in insulators.
  - **c** Heat transfer by conduction is very slow in liquids and gases.
  - **d** The sun transfers heat energy to the Earth by the process of convection.
  - **e** The hotter an object is, the less radiation it emits.
  - **f** When an object absorbs radiation its temperature rises.
  - **g** Heat radiation travels at the speed of light.

5 If two objects are at different temperatures, what can you say about the movement of the particles in the hotter one?

6 Which has more heat energy—a teaspoon of water at 80°C or a bucket of water at 80°C? Explain.

7 If you hold your hand *above* a burning candle, you will burn yourself. Yet you can quite comfortably hold your hand *beside* the flame. Why is this?

8 Look at the diagram of a toasted cheese sandwich being cooked in a griller.
  - **a** How does heat travel from the heating element to the sandwich?
  - **b** Why can't the heat travel by conduction or convection?




9 Rory and Trent poured equal volumes of cold water into two identical styrofoam cups, then put identical thermometers in each. They put one cup in the sun and the other in the shade, and recorded the temperatures every 10 minutes. Here are their results.

| Times (minutes) | Temperature (°C) in sun | Temperature (°C) in shade |
|---|---|---|
| 0 | 15 | 15 |
| 10 | 16.5 | 16 |
| 20 | 18 | 17 |
| 30 | 20 | 17.5 |
| 40 | 21 | 18.5 |
| 50 | 23 | 19.5 |
| 60 | 24 | 20.5 |

  - **a** Plot the results on a graph.
  - **b** What conclusion can you draw from the graph?
  - **c** What variables did Rory and Trent control in this experiment?
  - **d** Which method of heat transfer caused the increase in temperature of the water in the cups?
  - **e** What would be the effect of painting the cup in the sun black?

10 A manufacturer claims that a certain insulating material is good 'to keep the cold out'. Is this expression accurate? Explain using a diagram.

11 Do sheep get colder when it is raining and their wool is wet? Design an experiment to find out, listing the steps you would need to take to make it a fair test.

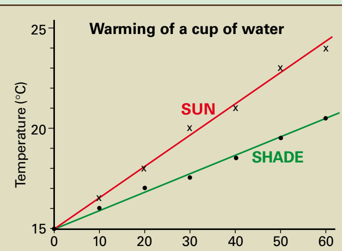
Check your answers on pages 318–319.

conductor of heat. The candle is not hot enough to produce a lot of radiation.

**8** **a** Heat travels from the heating element to the sandwich by **radiation**.

**b** Heat cannot travel *downwards* by convection, and conduction through the air would be very slow because air is a poor conductor.

**9** **a**



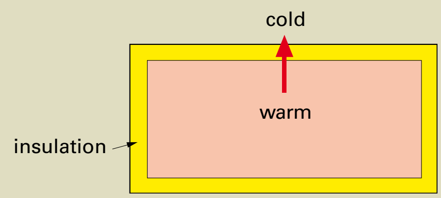

**b** The cup of water in the Sun warms up more rapidly than the cup of water in the shade.

**c** Same volume of water in each cup
Identical cups
Same initial water temperature
Identical thermometers

**d** Heat was transferred to the cups by **radiation** from the Sun.

**e** If you painted the cup black it would absorb more radiation. However, as it warmed up it would probably lose heat more rapidly than an ordinary styrofoam cup.

**10** Heat flows from warm places to cold places. So the insulation is to slow down the movement of heat from warm to cold. It is therefore better to say 'to keep the warm in' rather than 'to keep the cold out'.




**11** You can base your experiment on Investigate 7 on page 57.

1. Make two model sheep, eg by wrapping wool around soft drink cans.
2. Wet the wool on one of the cans.
3. Fill both cans with warm water at the same temperature, and put a thermometer in each.
4. Record the temperature in each can every minute for 15 minutes.
5. Plot the results on a graph and decide which 'sheep' cools more rapidly. This should give you some idea of whether sheep get colder when it is raining.