Unit 6.2 Heat

context

In summer you can feel the warming heat of the Sun. You sweat and fan yourself and need to take off layers of clothing to stay cool. In winter you put on extra clothing to stop you from cooling down too much. Heat warms, dries, cooks, melts and burns. Heat is a form of energy that affects us every day.

Fig 6.2.1 Heat is a form of energy that can cook and warm us. It can also destroy.

Heat and temperature

Heat something and the extra energy will raise its temperature or change its state. Temperature depends on heat but is very different to it—**heat** is a form of energy, but temperature is not.

To understand the difference, consider two Bunsen burners set on a blue flame. One heats a beaker half-filled with water and the other heats a beaker filled with water. After one minute, both beakers have been supplied the same amount of heat energy, but the full beaker will be at a lower temperature.

When an object gets hotter, its particles vibrate more rapidly. Cool it and the particles vibrate slower. **Temperature** measures how much these particles are vibrating.

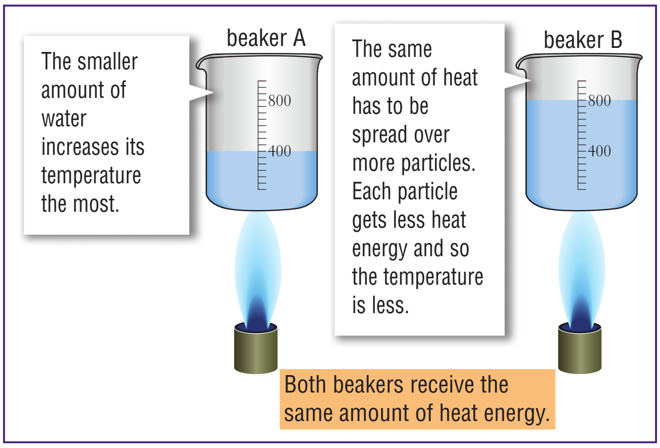

Fig 6.2.2 Heat is not the same as temperature.

Temperature is commonly measured in degrees Celsius (°C). As shown in the table, other temperature scales are also used in different parts of the world and by different people.

Heat moves from one area to any other area that is at a lower temperature. Heat can move in three ways—by conduction, convection or radiation.

Temperature scale	Symbol	Inventor	Water freezes at	Water boils at	Commonly used by
degrees Celsius	°C	Anders Celsius (1742)	0°C	100°C	• Most countries for weather • Scientists
degrees Fahrenheit	°F	Gabriel Fahrenheit (1717)	32°F	212°F	• USA for weather
kelvin	K	William Thomson (later known as Lord Kelvin) (1848)	273 K	373 K	• Scientists only

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Worksheet 6.2 Temperature

Science Fact File

People in science:

Anders Celsius (1701–1744)

Anders Celsius was born in Uppsala, Sweden, in 1701 into a family of scientists. One grandfather was a mathematician and the other an astronomer, as was his father. Anders himself became a professor of astronomy at the age of 29. He went on several geographical expeditions, including some to polar regions and the equator to compare the length of a degree along a line of longitude in both places. His measurements confirmed Isaac Newton's opinion that the Earth was slightly flattened at the Poles compared to a perfect sphere.

This expedition helped make Celsius famous, and enabled him to raise funds to build the Uppsala Observatory, where he became director.

Celsius is most famous for inventing the Celsius temperature scale, in which he made the boiling point of water zero degrees, and freezing point 100 degrees (the opposite of today's scale). In 1745 Carolus Linnaeus reversed this to the scale we use today.

Celsius contributed to astronomy by making many observations, including measuring the brightness of 300 stars. To do this, he tested how many glass plates were needed to stop light from each star getting through. It took 25 glass plates to stop light from the brightest star in the sky, Sirius, from getting through.

Conduction

You may have experienced conduction if you have touched a metal tap that has had hot water running from it, or felt the handle of a metal spoon that has been left in a cup of hot water.

Conduction occurs when the particles in one part are heated, causing them to vibrate more. These vibrations are then passed on from particle to particle through the object. The particles do not actually move along the length of the object—they just pass along the more increased vibrations.

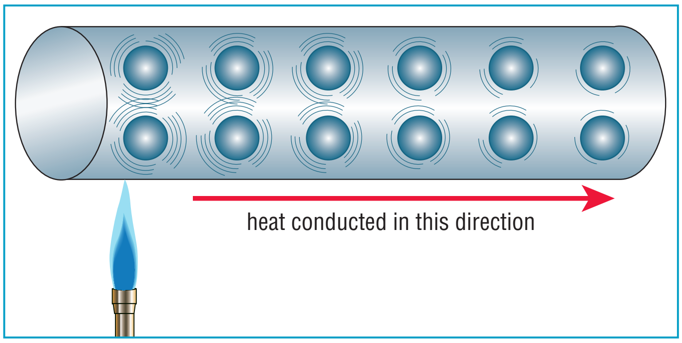

Fig 6.2.3 Conduction—vibrations pass along from particle to particle away from the heat source.

Conductors

Different substances conduct heat at different rates. Metals are good conductors of heat, whereas non-metals like paper, wood and plastics are not. Among the metals, copper and gold are particularly good conductors. Solids are better conductors than liquids, which are better conductors than gases. The particles in a solid are packed closer together and so any increased vibration causes a particle to bump into its neighbours. The particles in liquids are a little more spread out than the particles in a solid, so any bump is less likely to be passed on. Gases are very poor conductors because their particles are spread out even more. Gases are less efficient conductors than liquids, as the particles in a gas are spread out much more.

When you walk barefoot across a tiled floor, it feels colder than one that is carpeted, even though they are both at roughly the same temperature as the rest of the room. Meanwhile, the rest of your body doesn't feel cold. The reason is that the tiled floor is a better conductor than carpet and the air surrounding the rest of your body. The tiles conduct heat away from your feet, leaving the particles in them vibrating less and feeling cold. In contrast, the carpet and air keep the heat where it should be, in your feet and skin, keeping them warm.

Fig 6.2.4 Firewalkers do not get burnt because the coals are porous and do not hold much heat.

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Science Clip: Firewalking

Firewalking is not magic. Only a thin outer layer of the charcoal is on fire and only a small amount of heat needs to be conducted out of the burning coals into the foot for the coal to stop burning. Pure charcoal coals are porous, containing many small holes. The coal would need to be in contact for about a second to harm the foot. At normal walking pace each foot is in ground contact for only half a second, so there is plenty of time for a firewalker to cross a few metres of hot coals.

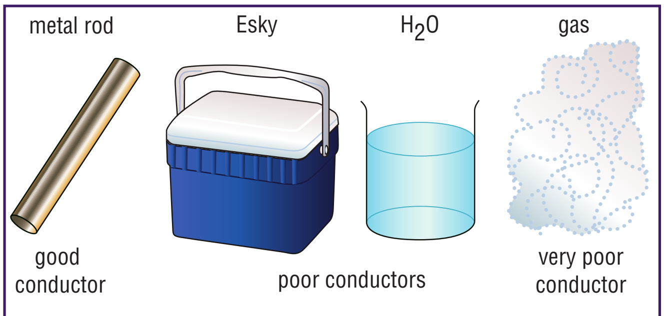

Fig 6.2.5 Different substances, different conducting abilities.

Insulators

Poor conductors are known as **insulators**. Insulators are particularly useful in the kitchen, being used for saucepan handles, oven mitts and pot stands to prevent burns to people or surfaces.

The reason many substances are insulators is that they contain trapped air. Air is a gas and is an extremely poor conductor of heat. Anything that traps air is likely to provide good insulation from the heat and cold.

- Many animals make use of the poor conducting ability of air by having thick fur coats or feathers that trap air and insulate them against harsh, cold conditions. Birds 'fluff up' on cold days to trap more air under their feathers and some animals grow a thicker 'winter coat'.
- Jumpers and blankets are made from fluffy fibres, like wool or Polartec, which trap air and insulate against the cold.
- Sleeping bags, ski-parkas and doonas have fluffy padding wedged between two layers of smooth fabric. Doonas become less effective as they are crushed and occasionally need to be fluffed up again to trap more air.
- Normally, windows only have one sheet of glass. Double-glazed windows have two layers of glass with an insulating layer of air trapped in between them. This limits the heat entering a building on hot days and exiting on a cold one.
- Walls and ceilings often contain fibreglass insulation batts that trap air within fibreglass fibres. They stop heat from flowing in or out of a building, keeping it cooler in summer and warmer in winter.

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Science Clip: Cool pools

When you jump into a swimming pool, the water gives you a chill, even if it is at the same temperature as the surrounding air.

Water is a much better conductor of heat than air, so although you may be comfortable in air at 20°C, water at the same temperature conducts heat away from your body more rapidly, leaving you feeling colder for a while.

Science Clip: Insulation can mean life or death

The lower surface of the space shuttle is protected by tiles made of an insulating material that stops the incredible heat of re-entry from getting inside the shuttle and melting it. In 2003, the space shuttle *Columbia* broke up on re-entry, killing all seven astronauts on board. When *Columbia* was launched a week earlier, a small piece of foam had broken off and punched a hole in those life-saving tiles!

Fig 6.2.6 Fur and feathers provide good insulation by trapping air.

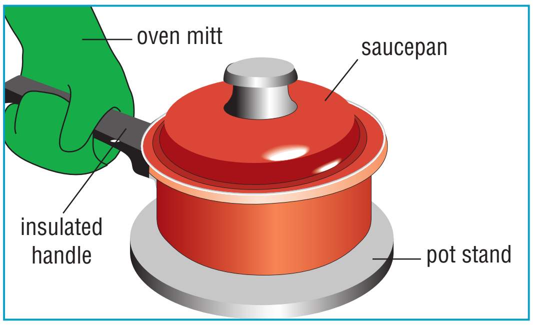

Fig 6.2.7 In the kitchen, burns would happen without insulation.

R ratings

Insulation batts are often given 'R' ratings. The R stands for resistance to heat flow.

Material	R rating (for a 2.5 cm thickness of the material)
Polystyrene foam	4.5
Insulation batt	4.0
Wood	2.3
Chipboard	2.0
Window (double glazing)	1.6
Window (single glazing)	0.9

Fig 6.2.8 Insulation batts can be used to insulate roofs, floors and walls.

Convection

More heat is transferred in liquids and gases by convection than by conduction. Whereas the particles in a solid have fixed positions and can only vibrate, the particles in liquids and gases can move about. They can easily carry their heat energy with them, spreading the heat to other parts of the substance. The spread of heat due to the movement of particles in liquids and gases is called **convection**.

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Hot air rises

Hot air rises because its particles are spread out more than in cold air. This makes hot air less dense than cold air and so it will rise to get on top of it. The same happens to liquids—hot liquids rise because they are less dense than cold liquids. As they rise, the hot gases and liquids take their heat energy with them, spreading it throughout the container.

Convection explains why:

- Hot-air balloons rise.
- Smoke rises from a fire.
- It is hotter near the ceiling than near the floor.
- Central heating vents are usually fitted in the floor, allowing hot air to rise from them.
- Hot-water systems have their heating elements or flames at the bottom of the tank so that the heated water will rise and mix with the cold water in the tank.

Fig 6.2.9 Gliders and hang-gliders use convection currents in the air to stay aloft much longer than would be possible otherwise.

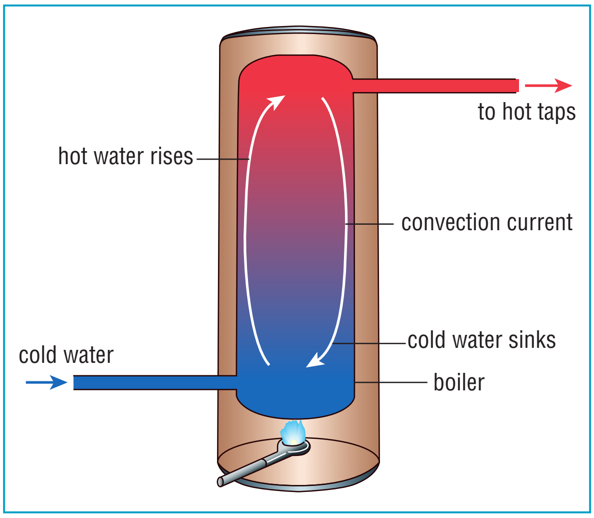

Fig 6.2.10 A hot-water system showing the movement of water by convection.

Cold air drops

Cold air drops because its particles are packed together more tightly than in hot air. The same happens in liquids. Cold liquids are denser than hot liquids and so will drop to the bottom of their container.

This is why:

- Air conditioning vents are often in the ceiling.
- There is a flow of cold air onto your feet when you open an upright freezer's door.
- 'Tub' type supermarket freezers do not need a lid since the cold air cannot escape easily.
- If caught in a fire, the safest place to be is close to the floor.

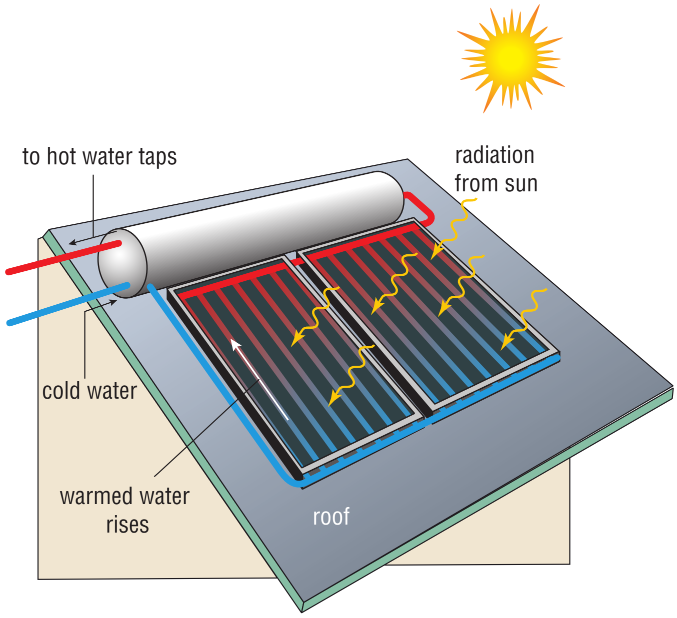

Fig 6.2.11 A solar hot-water system also makes use of convection.

Winds

Hot air rises and cold air drops. This results in convection currents. In the atmosphere, these currents are felt as wind. Wind is caused by hot air in one region rising and its place being taken by colder air coming in from another region. For example, air at the equator is hotter than air at the Poles, causing global winds.

A sea breeze occurs during the day because the land warms up more quickly than the sea. As warm air rises above land, cooler air moves in from just above the sea to replace it. The opposite occurs at night, when the land loses heat more quickly than the sea.

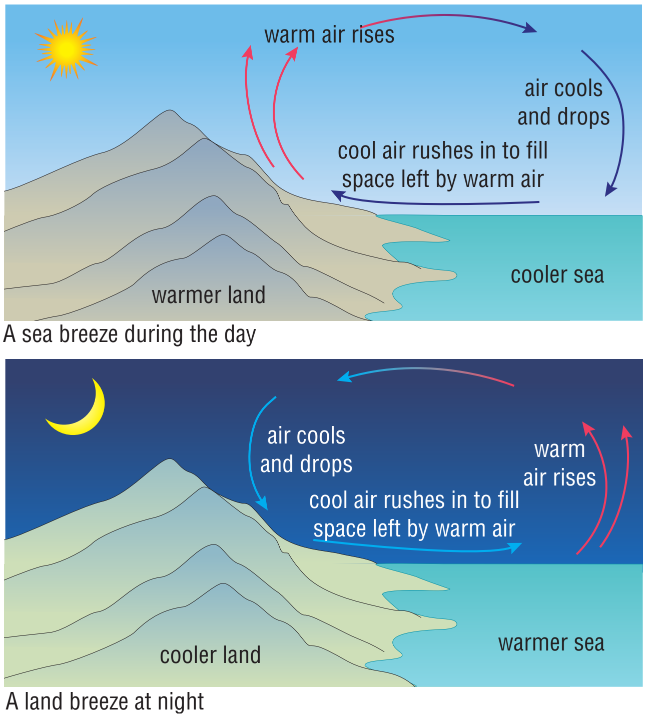

Fig 6.2.12 Land and sea breezes are convection currents at work.

Radiation

When you step outside into bright sunlight, you feel the warmth of the Sun on your skin.

Heat from the Sun cannot reach you by conduction or convection because space is a vacuum. There are no particles between the Sun and Earth to pass along vibrations or move in convection currents. The heat transfer from the Sun to the Earth is called radiation. **Radiation** is the transfer of heat energy by invisible waves that do not need a material to travel through.

Heat radiation is sometimes referred to as **infra-red radiation**. Infra-red radiation travels at the speed of light and is a type of electromagnetic wave. Visible light, X-rays and the waves that send signals to radios and the TV are other types of **electromagnetic waves**.

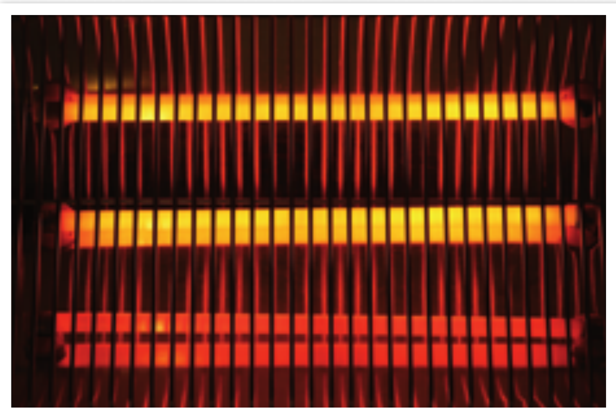

Fig 6.2.13 A radiator and red-hot coals emit a great deal of radiation.

All objects give out heat radiation—the hotter the object, the more heat it radiates. Dark objects tend to radiate more heat than shiny or light-coloured ones at the same temperature.

The red-hot coals of an open fire radiate a great deal of heat. If someone stands between you and the glowing embers, you notice the loss of radiated heat immediately! An electric radiator gives the same effect.

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Absorption, reflection and transmission

When infra-red radiation hits something, it can be:

- absorbed into the object, warming it up or changing its state
- reflected off the object
- transmitted through the object.

Usually a combination of all three happens, although the amounts depend on each object.

Black and dark colours are good absorbers of radiation, whereas white, silver and light colours are good at reflecting it. This is the reason why:

- The plastic coils commonly placed on the roof to heat swimming pools are black.
- Black cars tend to heat up more than lighter-coloured ones.
- Light-coloured clothing stays cooler than dark colours.

Science Clip

Killer heat

In bushfires, it is often radiant heat that is deadly—it can kill well before flames actually reach the victims.

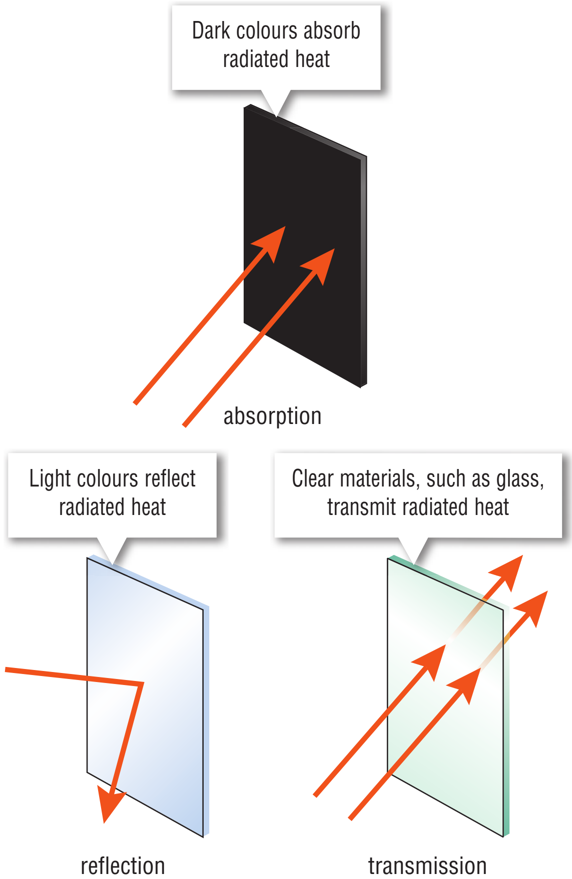

Fig 6.2.14 Heat radiation can be absorbed, reflected or transmitted.

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The thermos flask

The thermos flask is constructed to minimise all three possible ways of losing heat.

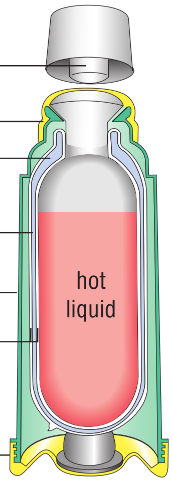

Fig 6.2.15 A vacuum flask reduces heat loss by conduction, convection and radiation.

6.2 QUESTIONS

Remembering

1 **List** three sources of heat.

2 **List** the following in order from best to worst conductor of heat:
water, air, copper, outer space.

3 **State** another name for a poor conductor. Give an example.

4 **List** the three ways that heat can move from one place to another.

Understanding

5 **Explain** the difference between *temperature* and *heat*.

6 **Explain** conduction in terms of what is happening to the particles involved.

7 For heat to conduct from one solid to another, two things must happen. **Explain** what are these two requirements.

8 **Explain** how a fur coat insulates the person who wears it.

9 **Describe** what double glazing is and when it is used.

10 There are many differences between *convection* and *conduction*. **Explain** some of these.

11 **Explain** why cloudy nights are usually not as cold as nights when the sky is clear.

12 **Explain** how some supermarket freezers can be open at the top without losing too much cold air.

13 Some central-heating systems release hot air into a house through vents near the ceiling. **Explain** why this is a poor design.

14 **Explain** why heat cannot reach the Earth from the Sun by conduction or convection.

Applying

15 Draw a particle diagram to **demonstrate** conduction in a metal rod.

16 Draw a diagram to **demonstrate** convection currents in a beaker of water being heated from underneath by a Bunsen burner.

17 Draw a diagram to **demonstrate** how a sea breeze works.

18 **Identify** the type of heat transfer that applies in each case below.

- **a** No material is required.
- **b** Particles vibrate.
- **c** Particles move through a material.

19 **Identify** a household device that gives out both light and radiated heat.

20 **Identify** the correct statement and copy it into your workbook.

- **A** Black objects are better emitters but poorer absorbers of heat than white objects.
- **B** Black objects are better emitters and better absorbers of heat than white objects.
- **C** Black objects are worse emitters and better absorbers of heat than white objects.
- **D** Black objects are worse emitters and worse absorbers of heat than white objects.
- **E** The colour of an object does not affect how it emits or absorbs heat.

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