P1 1.1 Infrared radiation

Learning objectives

- What is infrared radiation?
- Do all objects give off infrared radiation?
- How does infrared radiation depend on the temperature of an object?

Figure 1 Keeping watch in darkness

links

For more information on infrared heaters see P1 1.9 Heating and insulating buildings.

links

For more information on electromagnetic waves see P1 6.1 The electromagnetic spectrum.

Did you know ... ?

A **passive infrared (PIR) detector** in a burglar alarm circuit will 'trigger' the alarm if someone moves in front of the detector. The detector contains sensors that detect infrared radiation from different directions.

Seeing in the dark

We can use special cameras to 'see' animals and people in the dark. These cameras detect infrared radiation. Every object gives out (emits) **infrared radiation**.

The hotter an object is, the more infrared radiation it emits in a given time.

Look at the photo in Figure 1. The rhinos are hotter than the ground.

a Why is the ground darker than the rhinos?
b Which part of each rhino is coldest?

Practical

Detecting infrared radiation

You can use a thermometer with a blackened bulb to detect infrared radiation. Figure 2 shows how to do this.

- The glass prism splits a narrow beam of white light into the colours of the spectrum.
- The thermometer reading rises when it is placed just beyond the red part of the spectrum. Some of the infrared radiation in the beam goes there. Our eyes cannot detect it but the thermometer can.
- Infrared radiation is beyond the red part of the visible spectrum.
- What would happen to the thermometer reading if the thermometer were moved away from the screen?

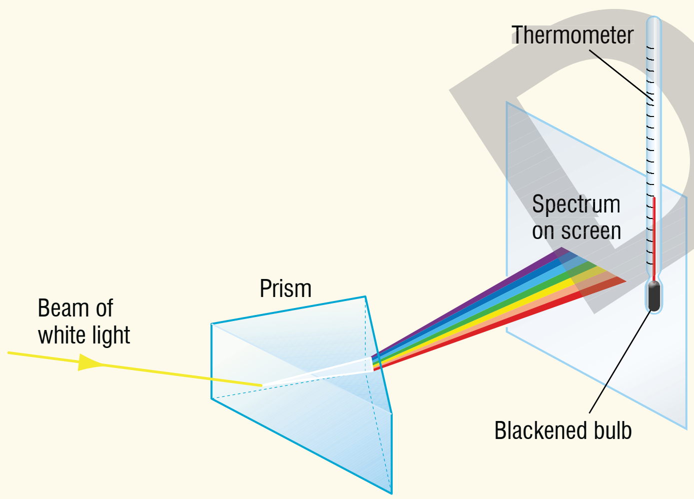


Figure 2 Detecting infrared radiation

The electromagnetic spectrum

Radio waves, microwaves, infrared radiation and visible light are parts of the electromagnetic spectrum. So too are ultraviolet rays and X-rays. Electromagnetic waves are electric and magnetic waves that travel through space.

Energy from the Sun

The Sun emits all types of electromagnetic radiation. Fortunately for us, the Earth's atmosphere blocks most of the radiation that would harm us. But it doesn't block infrared radiation from the Sun.

Figure 3 shows a solar furnace. This uses a giant reflector that focuses sunlight.

The temperature at the focus can reach thousands of degrees. That's almost as hot as the surface of the Sun, which is 5500 °C.

Figure 3 A solar furnace in the Eastern Pyrenees, France

The greenhouse effect

The Earth's atmosphere acts like a greenhouse made of glass. In a greenhouse,

- short wavelength infrared radiation (and light) from the Sun can pass through the glass to warm the objects inside the greenhouse
- infrared radiation from these warm objects is trapped inside by the glass, because the objects emit longer wavelength infrared radiation that can't pass through the glass.

So the greenhouse stays warm.

Gases in the atmosphere, such as water vapour, methane and carbon dioxide, trap infrared radiation from the Earth. This makes the Earth warmer than it would be if it had no atmosphere.

But the Earth is becoming too warm. If the polar ice caps melt, it will cause sea levels to rise. Reducing our use of fossil fuels will help to reduce the production of 'greenhouse gases'.

How science works

A huddle test

Design an investigation to model the effect of penguins huddling together. You could use beakers of hot water to represent the penguins.

Figure 4 Penguins keeping warm

Summary questions

1 Copy and complete sentences **a** and **b** using the words below. Each word can be used more than once.

temperature radiation waves

a Infrared .... is energy transfer by electromagnetic ....
b The higher the .... of an object is, the more .... it emits each second.

2 **a** Copy and complete the table to show if the object emits infrared radiation or light or both.

Object	Infrared	Light
A hot iron		
A light bulb		
A TV screen		
The Sun		

b How can you tell if an electric iron is hot without touching it?

3 Explain why penguins huddle together to keep warm.

Key points

- Infrared radiation is energy transfer by electromagnetic waves.
- All objects emit infrared radiation.
- The hotter an object is, the more infrared radiation it emits in a given time.

P1 1.2 Surfaces and radiation

Learning objectives

- Which surfaces are the best emitters of infrared radiation?
- Which surfaces are the best absorbers of infrared radiation?
- Which surfaces are the best reflectors of infrared radiation?

Figure 1 A thermal blanket in use

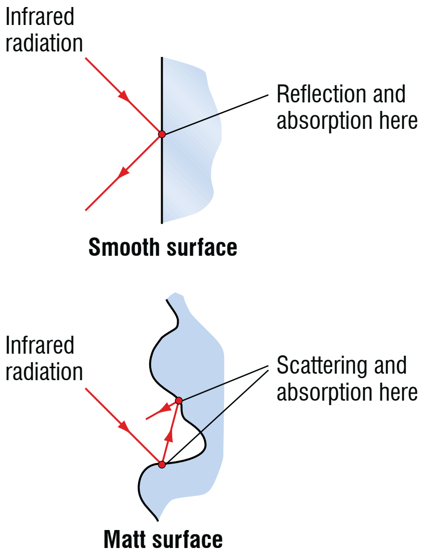


Figure 3 Absorbing infrared radiation

links
Infrared heaters use light, shiny surfaces to reflect infrared radiation. See P1 3.4 Cost effectiveness matters.

Which surfaces are the best emitters of radiation?

Rescue teams use light shiny thermal blankets to keep accident survivors warm. A light, shiny outer surface emits much less radiation than a dark, matt surface.

Practical

Testing radiation from different surfaces

To compare the radiation from two different surfaces, you can measure how fast two beakers (or cans) of hot water cool. The surface of one can is light and shiny and the other has a dark matt surface. See Figure 2. At the start, the volume and temperature of the water in each beaker must be the same.

- Why should the volume and temperature of the water be the same at the start?
- Which beaker (or can) will cool faster?

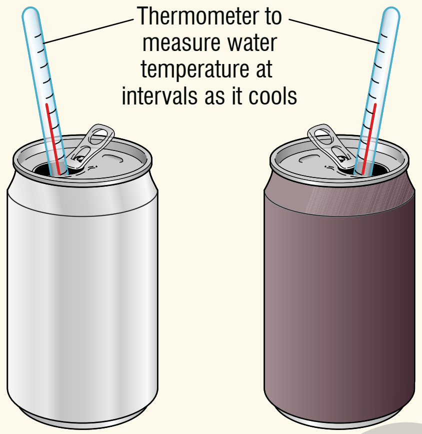


Figure 2 Testing different surfaces

Your tests should show that:

- **Dark, matt surfaces are better at emitting radiation than light, shiny surfaces.**

Which surfaces are the best absorbers and reflectors of radiation?

When you use a photocopier, infrared radiation from a lamp dries the ink on the paper. Otherwise, the copies will be smudged. Black ink absorbs more infrared radiation than white paper.

A light shiny surface absorbs less radiation than a dark matt surface. A matt surface has lots of cavities, as shown in Figure 3.

- The radiation reflected from the matt surface hits the surface again.
- The radiation reflected from the shiny surface travels away from the surface.

So the shiny surface absorbs less and reflects more radiation than a matt surface.

In general:

- **Light, shiny surfaces absorb less radiation than dark, matt surfaces.**
- **Light, shiny surfaces reflect more radiation than dark, matt surfaces.**

a Why does ice on a road melt faster in sunshine if sand is sprinkled on it?
b Why are solar heating panels painted matt black?

Practical

Absorption tests

Figure 4 shows how we can compare absorption by two different surfaces.

- The front surfaces of the two metal plates are at the same distance from the heater.
- The back of each plate has a coin stuck on with wax. The coin drops off the plate when the wax melts.
- The coin at the back of the matt black surface drops off first. The matt black surface absorbs more radiation than the light shiny surface.

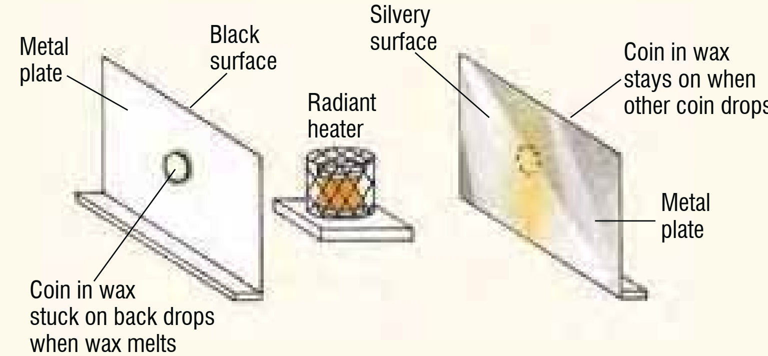


Figure 4 Testing different absorbers of infrared radiation

Summary questions

1 Copy and complete sentences **a** and **b** using the words below:

absorber emitter reflector

a A dark, matt surface is a better .... and a better .... of infrared radiation than a light, shiny surface.
b A light, shiny surface is a better .... of infrared radiation than a dark, matt surface.

2 A black car and a metallic silver car are parked next to each other on a sunny day. Why does the temperature inside the black car rises more quickly than the temperature inside the silver car?

3 A metal cube filled with hot water was used to compare the infrared radiation emitted from its four vertical faces, A, B, C and D.

An infrared sensor was placed opposite each face at the same distance, as shown in Figure 5. The sensors were connected to a computer. The results of the test are shown in the graph below.

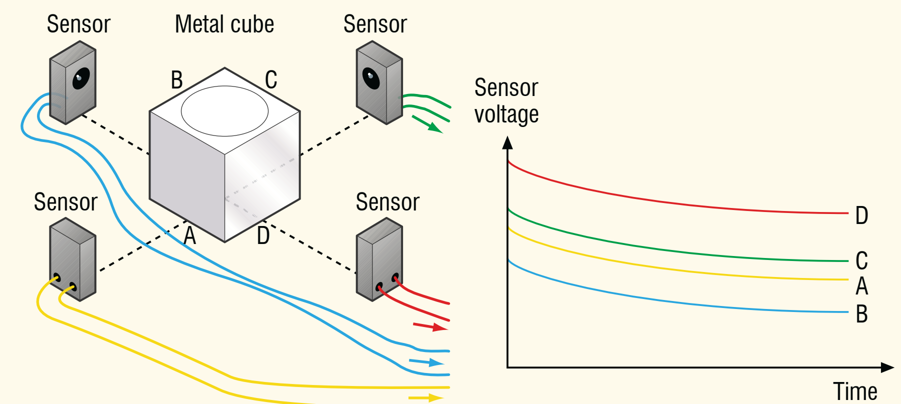


Figure 5

a Why was it important for the distance from each sensor to the face to be the same?
b One face was light and shiny, one was light and matt, one was dark and shiny, and one was dark and matt.
Which face A, B, C or D was **i** radiates least, **ii** radiates most?
c What are the advantages of using data logging equipment to collect the data in this investigation?

Did you know ...?

Scientists are developing blacker and blacker materials. These new materials have very tiny pits in the surface to absorb almost all the light that hits them. They can be used to coat the insides of telescopes so that there are no reflections.

Key points

- Dark matt surfaces emit more infrared radiation than light, shiny surfaces.
- Dark matt surfaces absorb more infrared radiation than light, shiny surfaces.
- Light, shiny surfaces reflect more infrared radiation than dark matt surfaces.

P1 1.3 States of matter

Learning objectives

- How are solids, liquids and gases different?
- How are the particles in a solid, liquid and a gas arranged?
- Why is a gas much less dense than a solid or a liquid?

Figure 1 Spot the three states of matter

Everything around us is made of matter in one of three states – solid, liquid or gas. Table 1 summarises the main differences between the three **states of matter**.

Table 1

	Flow	Shape	Volume	Density
Solid	no	fixed	fixed	much higher than a gas
Liquid	yes	fits container shape	fixed	much higher than a gas
Gas	yes	fills container	can be changed	low compared with a solid or liquid

a We can't see it and yet we can fill objects like balloons with it. What is it?
b When an ice cube melts, what happens to its shape?

Change of state

A substance can change from one state to another, as shown in Figure 2. We can make these changes by heating or cooling the substance. For example,

- when water in a kettle boils, the water turns to steam. Steam, also called water vapour, is water in its gaseous state
- when solid carbon dioxide or 'dry ice' warms up, the solid turns into gas directly
- when steam touches a cold surface, the steam condenses and turns to water.

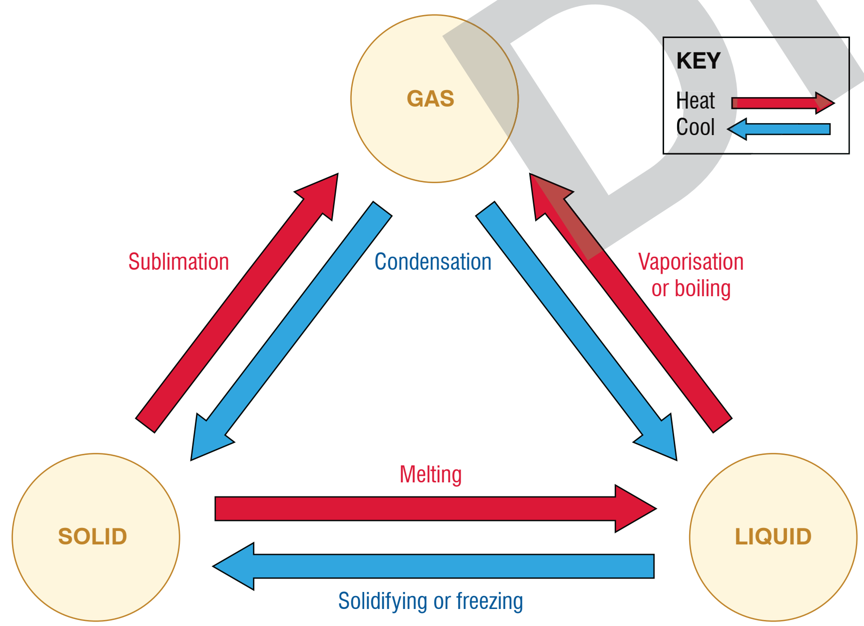


Figure 2 Change of state

c What change of state occurs when hailstones form?

Practical

Changing state

1 Heat some water in a beaker using a Bunsen burner, as shown in Figure 3. Notice that
- steam or 'vapour' leaves the water surface before the water boils
- when the water boils, bubbles of vapour form inside the water and rise to the surface to release steam.

2 Switch the Bunsen burner off and hold a cold beaker or cold metal object above the beaker. Observe condensation of steam from the beaker on the object. Take care with boiling water.

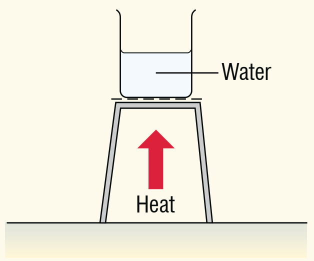


Figure 3 Changing state

The kinetic theory of matter

Solids, liquids and gases consist of particles. Figure 4 shows the arrangement of the particles in a solid, a liquid and a gas. When the temperature of the substance is increased, the particles move faster.

- The particles in a solid are held next to each other in fixed positions. They vibrate about their fixed positions so the solid keeps its own shape.
- The particles in a liquid are in contact with each other. They move about at random. So a liquid doesn't have its own shape and it can flow.
- The particles in a gas move about at random much faster. They are, on average, much further apart from each other than in a liquid. So the density of a gas is much less than that of a solid or liquid.
- The particles in solids, liquids and gases have different amounts of energy. In general, the particles in a gas have more energy than those in a liquid, which have more energy than those in a solid.

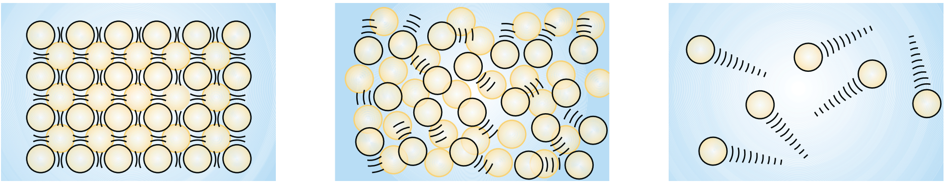


Figure 4 The arrangement of particles in a solid, a liquid and a gas

Did you know ... ?

Random means unpredictable. Lottery numbers are chosen at random.

Summary questions

1 Copy and complete sentences **a** to **d** using the words below. Each word can be used more than once.

gas liquid solid

a A .... has a fixed shape and volume.
b A .... has a fixed volume but no shape.
c A .... and a .... can flow.
d A .... does not have a fixed volume.

2 State the scientific word for each of the following changes.
a A mist appears on the inside of a window in a bus full of people.
b Steam is produced from the surface of the water in a pan when the water is heated before it boils.
c Ice cubes taken from a freezer thaw out.
d Water put into a freezer gradually turns to ice.

3 Describe the changes that take place in the arrangement of the particles in an ice cube when the ice cube melts.

Key points

- Flow, shape, volume and density are the properties used to describe each state of matter.
- The particles in a solid are held next to each other in fixed positions.
- The particles in a liquid move about at random and are in contact with each other.
- The particles in a gas move about randomly and are much further apart than particles in a solid or liquid.

P1 1.4 Conduction

Learning objectives

- What materials make the best conductors?
- What materials make the best insulators?
- Why are metals good conductors?
- Why are non-metals poor conductors?

Figure 1 At a barbecue – the steel cooking utensils have wooden or plastic handles

links

For more information on independent and dependent variables see H3 Starting an investigation.

When you have a barbecue, you need to know which materials are good at transferring energy and which are good insulators. If you can't remember, you are likely to burn your fingers!

Testing rods of different materials as conductors

The rods need to be the same width and length for a fair test. Each rod is coated with a thin layer of wax near one end. The uncoated ends are then heated together.

Look at Figure 2. The wax melts fastest on the rod that conducts thermal energy best.

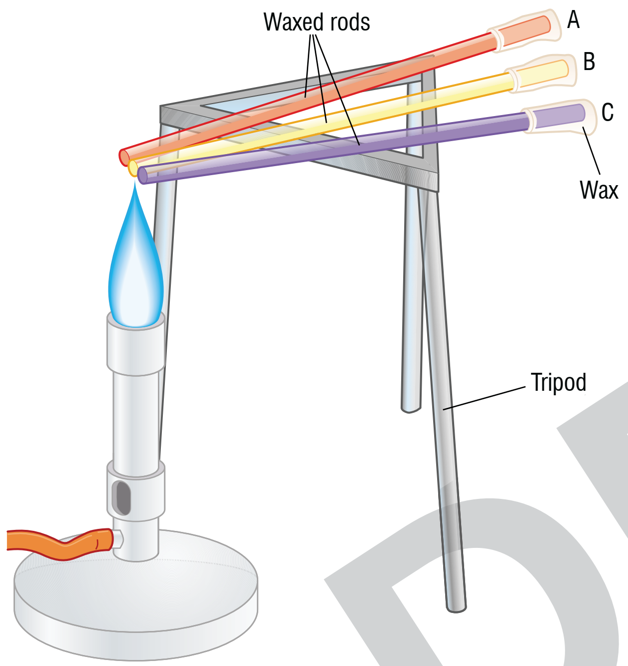


Figure 2 Comparing conductors

- Metals conduct **thermal energy** better than non-metals.
- Copper is a better conductor of energy than steel.
- Wood conducts energy better than glass.

a Why do steel pans have handles made of plastic or wood?
b Name the independent and the dependent variables investigated in Figure 2.

Practical

Testing sheets of materials as insulators

Use different materials to insulate identical cans (or beakers) of hot water. The volume of water and its temperature at the start should be the same.

Use a thermometer to measure the water temperature after a fixed time. The results should tell you which insulator was best.

Table 1 below gives the results of comparing two different materials using the method above.

Table 1

Material	Starting temperature (°C)	Temperature after 300 s (°C)
paper	40	32
felt	40	36

c Which material, felt or paper, was the best insulator?
d Which variable shown in the table was controlled to make this a fair test?

Conduction in metals

Metals contain lots of **free electrons**. These electrons move about at random inside the metal and hold the positive metal ions together. They collide with each other and with the positive ions. (Ions are charged particles.)

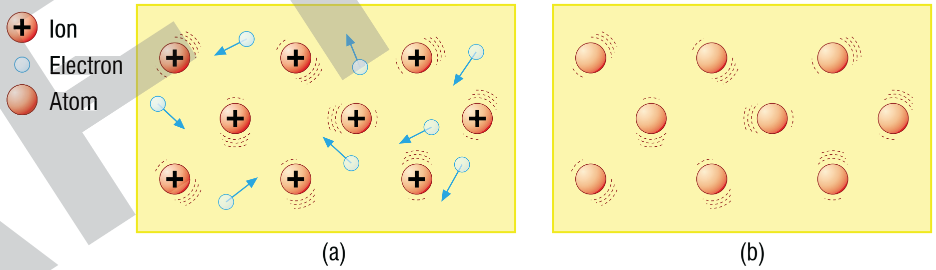


Figure 4 Energy transfer in **(a)** a metal, **(b)** a non-metal

When a metal rod is heated at one end, the free electrons at the hot end gain kinetic energy and move faster.

- These electrons **diffuse** (i.e. spread out) and collide with other free electrons and ions in the cooler parts of the metal.
- As a result, they transfer kinetic energy to these electrons and ions.

So energy is transferred from the hot end of the rod to the colder end.

In a non-metallic solid, all the electrons are held in the atoms. Energy transfer only takes place because the atoms vibrate and shake each other. This is much less effective than energy transfer by free electrons. This is why metals are much better conductors than non-metals.

Summary questions

1 Copy and complete sentences **a** to **c** using the words below:

fibreglass plastic steel wood

a .... is used to insulate a house loft.
b The handle of a frying pan is made of .... or ....
c A radiator in a central heating system is made from ....

2 **a** Choose a material you would use to line a pair of winter boots. Explain your choice of material.
b How could you carry out a test on three different lining materials?

3 Explain why metals are good conductors of thermal energy.

Figure 3 Insulating a loft. The air trapped between fibres make fibreglass a good thermal insulator.

Did you know ... ?

Materials like wool and fibreglass are good insulators. This is because they contain air trapped between the fibres. Trapped air is a good insulator. We use materials like fibreglass for loft insulation and for lagging water pipes.

Key points

- Metals are the best conductors of energy.
- Materials such as wool and fibreglass are the best insulators.
- Conduction of energy in a metal is due mainly to free electrons transferring energy inside the metal.
- Non-metals are poor conductors because they do not contain free electrons.

P1 1.5 Convection

Learning objectives

- What is convection?
- Where can convection take place?
- Why does convection occur?

Did you know … ?

The Gulf Stream is a current of warm water that flows across the Atlantic Ocean from the Gulf of Mexico to the British Isles. If it ever turned away from us, our winters would be much colder!

Figure 1 A natural glider – birds use convection currents to soar high above the ground

Gliders and birds use convection to stay in the air. Convection currents (called thermals) can keep them high above the ground for hours.

Convection happens whenever we heat **fluids**. A fluid is a gas or a liquid. Look at the diagram in Figure 2. It shows a simple demonstration of convection.

- The hot gases from the burning candle go straight up the chimney above the candle.
- Cold air is drawn down the other chimney to replace the air leaving the box.

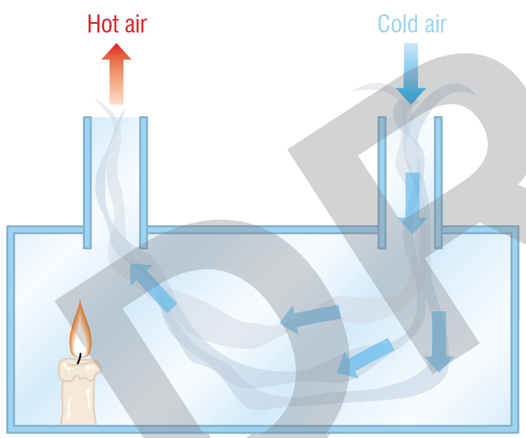


Figure 2 Convection

Using convection

Hot water at home

Many homes have a hot water tank. Hot water from the boiler rises and flows into the tank where it rises to the top. Figure 3 shows the system. When you use a hot water tap at home, you draw off hot water from the top of the tank.

a What would happen if we connected the hot taps to the bottom of the tank?

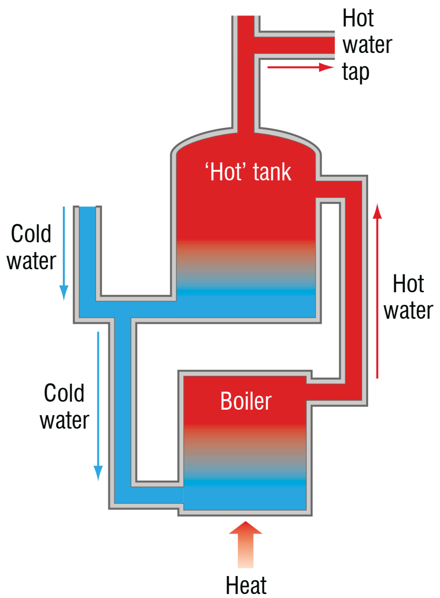


Figure 3 Hot water at home

Sea breezes

Sea breezes keep you cool at the seaside. On a sunny day, the ground heats up faster than the sea. So the air above the ground warms up and rises. Cooler air from the sea flows in as a 'sea breeze' to take the place of the rising warm air.

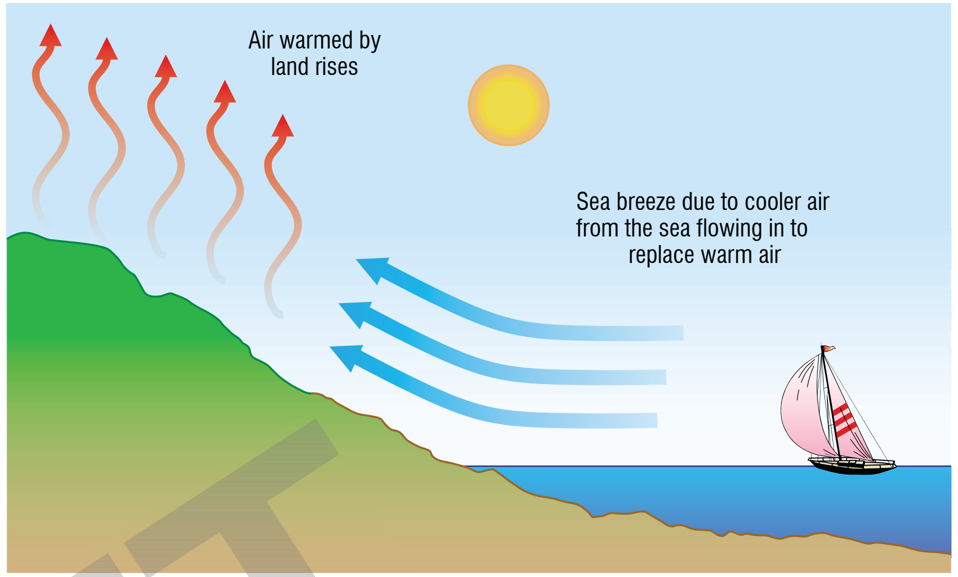


Figure 4 Sea breezes

How convection works

Convection takes place:

- only in fluids (liquids and gases)
- due to circulation (convection) currents within the fluid.

The circulation currents are caused because fluids rise where they are heated (as heating makes them less dense). Then they fall where they cool down (as cooling makes them more dense). Convection currents transfer thermal energy from the hotter parts to the cooler parts.

So why do fluids rise when heated?

Most fluids expand when heated. This is because the particles move about more, taking up more space. Therefore the **density** decreases because the same mass of fluid now occupies a bigger volume. So heating part of a fluid makes that part less dense and therefore it rises.

AQA Examiner's tip

When you explain convection, remember it is the hot fluid that rises, NOT 'heat'.

Summary questions

1 Copy and complete using the words below:

cools falls mixes rises

When a fluid is heated, it .... and .... with the rest of the fluid. The fluid circulates and .... then it ....

2 Figure 5 shows a convector heater. It has an electric heating element inside and a metal grille on top.

a What does the heater do to the air inside the heater?

b Why is there a metal grille on top of the heater?

c Where does air flow into the heater?

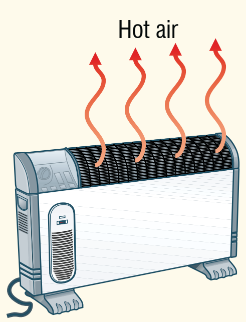


Figure 5 A convector heater

3 Describe how you could demonstrate convection currents in water using a strongly coloured crystal or a suitable dye. Explain in detail what you would see.

Key points

- Convection is the circulation of a fluid (liquid or gas) caused by heating it.
- Convection takes place only in liquids and gases.
- Heating a liquid or a gas makes it less dense so it rises and causes circulation.

P1 1.6 Evaporation and condensation

Learning objectives

- What is evaporation?
- What is condensation?
- How does evaporation produce cooling?
- What factors affect the rate of evaporation from a liquid?
- What factors affect the rate of condensation on a surface?

Drying off

If you hang wet clothes on a washing line in fine weather, they will gradually dry off. The water in the wet clothes **evaporates**. You can observe evaporation of water if you leave a saucer of water in a room. The water in the saucer gradually seems to disappear. Water molecules escape from the water and enter the air in the room.

In a well-ventilated room, the water molecules in the air are not likely to re-enter the liquid. They continue to leave the liquid until all the water has evaporated.

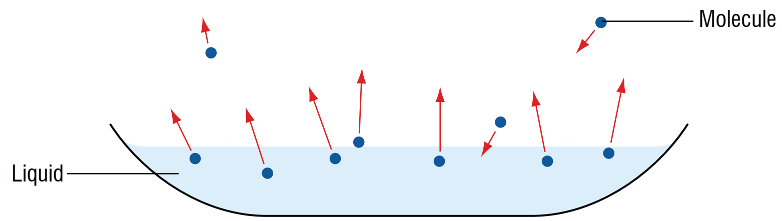


Figure 1 Water molecules escaping from a liquid

Condensation

In a steamy bathroom, a mirror is often covered by a film of water. There are lots of water molecules in the air. Some of them hit the mirror, cool down and stay there. We say water vapour in the air **condenses** on the mirror.

Figure 2 Condensation

a Why does opening a window in a steamy room clear the condensation?

Cooling by evaporation

If you have an injection, the doctor or nurse might 'numb' your skin by dabbing it with a liquid that easily evaporates. As the liquid evaporates, your skin becomes too cold to feel any pain.

Demonstration

Cooling by evaporation

Watch your teacher carry out this experiment in a fume cupboard.

- Why is ether used in this experiment?

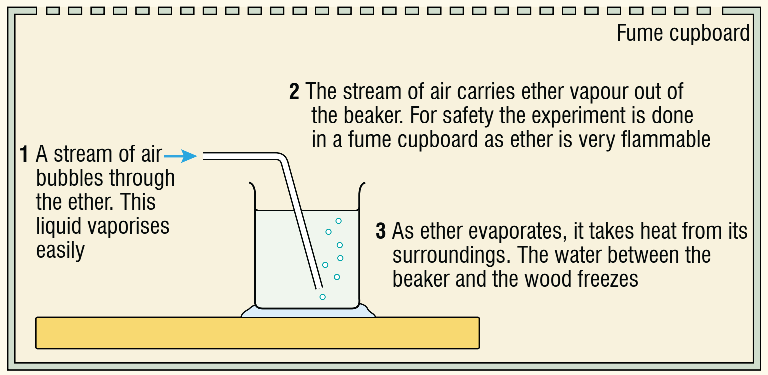


Figure 3 A demonstration of cooling by evaporation

Figure 4 explains why evaporation causes this cooling effect.

- Weak attractive forces exist between the molecules in the liquid.
- The faster molecules, which have more kinetic energy, break away from the attraction of the other molecules and escape from the liquid.
- After they evaporate, the liquid is cooler because the average kinetic energy of the remaining molecules in the liquid has decreased.

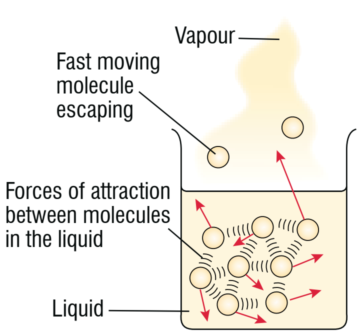


Figure 4 Explanation of cooling by evaporation

Factors affecting the rate of evaporation

Clothes dry faster on a washing line

- if each item of wet clothing is spread out when it is hung on the line. This increases the area of the wet clothing that is in contact with dry air.
- if the washing line is in sunlight. Wet clothes dry faster the warmer they are.
- if there is a breeze to take away the molecules that escape from the water in the wet clothes.

The example above shows that the rate of evaporation from a liquid is increased by

- increasing the surface area of the liquid
- increasing the temperature of the liquid
- creating a draught of air across the liquid's surface.

Factors affecting the rate of condensation

In a steamy kitchen, water can often be seen trickling down a window pane. The glass pane is a cold surface so water vapour condenses on it. The air in the room is moist or 'humid'. The bigger the area of the window pane, or the colder it is, the greater the rate of condensation. This example shows that the rate of condensation of a vapour on a surface is increased by

- increasing the surface area
- reducing the surface temperature.

b Why does washing on a line take longer to dry on a damp day?

Summary questions

1 Copy and complete sentences **a** to **c** using the words below. Each word can be used more than once.

condenses cools evaporates

a A liquid .... when its molecules escape into the surrounding air.
b When water .... on glass, water molecules in the air form a liquid on the glass.
c When a liquid ...., it loses its faster-moving molecules and it ....

2 Why do the windows on a bus become misty when there are lots of people on the bus?

3 Explain the following statements.
a Wet clothes on a washing line dry faster on a hot day than on a cold day.
b A person wearing wet clothes on a cold windy day is likely to feel much colder than someone wearing dry clothes.

Did you know ...?

Air conditioning

An **air conditioning unit** in a room transfers energy from inside the room to the outside. The unit contains a 'coolant' liquid that easily evaporates. The coolant is pumped round a sealed circuit of pipes that go through the unit and the outside.

- The liquid coolant evaporates in the pipes in the room and cools the room.
- The evaporated coolant condenses in the pipes outside and transfers energy to the surroundings.

Figure 5 An air-conditioning unit

Key points

- Evaporation is when a liquid turns into a gas.
- Condensation is when a gas turns into a liquid.
- Cooling by evaporation of a liquid is due to the faster-moving molecules escaping from the liquid.
- Evaporation can be increased by increasing the surface area of the liquid, by increasing the liquid's temperature, or by creating a draught of air across the liquid's surface.
- Condensation on a surface can be increased by increasing the area of the surface or reducing the temperature of the surface.

P1 1.7 Energy transfer by design

Learning objectives

- What design factors affect the rate at which a hot object transfers energy by heating?
- What can we do to control the rate of energy transfer to or from an object?
- How can I plan to investigate the rate of energy transfer by heating?

Cooling by design

Lots of things can go wrong if we don't control energy transfer. For example, a car engine that overheats can go up in flames.

- The cooling system of a car engine transfers energy from the engine to a radiator. The radiator is shaped so it has a large surface area. This increases the rate of energy loss through convection in the air and through radiation.
- A motorcycle engine is shaped with **fins** on its outside surface. The fins increase the surface area of the engine in contact with air. So the engine loses energy faster than if it had no fins.
- Most cars also have a cooling fan that switches on when the engine is too hot. This increases the flow of air over the surface of the radiator.

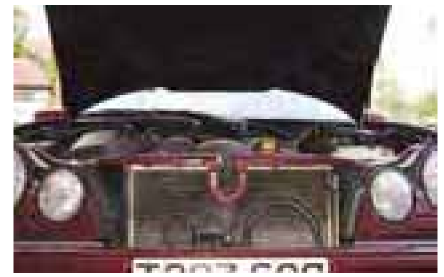


Figure 1 A car radiator helps to transfer energy from the engine

Figure 2 Motorcycle engine fins

a Why are car radiators painted black?
b What happens to the rate of energy transfer when the cooling fan switches on?

Did you know ...?

Heat sinks

Some electronic components get warm when they are working, but if they become too hot they stop working. Such components are often fixed to a metal plate to keep them cool. The metal plate increases the effective surface area of the component. We call the metal plate a **heat sink** because it increases the energy loss from the component.

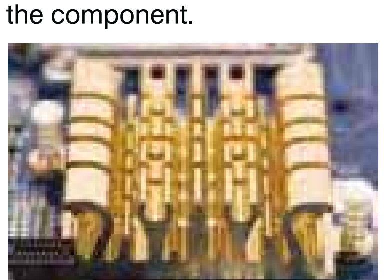


Figure 3 A heat sink in a computer

The vacuum flask

If you are outdoors in cold weather, a hot drink from a vacuum flask keeps you warm. In the summer the same vacuum flask keeps your drinks cold.

In Figure 4, the liquid you drink is in the double-walled glass container.

- The vacuum between the two walls of the container cuts out energy transfer by conduction and convection between the walls.
- Glass is a poor conductor so there is little energy transfer by conduction through the glass.
- The glass surfaces are silvery to reduce radiation from the outer wall.
- The spring supporting the double-walled container is made of plastic which is a good insulator of energy.
- The plastic cap stops cooling by evaporation as it stops vapour loss from the flask. In addition, energy transfer by conduction is cut down because the cap is made from plastic.

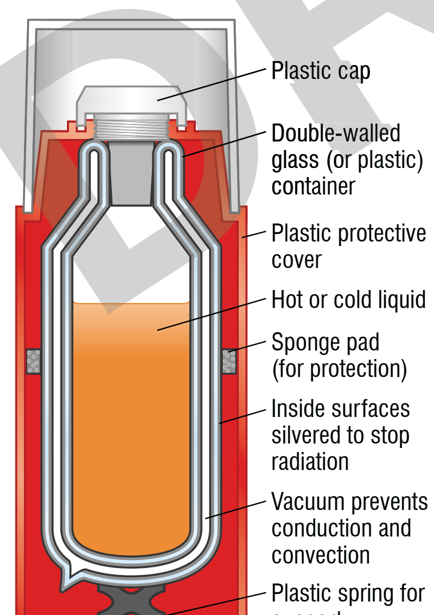


Figure 4 A vacuum flask

So why does the liquid in the flask eventually cool down?

The above features cut down but do not totally stop transfer of energy from the liquid. Energy transfer occurs at a very low rate due to radiation from the silvery glass surface and conduction through the cap, spring and glass walls. The liquid loses energy slowly so it eventually cools.

c List the other parts of the flask that are good insulators. What would happen if they weren't good insulators?

Factors affecting the rate of energy transfer

The bigger the temperature difference between an object and its surroundings, the faster the rate at which energy is transferred. In addition, the above examples show that the rate at which an object transfers energy depends on its design. The design factors that matter are:

- the materials the object is in contact with
- the object's shape
- the object's surface area.

In addition, the object's mass and the material it is made from are important because they affect how much its temperature changes (and therefore the rate of transfer of energy to or from it) when it loses or gains energy.

Foxy survivors

A desert fox has much larger ears than an arctic fox. Blood flowing through the ears transfers energy from inside the body to the surface of the ears. Big ears have a much larger surface area than little ears so they transfer energy more quickly than little ears.

- A desert fox has big ears so it keeps cool by transferring lots of energy to its surroundings.
- An arctic fox has little ears so it doesn't transfer much energy to its surroundings. This helps keep it warm.

Summary questions

1 Hot water is pumped through a radiator like the one in Figure 6.
Copy and complete sentences **a** to **c** using the words below:

conduction convection radiation

a Energy transfer through the walls of the radiator is due to ....
b Hot air in contact with the radiator causes energy transfer to the room by ....
c Energy transfer to the room takes place directly due to ....

Figure 6 A central heating radiator

2 An electronic component in a computer is attached to a heat sink.
a Explain why the heat sink is necessary.
b Why is a metal plate used as the heat sink?
c Plan a test to show that double glazing is more effective at preventing energy transfer than single glazing.

3 Describe, in detail, how the design of a vacuum flask reduces the rate of energy transfer.

links

For more information on factors affecting thermal energy transfer see P1 1.8 Specific heat capacity.

Practical

Investigating the rate of energy transfer

You can plan an investigation using different beakers and hot water to find out what affects the rate of cooling.

- Write a question that you could investigate.
- Identify the independent, dependent and control variables in your investigation.

Figure 5 Fox ears **(a)** A desert fox **(b)** An arctic fox

Key points

- The rate of transfer of thermal energy to or from an object depends on:
  - the shape, size and type of material of the object
  - the materials the object is in contact with
  - the temperature difference between an object and its surroundings.

P1 1.8 Specific heat capacity

Learning objectives

- How does the mass of a substance affect its temperature change when it is heated?
- What else affects the temperature change of a substance when it is heated?
- How do storage heaters work?

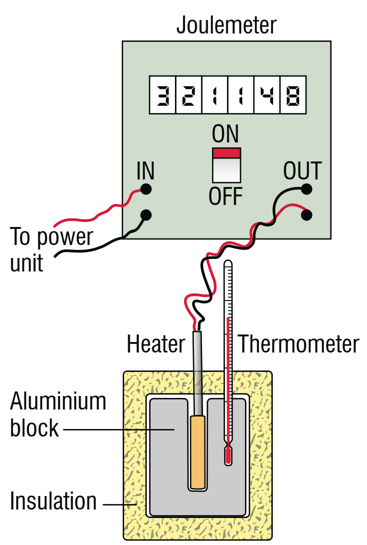


Figure 1 Heating an aluminium block

A car in strong sunlight can become very hot. A concrete block of equal mass would not become as hot. Metal heats up more easily than concrete. Investigations show that when a substance is heated, its temperature rise depends on:

- the amount of energy supplied to it
- the mass of the substance
- what the substance is.

Practical

Investigating heating

Figure 1 shows how we can use a low voltage electric heater to heat an aluminium block.

Energy is measured in units called joules (J).

Use the energy meter (or joulemeter) to measure the energy supplied to the block and the thermometer to measure its temperature rise.

Replace the block with an equal mass of water in a suitable container. Measure the temperature rise of the water when the same amount of energy is supplied to it by the heater.

Your results should show that aluminium heats up more than water.

The following results were obtained using two different amounts of water. They show that:

- 1600 J was used to heat 0.1 kg of water by 4 °C
- 3200 J was used to heat 0.2 kg of water by 4 °C.

Using these results we can say that

- 16 000 J of energy would have been needed to heat 1.0 kg of water by 4 °C
- 4000 J of energy is needed to heat 1.0 kg of water by 1 °C.

More accurate measurements would give 4200 J per kg per °C for water. This is its **specific heat capacity**.

The specific heat capacity of a substance is the energy needed or heat transferred to 1 kg of the substance to raise its temperature by 1 °C.

The unit of specific heat capacity is the joule per kilogram per °C.

For a known change of temperature of a known mass of a substance:

$$\text{heat transferred (joules, J)} = \text{mass (kilograms, kg)} \times \text{specific heat capacity (joules/kilogram °C)} \times \text{temperature change (degrees Celsius, °C)}$$

Rearranging the above equation gives

$$\textbf{specific heat capacity (J/kg °C)} = \frac{\textbf{heat transferred (J)}}{\textbf{mass (kg)} \times \textbf{temperature change (°C)}}$$

a How much energy is needed to heat 5.0 kg of water from 20 °C to 60 °C?

Did you know ... ?

Coastal towns are usually cooler in summer and warmer in winter than towns far inland. This is because water has a very high specific heat capacity. Heat from the Sun (or lack of heat) affects the temperature of the sea much less than the land.

Practical

Measuring the specific heat capacity of a metal

Use the arrangement shown in Figure 1 to heat a metal block of known mass. Here are some measurements using an aluminium block of mass 1.0 kg.

Starting temperature = 14 °C
Final temperature = 22 °C
Energy supplied = 7200 J

To find the specific heat capacity of aluminium, using the measurements above, gives
heat transferred = energy supplied = 7200 J
temperature change = 22 °C − 14 °C = 8 °C

Inserting these values into the rearranged equation above gives

$$\text{specific heat capacity} = \frac{\text{heat transferred}}{\text{mass} \times \text{temperature change}} = \frac{7200\,\text{J}}{1.0\,\text{kg} \times 8\,°\text{C}} = 900\,\text{J/kg °C}$$

The table below shows the values for some other substances.

Table 1

Substance	water	oil	aluminium	iron	copper	lead	concrete
Specific heat capacity (joules per kg per °C)	4200	2100	900	390	490	130	850

Storage heaters

A storage heater uses electricity at night (off-peak) to heat special bricks of concrete in the heater. Heat transfer from the bricks keeps the room warm. The bricks have a high specific heat capacity so they store lots of energy. They warm up slowly when the heater element is on and cool slowly when it is off.

Electricity consumed at off-peak times is sometimes charged for at a cheaper rate, so storage heaters are designed to be cost-effective.

Figure 2 A storage heater

b How would the temperature of the room change if the bricks cooled quickly ?

Summary questions

1 A small bucket of water and a large bucket of water are left in strong sunlight. Which one warms up faster? Give a reason for your answer.

2 Use the information in Table 1 to answer this question
 a Explain why a mass of lead heats up more quickly than an equal mass of aluminium.
 b Calculate the energy needed
  i to raise the temperature of 0.20 kg of aluminium from 15 °C to 40 °C
  ii to raise the temperature of 0.40 kg of water from 15 °C to 40 °C.

3 State two ways in which a storage heater differs from a radiant heater.

Key points

- The greater the mass of an object, the less its temperature change is when it is heated.
- The temperature change of a substance when it is heated depends on:
  - the energy supplied to it
  - its mass
  - its specific heat capacity.
- Storage heaters use off-peak electricity to store energy in special bricks.

P1 1.9 Heating and insulating buildings

Learning objectives

- How can we cut down energy loss from our homes?
- What are U-values?
- Is solar heating free?

Did you know ... ?

A duvet is a bed cover filled with 'down' or soft feathers or some other suitable thermal insulator such as wool. Because the filling material traps air, a duvet on a bed cuts down the transfer of energy from the sleeper. The 'tog' rating of a duvet tells us how effective it is as an insulator. The higher its tog rating is, the more effective it is as an insulator.

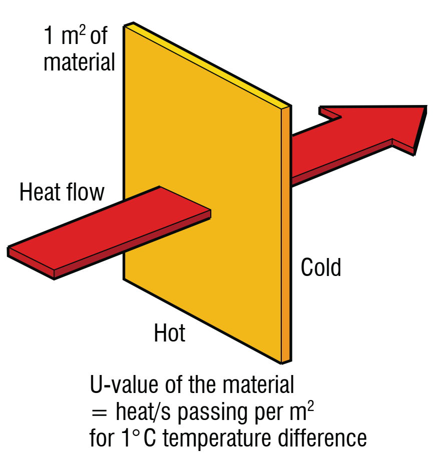


Figure 2 U-values

Reducing thermal energy losses at home

Home heating bills can be expensive. Figure 1 shows how we can reduce the loss of energy at home and reduce our home heating bills.

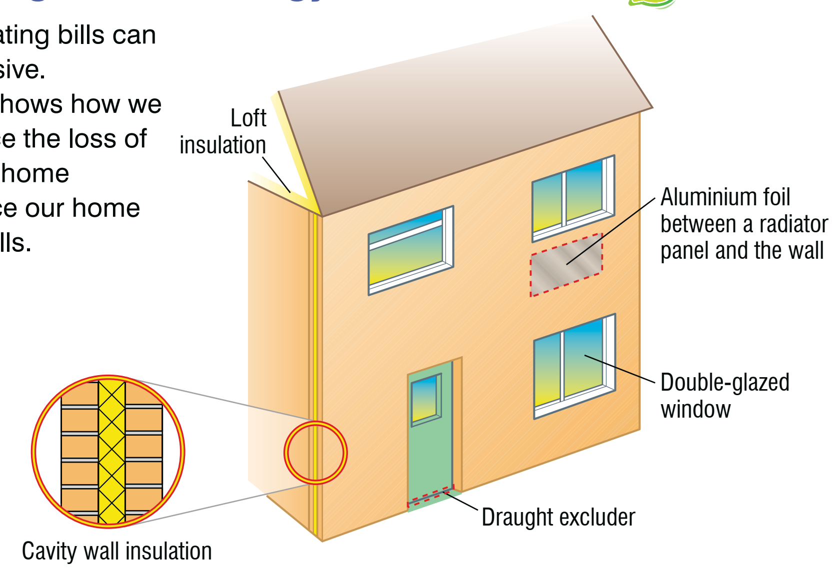


Figure 1 Saving money

- **Loft insulation** such as fibreglass reduces thermal energy loss through the roof. Fibreglass is a good insulator and the air between the fibres also helps to reduce energy loss by conduction.
- **Cavity wall insulation** reduces energy loss through the outer walls of the house. The 'cavity' of an outer wall is the space between the two layers of brick that make up the wall. The insulation is pumped into the cavity. It is a better insulator than the air it replaces. It traps the air in pockets, reducing convection currents.
- **Aluminium foil** between a radiator panel and the wall reflects radiation away from the wall.
- **Double-glazed windows** have two glass panes with dry air or a vacuum between the panes. Dry air is a good insulator so it cuts down energy conduction. A vacuum cuts out energy transfer by convection as well.

a Why is cavity wall insulation better than air in the cavity between the walls of a house?

U-values

We can compare different insulating materials if we know their U-values. This is the energy per second that passes through one square metre of material when the temperature difference across it is 1 °C.

The lower the U-value, the more effective the material is as an insulator.

For example, replacing a single-glazed window with a double-glazed window that has a U-value four times smaller would make the energy loss through the window four times smaller.

b The U-value of 'MoneySaver' loft insulation is twice that of 'Staywarm'. Which type is more effective as an insulator?

Solar heating panels

Heating water at home using electricity or gas can be expensive. A solar heating panel uses solar energy to heat water. The panel is usually fitted on a roof that faces south, making the most of the Sun's energy. Figure 3 shows the design of one type of solar heating panel.

- The panel is a flat box containing liquid-filled copper pipes on a matt black metal plate.
- The pipes are connected to a heat exchanger in a water storage tank in the house.

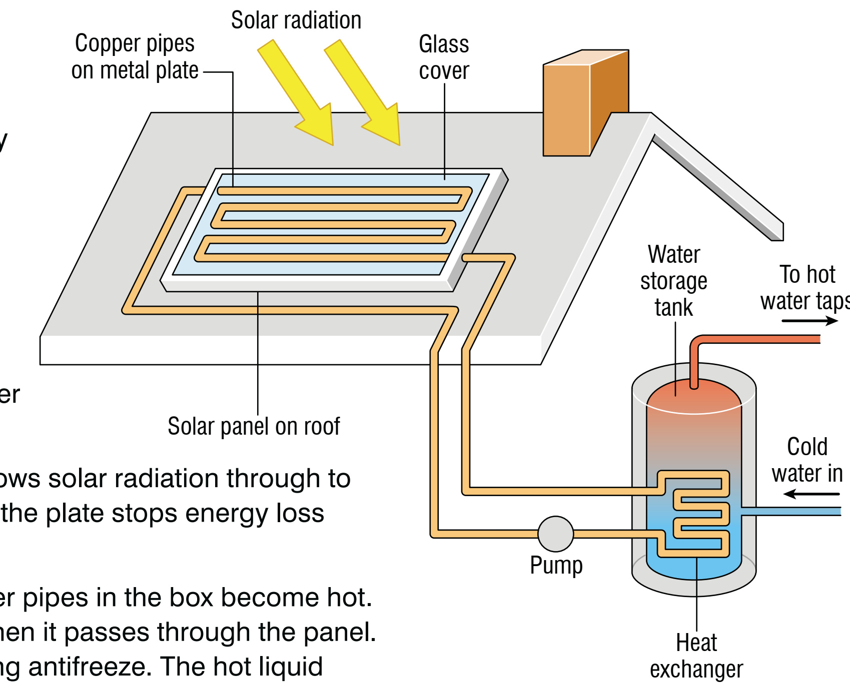


Figure 3 A solar heating panel

A transparent cover on the top of the panel allows solar radiation through to heat the metal plate. Insulating material under the plate stops energy loss through the back of the panel.

On a sunny day, the metal plate and the copper pipes in the box become hot. Liquid pumped through the pipes is heated when it passes through the panel. The liquid may be water or a solution containing antifreeze. The hot liquid passes through the heat exchanger and transfers energy to the water in the storage tank.

Payback time

Solar heating panels save money because no fuel is needed to heat the water. But they are expensive to buy and to install.

Suppose you pay £2000 to buy and install a solar panel and you save £100 each year on your fuel bills. After 20 years you would have saved £2000 on your fuel bills and therefore recovered the 'up-front' costs.

In other words, the **payback time** for the solar panel is 20 years. This is the time taken to recover the up-front costs from the savings on fuel bills.

links

For more information on payback times see P1 3.4 Cost effectiveness matters.

Summary questions

1 Copy and complete sentences **a** to **c** using the words below. Each word can be used more than once.

conduction convection radiation

a Cavity wall insulation reduces energy loss due to ………… .
b Aluminium foil behind a radiator cuts down energy loss due to ………… .
c Closing the curtains in winter cuts down energy loss due to ………… and ………… .

2 Some double-glazed windows have a plastic frame and a vacuum between the panes.
a Why is a plastic frame better than a metal frame?
b Why is a vacuum between the panes better than air?

3 A manufacturer of loft insulation claimed that each roll of loft insulation would save £10 per year on fuel bills. A householder bought 6 rolls of the loft insulation at £15 per roll and paid £90 to have the insulation fitted in her loft.
a How much did it cost to buy and install the loft insulation?
b What would be the saving each year on fuel bills?
c Calculate the payback time.

Key points

- Energy loss from our homes can be reduced by fitting:
  - loft insulation
  - cavity wall insulation
  - double glazing
  - draught proofing
  - aluminium foil behind radiators.
- U-values tell us how much heat per second passes through different materials.
- Solar heating panels do not use fuel to heat water but they are expensive to buy and install.

Summary questions

1 **a** Why does a matt surface in sunshine get hotter than a shiny surface?

b What type of surface is better for a flat roof – a matt dark surface or a smooth shiny surface? Explain your answer.

c A solar heating panel is used to heat water. Why is its top surface painted matt black?

d Why is a car radiator painted matt black?

2 Copy and complete sentences **a** and **b** using the words below:

collide electrons ions vibrate

a Energy transfer in a metal is due to particles called .... moving about freely inside the metal. They transfer energy when they .... with each other.

b Energy transfer in a non-metallic solid is due to particles called .... inside the non-metal. They transfer energy because they ....

3 A heat sink is a metal plate or clip fixed to an electronic component to stop it overheating.

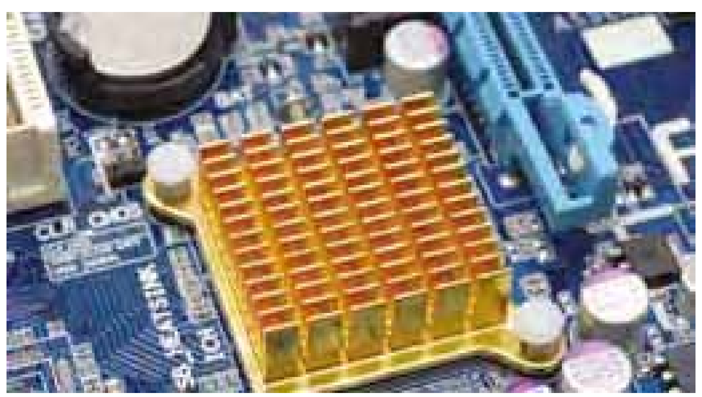


Figure 1 A heat sink

a When the component becomes hot, how does energy transfer from where it is in contact with the plate to the rest of the plate?

b Why does the plate have a large surface area?

4 Copy and complete sentences **a** to **d** using the words below. Each word can be used more than once.

conduction convection radiation

a .... cannot happen in a solid or through a vacuum.

b Energy transfer from the Sun is due to ....

c When a metal rod is heated at one end, energy transfer due to .... takes place in the rod.

d .... is energy transfer by electromagnetic waves.

5 **a** In winter, why do gloves keep your hands warm outdoors?

b Why do your ears get cold outdoors in winter if they are not covered?

6 Energy transfer takes place in each of the following examples. In each case, state where the energy transfer occurs and if the energy transfer is due to conduction, convection or radiation.

a The metal case of an electric motor becomes warm due to friction when the motor is in use.

b A central heating radiator warms up first at the top when hot water is pumped through it.

c A slice of bread is toasted under a red-hot electric grill.

7 A glass tube containing water with a small ice cube floating at the top was heated at its lower end. The time taken for the ice cube to melt was measured. The test was repeated with a similar ice cube weighted down at the bottom of the tube of water. The water in this tube was heated near the top of the tube. The time taken for the ice cube to melt was much longer than in the first test.

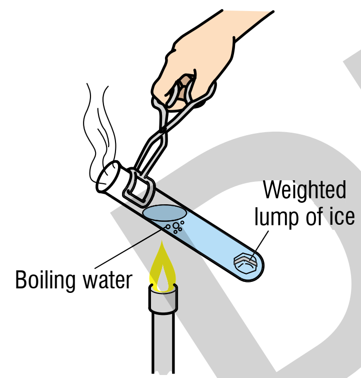


Figure 2 Energy transfer in water

a Energy transfer in the tube is due to conduction or convection or both.

i Why was convection the main cause of energy transfer to the ice cube in the first test?

ii Why was conduction the only cause of energy transfer in the second test?

b Which of the following conclusions about these tests is true?

1 Energy transfer due to conduction does not take place in water.

2 Energy transfer in water is mainly due to convection.

3 Energy transfer in water is mainly due to conduction.

AQA Examination-style questions

1 Convection takes place in fluids.

Use words from the list to complete each sentence. Each word can be used once, more than once or not at all.

contracts expands rises sinks transfers

When a fluid is heated it ...., becomes less dense, and .... The warm fluid is replaced by cooler, denser, fluid. The resulting convection current .... heat throughout the fluid. (3)

2 There are three states of matter: solid, liquid and gas.

Complete each sentence.

a A solid has
a fixed shape and a fixed volume.
a fixed shape but not a fixed volume.
a fixed volume but not a fixed shape.
neither a fixed shape nor a fixed volume. (1)

b A liquid has
a fixed shape and a fixed volume.
a fixed shape but not a fixed volume.
a fixed volume but not a fixed shape.
neither a fixed shape nor a fixed volume. (1)

c A gas has
a fixed shape and a fixed volume.
a fixed shape but not a fixed volume.
a fixed volume but not a fixed shape.
neither a fixed shape nor a fixed volume. (1)

d Fluids are
solids or liquids.
solids or gases.
liquids or gases. (1)

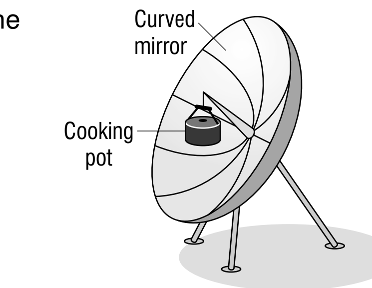
e The particles in a solid
move about at random in contact with each other.
move about at random away from each other.
vibrate about fixed positions. (1)

3 In an experiment a block of copper is heated from 25 °C to 45 °C.

a Give the name of the process by which heat travels through the copper block. (1)

b The mass of the block is 1.3 kg.
Calculate the heat needed to increase the temperature of the copper from 25 °C to 45 °C.
Specific heat capacity of copper = 380 J/kg °C.
Write down the equation you use. Show clearly how you work out your answer. (3)

4 The diagram shows some water being heated with a solar cooker.



The curved mirror reflects the sunlight that falls on it. The sunlight can be focused on to the cooking pot. The energy from the sunlight is absorbed by the pot, heating up the water inside.

a Explain why a matt black pot has been used. (2)

b When the water has been heated, equal amounts of the water are poured into two metal pans. The pans are identical except one has a matt black surface and the other has a shiny metal surface.

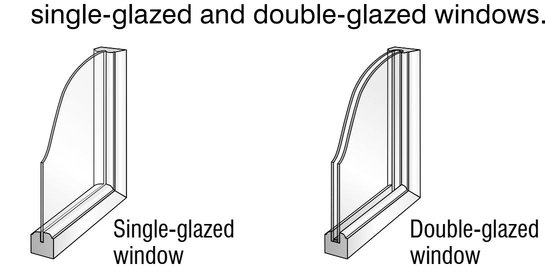
Which pan will keep the water warm for the longest time? Explain your answer. (2)

5 The continuous movement of water from the oceans to the air and land and back to the oceans is called the water cycle.

a The Sun heats the surface of the oceans which causes water to evaporate.
How does the rate of evaporation depend on
i the wind speed
ii the temperature
iii the humidity? (3)

b Explain how evaporation causes a cooling effect. (3)

6 Double-glazed windows are used to reduce heat loss from buildings. The diagrams show cross-sections of single-glazed and double-glazed windows.



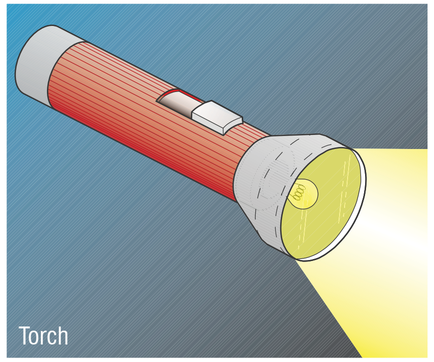
a Give two reasons why a double-glazed window reduces conduction more effectively than a single-glazed window. (2)

b Outline the similarities and differences between the process of conduction in metals and non-metals
In this question you will get marks for using good English, organising information clearly and using scientific words correctly. (5)

P1 2.1 Forms of energy

Learning objectives

- What forms of energy are there?
- How can we describe energy changes?
- What energy changes take place when an object falls to the ground?



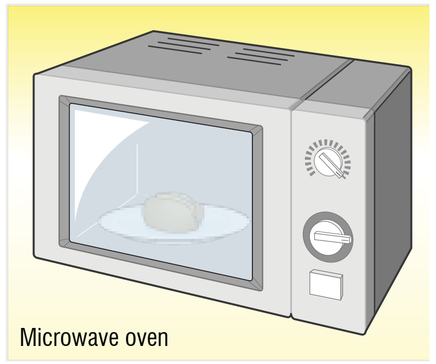


Figure 2 Energy transfers

On the move

Cars, buses, planes and ships all use energy from fuels. They carry their own fuel. Electric trains use energy from fuel in power stations. Electricity transfers energy from the power station to the train.

Figure 1 The French TGV (Train à grande vitesse) electric train can reach speeds of more than 500 km/hour

We describe energy stored or transferred in different ways as **forms of energy**.

Here are some examples of forms of energy:

- **Chemical energy** is energy stored in fuel (including food). This energy is released when chemical reactions take place.
- **Kinetic energy** is the energy of a moving object.
- **Gravitational potential energy** is the energy of an object due to its position.
- **Elastic potential energy** is the energy stored in a springy object when we stretch or squash it.
- **Electrical energy** is energy transferred by an electric current.
- **Thermal energy** of an object is energy due to its temperature. This is partly due to the random kinetic energy of the particles of the object.

a What form of energy is supplied to the train in Figure 1?

We say that energy is **transformed** when it changes from one form into another.

In the torch in Figure 2, the torch's battery pushes a current through the bulb. This makes the torch bulb emit light and it also gets hot. We can show the energy transfers using a flow diagram:

chemical energy in the battery → electrical energy → light energy → thermal energy

b What happens to the thermal energy of the torch bulb?

Practical

Energy transfers

When an object starts to fall freely, it gains kinetic energy because it speeds up as it falls. So its gravitational potential energy is transferred to kinetic energy as it falls.

Look at Figure 3. It shows a box that hits the floor with a thud. All of its kinetic energy is transferred to heat and sound energy at the point of impact. The proportion of kinetic energy transferred to sound is much smaller than that transferred to heat.

- Draw an energy flow diagram to show the changes in Figure 3.

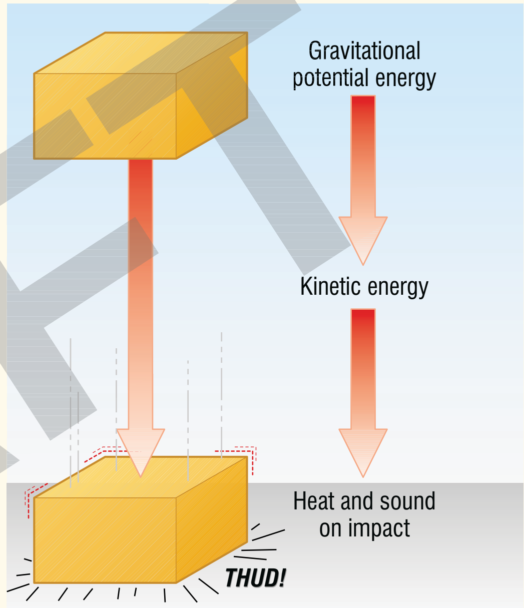


Figure 3 An energetic drop

Summary questions

1 Copy and complete sentences **a** and **b** using the words below:

electric kinetic gravitational potential thermal

a When a ball falls in air, it loses .... energy and gains .... energy.
b When an electric heater is switched on, it transfers .... energy into .... energy.

2 **a** List two different objects you could use to light a room if you have a power cut. For each object, describe the energy transfers that happen when it produces light.
b Which of the two objects in **a** is:
i easier to obtain energy from,
ii easier to use?

3 Read the 'Did you know' box on this page about the pile driver.
a What form of energy does the steel block have after it has been raised?
b Draw an energy flow diagram for the steel block from the moment it is released to when it stops moving.

Did you know ...?

Tall buildings need firm foundations. Engineers make the foundations using a pile driver to hammer steel girders end-on into the ground. The pile driver lifts a heavy steel block above the top end of the girder. Then it lets the block crash down onto the girder. The engineers keep doing this until the bottom end of the girder reaches solid rock.

Figure 4 A pile driver in action

Key points

- Energy exists in different forms.
- Energy can change (transform) from one form into another form.
- When an object falls and gains speed, its gravitational potential energy decreases and its kinetic energy increases.

P1 2.2 Conservation of energy

Learning objectives

- What do we mean by 'conservation of energy'?
- Why is conservation of energy a very important idea?

AQA Examiner's tip

Never use the term 'movement energy' in the exam; you will only gain marks for using 'kinetic energy'.

At the funfair

Funfairs are very exciting places because lots of energy transfers happen quickly. A roller coaster gains gravitational potential energy when it climbs. Then it loses gravitational potential energy when it races downwards.

As it descends:

its gravitational potential energy → kinetic energy + sound + thermal energy due to air resistance and friction

a When a roller coaster gets to the bottom of a descent, what energy transfers happen if:
- **i** we apply the brakes to stop it?
- **ii** it goes up and over a second 'hill'?

Figure 1 On a roller coaster – having fun with energy transfers!

Practical

Investigating energy changes

Pendulum swinging

When energy changes happen, does the total amount of energy stay the same? We can investigate this question with a simple pendulum.

Figure 2 shows a pendulum bob swinging from side to side.

As it moves towards the middle, its gravitational potential energy changes to kinetic energy.

As it moves away from the middle, its kinetic energy changes back to gravitational potential energy. You should find that the bob reaches the same height on each side.

- What does this tell you about the energy of the bob when it goes from one side at maximum height to the other side at maximum height?
- Why is it difficult to mark the exact height the pendulum bob rises to? How could you make your judgement more accurate?

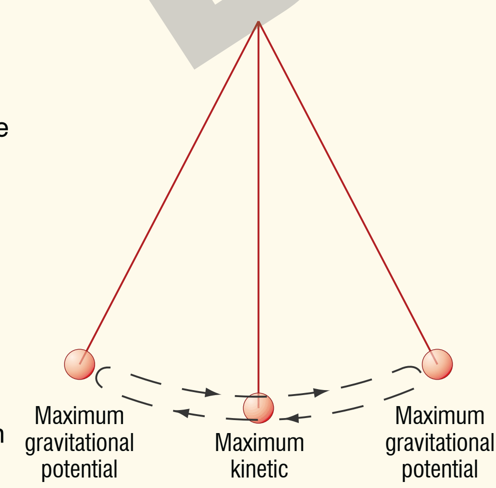


Figure 2 A pendulum in motion

Conservation of energy

Scientists have done lots of tests to find out if the total energy after a transfer is the same as the energy before the transfer. All the tests so far show it is the same.

This important result is known as the **conservation of energy**.

It tells us that **energy cannot be created or destroyed**.

Bungee jumping

What energy transfers happen to a bungee jumper after jumping off the platform?

- When the rope is slack, some of the gravitational potential energy of the bungee jumper is transferred to kinetic energy as the jumper falls.
- Once the slack in the rope has been used up, the rope slows the bungee jumper's fall. Most of the gravitational potential energy and kinetic energy of the jumper is transferred into elastic strain energy.
- After reaching the bottom, the rope pulls the jumper back up. As the jumper rises, most of the elastic strain energy of the rope is transferred back to gravitational potential energy and kinetic energy of the jumper.

The bungee jumper doesn't return to the same height as at the start. This is because some of the initial gravitational potential energy has been transferred to heat energy as the rope stretched then shortened again.

b What happens to the gravitational potential energy lost by the bungee jumper?

c Draw a flow diagram to show the energy changes.

Practical

Bungee jumping

You can try out the ideas about bungee jumping using the experiment shown in Figure 4.

Summary questions

1 Copy and complete using the words below. Each option can be used more than once.

electrical gravitational potential thermal

A person going up in a lift gains .... energy. The lift is driven by electric motors. Some of the .... energy supplied to the motors is transferred to .... energy instead of .... energy.

2 a A ball dropped onto a trampoline returns to almost the same height after it bounces. Describe the energy transfer of the ball from the point of release to the top of its bounce.

b What can you say about the energy of the ball at the point of release compared with at the top of its bounce?

c You could use the test in **a** above to see which of three trampolines was the bounciest.
- **i** Name the independent variable in this test.
- **ii** Is this variable categoric, discrete or continuous?

3 One exciting fairground ride acts like a giant catapult. The capsule, in which you are strapped, is fired high into the sky by the rubber bands of the catapult. Explain the energy transfers taking place in the ride.

Figure 3 Bungee jumping

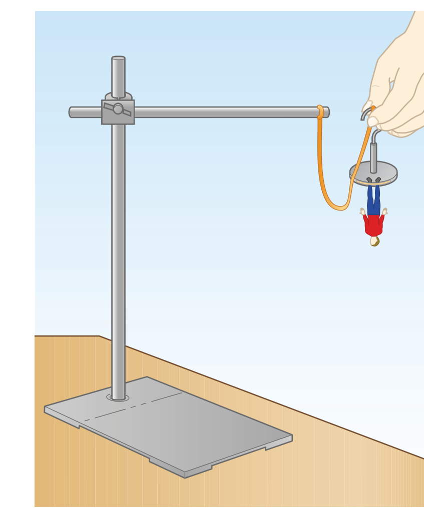


Figure 4 Testing a bungee jump

links

For more information on variables, look back at H2 Fundamental ideas about how science works.

Key points

- Energy can be transformed from one form to another or transferred from one place to another.
- Energy cannot be created or destroyed.
- Conservation of energy applies to all energy changes.

P1 2.3 Useful energy

Learning objectives

- What is 'useful' energy?
- What do we mean by 'wasted' energy?
- What eventually happens to wasted energy?
- Does energy become less useful after we use it?

Figure 1 Using energy

Did you know ... ?

Lots of energy is transferred in a car crash. The faster the car travels the more kinetic energy it has and the more it has to lose before stopping. In a crash, kinetic energy is quickly transferred to elastic energy, distorting the car's shape, and energy transferred to heat in metal. There is usually quite a lot of sound energy too!

Energy for a purpose

Where would we be without machines? We use washing machines at home. We use machines in factories to make the goods we buy. We use them in the gym to keep fit and we use them to get us from place to place.

a What happens to all the energy you use in a gym?

A machine transfers energy for a purpose. Friction between the moving parts of a machine causes the parts to warm up. So not all of the energy supplied to a machine is usefully transferred. Some energy is wasted.

- **Useful energy** is energy transferred to where it is wanted, in the form it is wanted.
- **Wasted energy** is energy that is not usefully transferred or transformed.

b What happens to the kinetic energy of a machine when it stops?

Practical

Investigating friction

Friction in machines always causes energy to be wasted. Figure 2 shows two examples of friction in action. Try one of them out.

In **a**, friction acts between the drill bit and the wood. The bit becomes hot as it bores into the wood. Some of the electrical energy supplied to the bit changes into thermal energy of the drill bit (and the wood).

In **b**, when the brakes are applied, friction acts between the brake blocks and the wheel. This slows the bicycle and the cyclist down. Some of the kinetic energy of the bicycle and the cyclist is transferred to energy heating the brake blocks (and the bicycle wheel).

You can practise your skills in 'How science works' by investigating friction on different surfaces.

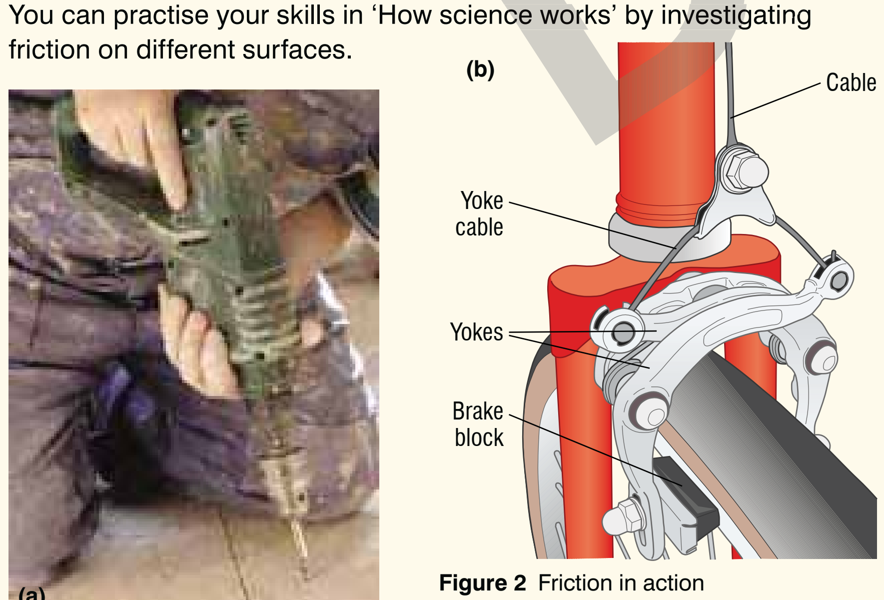


Figure 2 Friction in action
(a) Using a drill **(b)** Braking on a bicycle

Disc brakes at work

The next time you are in a car slowing down at traffic lights, think about what is making the car stop. Figure 3 shows how the disc brakes of a car work. When the brakes are applied, the pads are pushed on to the disc in each wheel. Friction between the pads and each disc slows the wheel down. Some of the kinetic energy of the car is transferred to energy heating the disc pads and the discs. In Formula One racing cars you can sometimes see the discs glow red hot.

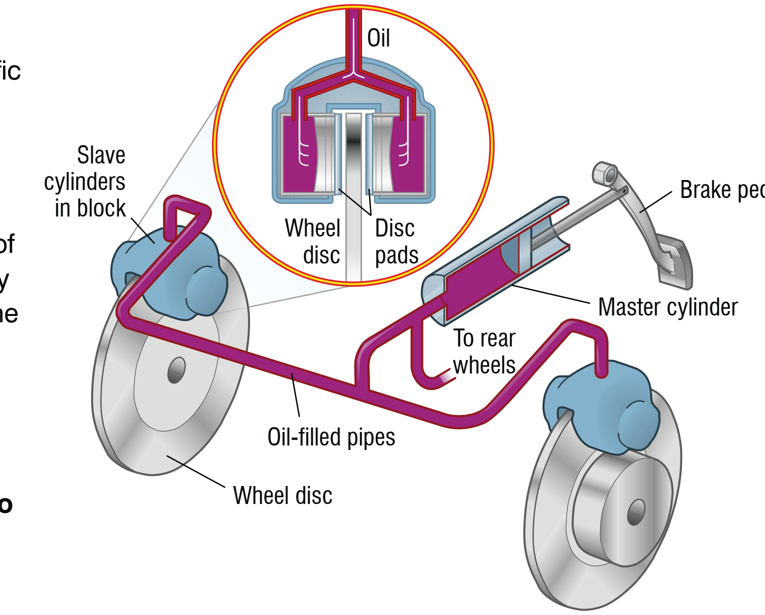


Figure 3 Disc brakes

Spreading out

- **Wasted energy is dissipated (spreads out) to the surroundings.**
  For example, the gears of a car get hot due to friction when the car is running. So energy transfers from the gear box to the surrounding air.
- **Useful energy eventually transfers to the surroundings too.**
  For example, the useful energy supplied to the wheels of a car is transferred to energy heating the tyres. This energy is then transferred to the road and the surrounding air.
- **Energy becomes less useful, the more it spreads out.**
  For example, the hot water from the cooling system of a CHP (combined heat and power) power station gets used to heat nearby buildings. The energy supplied to heat the buildings will eventually be lost to the surroundings.

c The hot water from many power stations flows into rivers or lakes. Why is this wasteful?

Summary questions

1 Copy and complete the table below. Show what happens to the energy transferred in each case.

Energy transfer by	Useful energy	Wasted energy
An electric heater		
A television		
An electric kettle		
Headphones		

2 What would happen, in terms of energy transfer, to
  a a gear box that was insulated so it could not lose energy heating the surroundings?
  b a jogger wearing running shoes, which are well-insulated?
  c a blunt electric drill if you use it to drill into hard wood?

3 a Describe the energy transfers of a pendulum as it swings from one side to the middle then to the opposite side.
  b Explain why a swinging pendulum eventually stops.

Key points

- Useful energy is energy in the place we want it and in the form we need it.
- Wasted energy is energy that is not useful energy.
- Useful energy and wasted energy both end up being transferred to the surroundings, which become warmer.
- As energy spreads out, it gets more and more difficult to use for further energy transfers.

P1 2.4 Energy and efficiency

Learning objectives

- What do we mean by efficiency?
- How efficient can a machine be?
- How can we make machines more efficient?

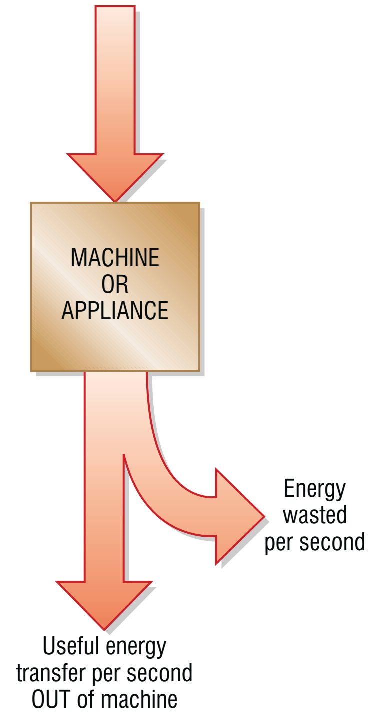


Figure 1 A Sankey diagram

When you lift an object, the useful energy from your muscles goes to the object as gravitational potential energy. This depends on its weight and how high it is raised.

- Weight is measured in **newtons (N)**. The weight of a 1 kilogram object on the Earth's surface is about 10 N.
- Energy is measured in **joules (J)**. The energy needed to lift a weight of 1 N by a height of 1 metre is equal to 1 joule.

Your muscles get warm when you use them so they do waste some energy.

a Think about lowering a weight. What happens to its gravitational potential energy?

Sankey diagrams

Figure 1 represents the energy transfer through a device. It shows how we can represent any energy transfer where energy is wasted. This type of diagram is called a **Sankey diagram**.

Because energy cannot be created or destroyed:

energy supplied = useful energy delivered + energy wasted

For any device that transfers energy:

$$\textbf{efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}} \ (\times 100\%)$$

Maths skills

Efficiency can be written as a number (which is never more than 1) or as a percentage.

For example, a light bulb with an efficiency of 0.15 would radiate 15 J of energy as light for every 100 J of electrical energy we supply to it.

- Its efficiency (as a number) $= \frac{15}{100} = 0.15$
- Its percentage efficiency $= 0.15 \times 100\% = 15\%$

b How much energy is wasted for every 100 J of electrical energy supplied?
c What happens to the wasted energy?

Maths skills

Worked example

An electric motor is used to raise an object. The object gains 60 J of gravitational potential energy when the motor is supplied with 200 J of electrical energy. Calculate the percentage efficiency of the motor.

Solution

Total energy supplied to the device = 200 J

Useful energy transferred by the device = 60 J

Percentage efficiency of the motor

$$= \frac{\text{useful energy transferred by the motor}}{\text{total energy supplied to the motor}} \times 100\%$$

$$= \frac{60\text{ J}}{200\text{ J}} \times 100\% = 0.30 \times 100\% = 30\%$$

Efficiency limits

No machine can be more than 100% efficient because we can never get more energy from a machine than we put into it.

Practical

Investigating efficiency

Figure 2 shows how you can use an electric winch to raise a weight. You can use the joulemeter to measure the electrical energy supplied.

- If you double the weight for the same increase in height, do you need to supply twice as much electrical energy to do this task?

The gravitational potential energy gained by the weight = weight in newtons × height increase in metres.

- Use this equation and the joulemeter measurements to work out the percentage efficiency of the winch.

Safety: Protect the floor and your feet. Stop the winch before the masses wrap round the pulley.

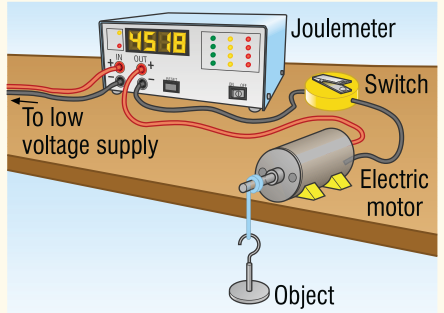


Figure 2 An electric winch

Improving efficiency

Table 1

	Why machines waste energy	How to reduce the problem
1	Friction between the moving parts causes heating.	Lubricate the moving parts to reduce friction.
2	The resistance of a wire causes the wire to get hot when a current passes through it.	In circuits, use wires with as little electrical resistance as possible.
3	Air resistance causes energy transfer to the surroundings.	Streamline the shapes of moving objects to reduce air resistance.
4	Sound created by machinery causes energy transfer to the surroundings.	Cut out noise (e.g. tighten loose parts to reduce vibration).

d Which of the above solutions would hardly reduce the energy supplied?

AQA Examiner's tip

- The greater the percentage of the energy that is usefully transferred in a device, the more efficient the device is.
- Efficiency and percentage efficiency are numbers without units. The maximum efficiency is 1 or 100%, so if a calculation produces a number greater than this it must be wrong.

Summary questions

1 Copy and complete sentences **a** to **c** using the words below. Each word can be used more than once.

supplied to wasted by

a The useful energy from a machine is always less than the total energy .... it.
b Friction between the moving parts of a machine causes energy to be .... the machine.
c Because energy is conserved, the energy .... a machine is the sum of the useful energy from the machine and the energy .... the machine.

2 An electric motor is used to raise a weight. When you supply 60 J of electrical energy to the motor, the weight gains 24 J of gravitational potential energy. Work out:
a the energy wasted by the motor
b the efficiency of the motor.

3 A machine is 25% efficient. If the total energy supplied to the machine is 3200 J, how much useful energy can be transferred?

Key points

- The efficiency of a device = useful energy transferred by the device/total energy supplied to the device (× 100%).
- No machine can be more than 100% efficient.
- Measures to make machines more efficient include reducing friction, air resistance, electrical resistance and noise due to vibrations.

Summary questions

1 The devices listed below transfer energy in different ways.

1 Car engine 2 Electric bell

3 Electric light bulb 4 Gas heater

The next list gives the useful form of energy the devices are designed to produce.

Match words A, B, C and D with the devices numbered 1 to 4.

A Heat (thermal energy) B Light

C Movement (kinetic energy) D Sound

2 Copy and complete using the words below:

useful wasted thermal light electrical

When a light bulb is switched on, ... energy is transferred .... energy and into .... energy of the surroundings. The energy that radiates from the light bulb is .... energy. The rest of the energy supplied to the light bulb is .... energy.

3 You can use an electric motor to raise a load. In a test, you supply the motor with 10 000 J of electrical energy and the load gains 1500 J of gravitational potential energy.

a Calculate its efficiency.

b How much energy is wasted?

c Copy and complete the Sankey diagram below for the motor.

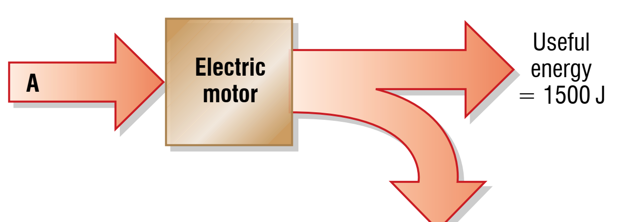


Figure 1 A Sankey diagram for an electric motor

4 A ball gains 4.0 J of gravitational potential energy when it is raised to a height of 2.0 m above the ground. When it is released, it falls to the ground and rebounds to a height of 1.5 m.

a How much kinetic energy did it have just before it hit the ground? Assume air resistance is negligible.

b How much gravitational potential energy did it lose when it fell to the ground?

c The ball gained 3.0 J of gravitational potential energy when it moved from the ground to the top of the rebound. How much energy did it lose in the impact at the ground?

d What happened to the energy it lost on impact?

5 A low energy light bulb has an efficiency of 80%. Using an energy meter, a student found the light bulb used 1500 J of electrical energy in 100 seconds.

a How much useful energy did the light bulb transfer in this time?

b How much energy was wasted by the light bulb?

c Draw a Sankey diagram for the light bulb.

6 A bungee jumper jumps from a platform and loses 12 000 J of gravitational potential energy before the rope attached to her becomes taut and starts to stretch. She then loses a further 24 000 J of gravitational potential energy before she stops falling and begins to rise.

a Describe the energy changes:

i after she jumps before the rope starts to stretch

ii after the rope starts to stretch until she stops falling.

b What is the maximum kinetic energy she has during her descent?

7 On a building site, an electric winch and a pulley were used to lift bricks from the ground.

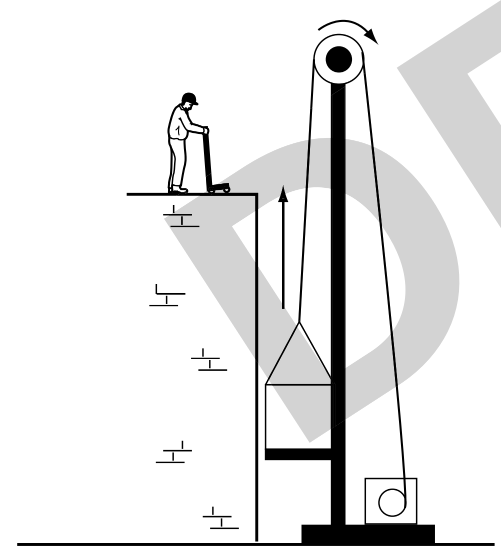


Figure 2 On a building site

The winch used 12 000 J of electrical energy to raise a load through a height of 3.0 m. The load gained 1500 J of gravitational potential energy when it was raised.

a i How much useful energy was transferred by the motor ?

ii Calculate the energy wasted.

iii Calculate the percentage efficiency of the system.

b How could the efficiency of the winch be improved?

AQA Examination-style questions

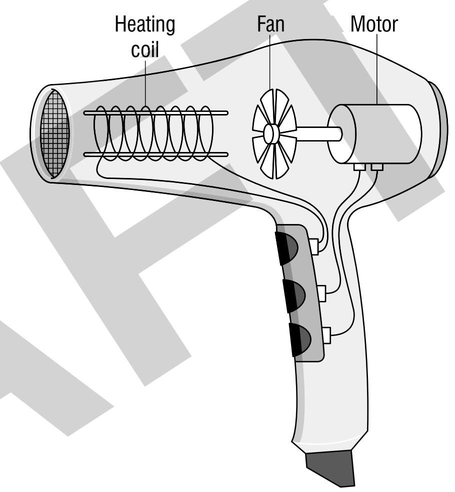
1 A television transforms electrical energy into other forms.

Use words from the list to complete each sentence. Each word can be used once, more than once or not at all.

electrical light sound thermal

A television is designed to transform .... energy into light and .... energy. Some energy is wasted as .... energy. (3)

2 A hairdryer contains an electrical heater and a fan driven by an electric motor. The hairdryer usefully transfers electrical energy into two other forms.



a Name these two forms of energy. (2)

b Not all of the energy supplied to the fan is usefully transferred. Name one form of energy that is wasted by the fan. (1)

c Which of the following statements about the energy wasted by the fan is true?

A It eventually becomes very concentrated.

B It eventually makes the surroundings warmer.

C It is eventually completely destroyed.

D It is eventually transformed into electrical energy. (1)

d The fan in another hairdryer transfers useful energy at the same rate but wastes more of the energy supplied to it. What does this tell you about the efficiency of this hairdryer? (1)

3 In a hot water system water is heated by burning gas in a boiler. The hot water is then stored in a tank. For every 111 J of energy released from the gas, 100 J of energy is absorbed by the water in the boiler.

a Calculate the percentage efficiency of the boiler.

Write down the equation you use. Show clearly how you work out your answer. (4)

b The energy released from the gas but **not** absorbed by the boiler is 'wasted'. Explain why this energy is of little use for further energy transfers. (1)

c The tank in the hot water system is surrounded by a layer of insulation. Explain the effect of the insulation on the efficiency of the hot water system. (3)

4 A chairlift carries skiers to the top of a mountain. The chairlift is powered by an electric motor.

a What type of energy have the skiers gained when they reach the top of the mountain? (1)

b The energy required to lift two skiers to the top of the mountain is 240 000 J.

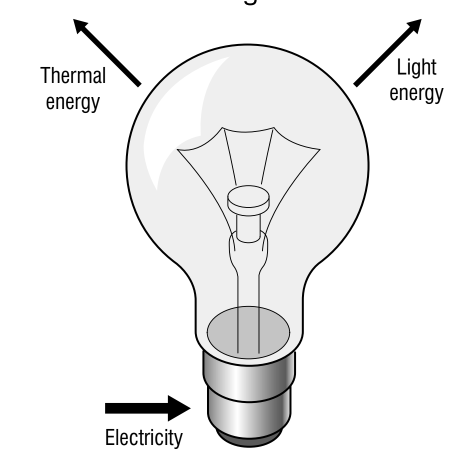
The electric motor has an efficiency of 40%.

Calculate the energy wasted in the motor.

Write down the equation you use. Show clearly how you work out your answer. (4)

c Explain why some energy is wasted in the motor. (2)

5 a A light bulb transfers electrical energy into useful light energy and wasted thermal energy. For every 100 J of energy supplied to the bulb, 5 J of energy is transferred into light.



Draw and label a Sankey diagram for the light bulb.

b Explain why an electric heater is the only device that can possibly be 100% efficient.

In this question you will get marks for using good English, organising information clearly and using scientific words correctly. (5)

P1 3.1 Electrical appliances

Learning objectives

- Why are electrical appliances so useful?
- What do we use most everyday electrical appliances for?
- How do we choose an electrical appliance for a particular job?

Practical

Energy transfers

Carry out a survey of electrical appliances you find at school or at home.

Record the useful and wasted energy transfers of each appliance.

Did you know ... ?

Frankenstein was a 19th century fictional character who used electricity from a lightning strike to turn a corpse into an ugly monster. No one liked the monster so it turned on Frankenstein.

Unlike high voltage electrical injuries, people do not get many burns when they are struck by lightning. Damage is usually to the nervous system. The brain is frequently damaged as the skull is the most likely place to be struck. Lightning that strikes near the head can enter the body through the eyes, ears and mouth and flow internally through the body.

Everyday electrical appliances

We use electrical appliances every day. They transfer electrical energy into useful energy at the flick of a switch. Some of the electrical energy we supply to them is wasted.

Figure 1 Electrical appliances – how many can you see in this photo?

Table 1

Appliance	Useful energy	Energy wasted
Light bulb	Light from the glowing filament.	Heat transfer from the filament to surroundings.
Electric heater	Energy heating the surroundings.	Light from the glowing element.
Electric toaster	Energy heating bread.	Energy heating the toaster case and the air around it.
Electric kettle	Energy heating water.	Energy heating the kettle itself.
Hairdryer	Kinetic energy heating the air driven by the fan. Energy heating air flowing past the heater filament.	Sound of fan motor (energy heating the motor heats the air going past it, so is not wasted). Energy heating the hairdryer itself.
Electric motor	Kinetic energy of object driven by the motor. Potential energy of objects lifted by the motor.	Energy heating the motor and sound energy of the motor.
Computer disc drive	Energy stored in magnetic dots on the disc.	Energy heating the motor that drives the disc.

a What energy transfers happen in an electric toothbrush?

How science works

Clockwork radio

People without electricity supplies can now listen to radio programmes – thanks to the British inventor Trevor Baylis. In the early 1990s, he invented and patented the clockwork radio. When you turn a handle on the radio, you wind up a clockwork spring in the radio. When the spring unwinds, it turns a small electric generator in the radio. It doesn't need batteries or mains electricity. So people in remote areas where there is no mains electricity can listen to their radios without having to walk miles for a replacement battery. But they do have to wind up the spring every time it runs out of energy.

Figure 2 Clockwork radios are now mass-produced and sold all over the world

Choosing an electrical appliance

We use electrical appliances for many purposes. Each appliance is designed for a particular purpose and it should waste as little energy as possible. Suppose you were a rock musician at a concert. You would need appliances that transfer sound energy into electrical energy and then back into sound energy. But you wouldn't want them to produce lots of energy heating the appliance itself and its surroundings. See if you can spot some of these appliances in Figure 3.

Figure 3 On stage

b What electrical appliance transfers:
  i sound energy into electrical energy?
  ii electrical energy into sound energy?

c What other electrical appliance would you need at a concert?

Summary questions

1 Copy and complete using the words below:

electrical light heating

When a battery is connected to a light bulb, ... energy is transferred from the battery to the light bulb. The filament of the light bulb becomes hot and transfers energy .... its surroundings (which is wasted), as well as .... energy.

2 Match each electrical appliance in the list below with the energy transfer A, B or C it is designed to bring about.

1 Electric drill 3 Electric oven
2 Food mixer 4 Electric bell

Energy transfer A Electrical energy → thermal energy
B Electrical energy → sound energy
C Electrical energy → kinetic energy

3 **a** Why does a clockwork radio need to be wound up before it can be used?
b What energy transfers take place in a clockwork radio when it is wound up then switched on?
c Give an advantage and a disadvantage of a clockwork radio compared with a battery-operated radio.

Key points

- Electrical appliances can transfer electrical energy into useful energy at the flick of a switch.
- Uses of everyday electrical appliances include heating, lighting, making objects move (using an electric motor) and creating sound and visual images.
- An electrical appliance is designed for a particular purpose and should waste as little energy as possible.

P1 3.2 Electrical power

Learning objectives

- What do we mean by power?
- How can we calculate the power of an appliance?
- How can we calculate the efficiency of an appliance in terms of power?

Figure 1 A lift motor

Figure 2 Rocket power

Powerful machines

When you use a lift to go up, a powerful electric motor pulls you and the lift upwards. The lift motor transfers energy from electrical energy to gravitational potential energy when the lift goes up at a steady speed. We also get electrical energy transferred to wasted energy heating the motor and the surroundings, and sound energy.

- The energy we supply per second to the motor is the **power** supplied to it.
- The more powerful the lift motor is, the faster it is able to move a particular load.

In general, we can say that:

the more powerful an appliance, the faster the rate at which it transforms energy.

We measure the power of an appliance in watts (W) or kilowatts (kW).

1 **watt** is a rate of transfer of energy of 1 joule per second (J/s).

1 **kilowatt** is equal to 1000 watts (i.e. 1000 joules per second or 1 kJ/s).

Power (in watts, W) = rate of transfer of energy

$$= \frac{\text{energy transerred (in joules, J)}}{\text{time taken (in seconds, s)}}$$

Maths skills

Worked example

A motor transfers 10 000 J of energy in 25 s. What is its power?

Solution

Power (in watts, W) $= \dfrac{\text{energy transerred (in joules, J)}}{\text{time taken (in seconds, s)}}$

Power $= \dfrac{10\,000\ \text{J}}{25\ \text{s}} = 400\ \text{W}$

a What is the power of a lift motor that transfers 50 000 J of energy from the electricity supply in 10 s?

Power ratings

Here are some typical values of power ratings for different energy transfers:

Table 1

Appliance	Power rating
A torch	1 W
An electric light bulb	100 W
An electric cooker	10 000 W = 10 kW (where 1 kW = 1000 watts)
A railway engine	1 000 000 W = 1 megawatt (MW) = 1 million watts
A Saturn V rocket	100 MW
A very large power station	10 000 MW
World demand for power	10 000 000 MW
A star like the Sun	100 000 000 000 000 000 000 MW

b How many 100 W electric light bulbs would use the same amount of power as a 10 kW electric cooker?

Muscle power

How powerful is a weightlifter?

A 30 kg dumbbell has a weight of 300 N. Raising it by 1 m would give it 300 J of gravitational potential energy. A weightlifter could lift it in about 0.5 seconds. The rate of energy transfer would be 600 J/s (= 300 J/0.5 s). So the weightlifter's power output would be about 600 W in total!

c An inventor has designed an exercise machine that can also generate 100 W of electrical power. Do you think people would buy this machine in case of a power cut?

Figure 3 Muscle power

Efficiency and power

For any appliance

- its useful power out (or output power) is the useful energy **per second** transferred by it.
- its total power in (or input power) is the energy **per second** supplied to it.

In P1 2.4 Energy and efficiency, we saw that the efficiency of an appliance

$$= \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to it}} (\times 100\%)$$

Because power = energy **per second** transferred or supplied, we can write the efficiency equation as:

$$\text{Efficiency} = \frac{\text{useful power out}}{\text{total power in}} (\times 100\%)$$

For example, suppose the useful power out of an electric motor is 20 W and the total power in is 80 W, the percentage efficiency of the motor is:

$$\frac{\text{useful power out}}{\text{total power in}} \times 100\% = \frac{20\ \text{W}}{80\ \text{W}} \times 100\% = 25\%$$

Summary questions

1 a Which is more powerful?
  i A torch bulb or a mains filament lamp.
  ii A 3 kW electric kettle or a 10 000 W electric cooker.
b There are about 20 million occupied homes in England. If a 3 kW electric kettle was switched on in 1 in 10 homes at the same time, how much power would need to be supplied?

2 The total power supplied to a lift motor is 5000 W. In a test, it transfers 12 000 J of electrical energy to gravitational potential energy in 20 seconds.
a How much electrical energy is supplied to the motor in 20 s?
b What is its efficiency in the test?

3 A machine has an input power rating of 100 kW. If the useful energy transferred by the machine in 50 seconds is 1500 kJ, calculate
a its output power in kilowatts
b its percentage efficiency.

Key points

- Power is rate of transfer of energy.
- Power (in watts) = $\dfrac{\text{energy transferred (in joules)}}{\text{time taken (in seconds)}}$
- Efficiency = $\dfrac{\text{useful power out}}{\text{total power in}}$ (× 100%)

P1 3.3 Using electrical energy

Learning objectives

- What is the kilowatt-hour?
- How can we work out the energy used by a mains appliance?
- How is the cost of mains electricity worked out?

When you use an electric heater, how much electrical energy is transferred from the mains? You can work this out if you know its power and how long you use it for.

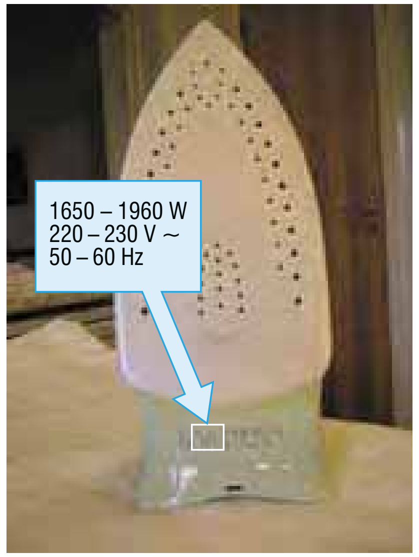


Figure 1 Mains power

For any appliance, the energy supplied to it depends on

- how long it is used for
- the power supplied to it.

A 1 kilowatt heater uses the same amount of electrical energy in 1 hour as a 2 kilowatt heater would use in half an hour. For ease, we say that:

the energy supplied to a 1 kW appliance in 1 hour is **1 kilowatt-hour (kWh)**.

We use the kilowatt-hour as the unit of energy supplied by mains electricity. You can use this equation to work out the energy, in kilowatt-hours, used by a mains appliance in a certain time:

Energy transferred (kilowatt-hours, kWh) = power of appliance (kilowatts, kW) × time in use (hours, h)

For example:

- a 1 kW heater switched on for 1 hour uses 1 kWh of electrical energy (= 1 kW × 1 hour)
- a 1 kW heater switched on for 10 hours uses 10 kWh of electrical energy (= 10 kW × 1 hour)
- a 0.5 kW or 500 W heater switched on for 6 hours uses 3 kWh of electrical energy (= 0.5 kW × 6 hours).

If we want to calculate the energy transferred in joules, we can use the formula:

energy supplied in joules = power in watts × time in use in seconds

a How many kWh of energy are used by a 100 W lamp in 24 hours?
b How many joules of energy are used by a 5 W torch lamp in 3000 seconds (= 50 minutes)?

Did you know ... ?

One kilowatt-hour is the amount of electrical energy supplied to a 1 kilowatt appliance in 1 hour.

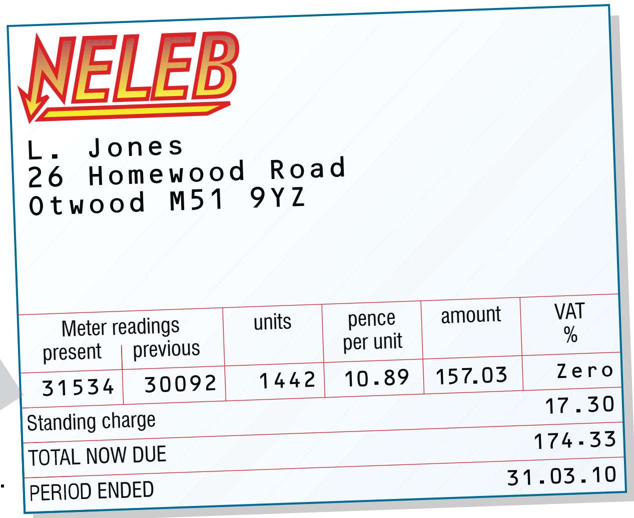
So **1 kilowatt-hour** = 1000 joules per second × 60 × 60 seconds = 3 600 000 J = **3.6 million joules**.

Paying for electrical energy

The **electricity meter** in your home measures how much electrical energy your family uses. It records the total energy supplied, no matter how many appliances you all use. It gives us a reading of the number of kilowatt-hours (kWh) of energy supplied by the mains.

Figure 2 An electricity meter

In most houses, somebody reads the meter every three months. Look at the electricity bill in Figure 3.


NELEB

L. Jones
26 Homewood Road
Otwood M51 9YZ

Meter readings present	Meter readings previous	units	pence per unit	amount	VAT %
31534	30092	1442	10.89	157.03	Zero
Standing charge					17.30
TOTAL NOW DUE					174.33
PERIOD ENDED					31.03.10

Figure 3 Checking your bill

The difference between the two readings is the number of kilowatt-hours supplied since the last bill.

c Check for yourself that 1442 kWh of electrical energy is supplied in the bill shown.

We use the kilowatt-hour to work out the cost of electricity. For example, a cost of 12p per kWh means that each kilowatt-hour of electrical energy costs 12p. Therefore:

total cost = number of kWh used × cost per kWh

d Work out the cost of 1442 kWh at 12p per kWh.

AQA Examiner's tip

Remember that a kilowatt-hour (kWh) is a unit of energy.

Summary questions

1 Copy and complete sentences **a** to **c** using the words below. Each word can be used more than once:

hour kilowatt kilowatt-hours

a The .... is a unit of power.
b Electricity meters record the mains electrical energy transferred in units of ....
c One .... is the energy transformed by a 1 .... appliance in 1 ....

2 a Work out the number of kWh transferred in each case below.
i A 3 kilowatt electric kettle is used 6 times for 5 minutes each time.
ii A 1000 watt microwave oven is used for 30 minutes.
iii A 100 watt electric light is used for 8 hours.
b Calculate the total cost of the electricity used in part **a** if the cost of electricity is 12p per kWh.

3 An electric heater is left on for 3 hours. During this time it uses 12 kWh of electrical energy.
a What is the power of the heater?
b How many joules are supplied?

Key points

- The kilowatt-hour is the energy supplied to a 1 kW appliance in 1 hour.
- Energy transferred (kilowatt-hours, kWh) = power of appliance (kilowatts, kW) × time in use (hours, h)
- Total cost = number of kWh used × cost per kWh

P1 3.4 Cost effectiveness matters

Learning objectives

- What do we mean by cost effectiveness?
- How can we compare the cost effectiveness of different energy-saving measures?

Costs

When we compare the effectiveness of different energy-saving appliances that do the same job, we need to make sure we get value for money. In other words, we need to make sure the appliance we choose is **cost effective**.

To compare the cost effectiveness of different cost-cutting measures, we need to consider:

- the capital costs such as buying and installing equipment
- the running costs, including fuel and maintenance
- environmental costs, for example
  - removal or disposal of old equipment (e.g. refrigerators, used batteries)
  - tax charges such as carbon taxes of fossil fuels
- other costs such as interest on loans.

Payback time again!

A householder wants to cut her fuel bills by reducing heat losses from her home. This would save fuel and reduce fuel bills. She is comparing loft insulation with cavity wall insulation in terms of payback time.

- The loft insulation costs £200 (including gloves and a safety mask) and she would fit the insulation herself. This could save £100 per year on the fuel bill. So the payback time would be 2 years.
- The cavity wall insulation for a house costs £500 and an additional £100 to fit the insulation. This could save £200 per year on the fuel bill. It would pay for itself after 3 years.

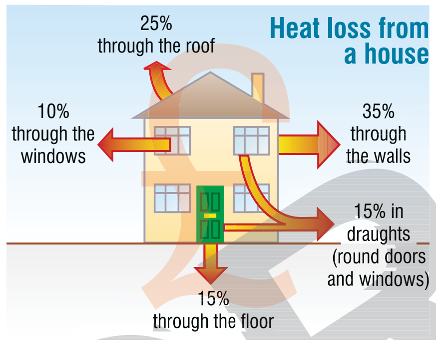


Figure 1 Heat loss from a house

a For each type of insulation, how much would the householder have saved after 5 years?

b A double-glazed window costs £200. It saves £10 per year on the fuel bill. How long is the payback time?

links

For more information on payback time see P1 1.9 Heating and insulating buildings.

Did you know ... ?

Infrared cameras can be used to identify heat losses from a house in winter. The camera image shows hot spots as a different colour.

Figure 2 Heat losses at home

Activity

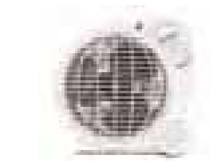
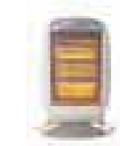
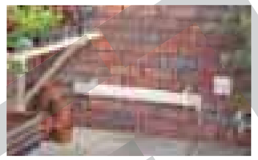
Buying a heater

An artist wants to buy an electric heater to provide instant heating in his workshop when he starts work on a cold morning. He can't decide between a fan heater, a radiant heater and a tubular heater.

Table 1 shows how each type of heater works and its main drawback.

Assuming the heaters cost the same to buy, write a short report advising the artist which type of heater would be most suitable for him.

Table 1

Heater type	Input power	How the heater works	Drawbacks
	2.0 kW	blows warm air from the hot element round the room	energy needed to run the fan motor
	1.0 kW	uses a reflector to direct radiation from the glowing element	the radiation only heats the air and objects in front of the heater
	0.5 kW	the heater element is inside a metal tube which heats the room	provides background heat gradually

Lighting costs

Low-energy lamps use much less electrical energy than filament lamps. This is why the UK government has banned the sale of filament lamps. Table 2 gives some data about different types of mains lamps.

Table 2

Type	Power in watts	Efficiency	Lifetime in hours	Cost of lamp	Typical use	Drawbacks
Filament lamp	100 W	20%	1000	50p	room lighting	inefficient, gets hot
Halogen lamp	100 W	25%	2500	£2.00	spotlight	inefficient, gets hot
Low-energy compact fluorescent lamp (CFL)	25 W	80%	15 000	£2.50	room lighting	takes a few minutes for full brightness, disposal must be in a sealed bag due to mercury (which is toxic) in it
Low-energy light-emitting diode (LED) lamp	2 W	90%	30 000	£7.00	spotlight	expensive, brightness of one halogen lamp needs several LEDs

c Which lamp has the greatest output in terms of useful energy?

d Which type of spotlight lamp produces the least heat?

Summary questions

1 Use the information in Table 2 to answer the following questions.

a State one advantage and one disadvantage of a CFL lamp compared with a filament lamp.

b State one advantage and one disadvantage of a LED lamp compared with a halogen lamp.

Key points

- Cost effectiveness means getting the best value for money.
- To compare the cost effectiveness of different appliances, we need to take account of costs to buy it, running costs and other costs such as environmental costs.

Summary questions

1 **a** Name an appliance that transfers electrical energy into:
  i light and sound energy
  ii kinetic energy.

b Complete the sentences below.
  i In an electric bell, electrical energy is transferred into useful energy in the form of .... energy and .... energy.
  ii In a washing machine, electrical energy is transferred into useful energy in the form of .... energy and sometimes as .... energy.

2 **a** Which two words in the list below are units that can be used to measure energy?

joule   kilowatt   kilowatt-hour   watt

b Rank the electrical appliances below in terms of energy used from highest to lowest
A a 0.5 kW heater used for 4 hours
B a 100 W lamp left on for 24 hours
C a 3 kW electric kettle used 6 times for 10 minutes each time
D a 750 W microwave oven used for 10 minutes.

3 **a** The readings of an electricity meter at the start and the end of a month are shown below.

0	9	3	7	2

Reading at start of month

0	9	6	1	5

Reading at end of month
  i Which is the reading at the end of the month?
  ii How many kilowatt-hours of electricity were used during the month?
  iii How much would this electricity cost at 12p per kWh?

b A pay meter in a holiday home supplies electricity at a cost of 12p per kWh.
  i How many kWh would be supplied for £1.20?
  ii How long could a 2 kW heater be used for after £1 is put in the meter slot?

4 An escalator in a shopping centre is powered by a 50 kW electric motor. The escalator is in use for a total time of 10 hours every day.

a How much electrical energy in kWh is supplied to the motor each day?

b The electricity supplied to the motor costs 12p per kWh. What is the daily cost of the electricity supplied to the motor?

c How much would be saved each day if the motor was replaced by a more efficient 40 kW motor?

5 The data below shows the electrical appliances used in a house in one evening.
A a 1.0 kW heater for 4 hours.
B a 0.5 kW television for 2 hours.
C a 3 kW electric kettle three times for 10 minutes each time.

a Which appliance uses most energy?

b How many kWh of electrical energy is used by each appliance?

c Each kWh costs 12p. How much did it cost to use the three appliances?

6 The battery of a laptop computer is capable of supplying 60 watts to the computer circuits for 2 hours before it needs to be recharged.

a Calculate the electrical energy the battery can supply in two hours in
  i kilowatt-hours
  ii joules.

b List three forms of energy that the electrical energy from the battery is transformed into when the computer is being used.

c A mains charging unit can be connected to the computer when in use to keep its battery fully charged. Would the computer use less energy with the charging unit connected than without it connected?

7 A student has an HD television at home that uses 120 watts of electrical power when it is switched on. He monitors its usage for a week and finds it is switched on for 30 hours.

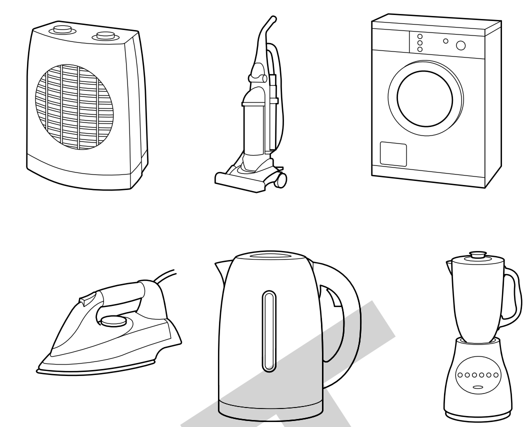
Figure 1 An HD TV in use

a How many kilowatt-hours of electrical energy are supplied to it in this time?

b Calculate the cost of this electrical energy at 12p per kilowatt-hour.

AQA Examination-style questions

1 The pictures show six different household appliances.



Name the **four** appliances in which electrical energy is usefully transferred into kinetic energy. (4)

2 An electric motor is used to lift a load. The useful power output of the motor is 30 watts. The total input power to the motor is 75 W.

Calculate the percentage efficiency of the motor.

Write down the equation you use. Show clearly how you work out your answer. (3)

3 Which two of the following units are units of energy?

a J

b J/s

c kWh

d W (1)

4 The diagram shows the readings on a household electricity meter at the beginning and end of one week.

5	2	3	4	0

Beginning of the week

5	2	5	5	5

End of the week

a How many kWh of electricity were used during the week? (1)

b On one day 35 kWh of electricity were used. The total cost of this electricity was £5.25.

How much did the electricity cost per kWh?

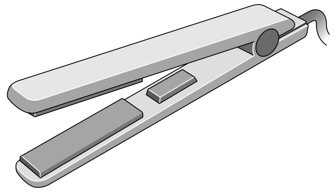
Write down the equation you use. Show clearly how you work out your answer. (3)

c During the week a 2.4 kW kettle was used for 2 hours.

How much energy was transferred by the kettle?

Write down the equation you use. Show clearly how you work out your answer. (3)

5 A student uses some hair straighteners.



a What useful energy transfer takes place in the hair straighteners? (1)

b The hair straighteners have a power of 90 W.

What is meant by *a power of 90 W*? (2)

c How many kilowatt-hours of electricity are used when the straighteners are used for 15 minutes?

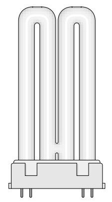
Write down the equation you use. Show clearly how you work out your answer. (2)

d The electricity supplier is charging 14p per kWh.

How much will it cost to use the straighteners for 15 minutes a day for one year?

Show clearly how you work out your answer. (2)

6 Filament lamps are being replaced by compact fluorescent lamps.



A compact fluorescent lamp costs £12, a filament lamp costs 50p.

A 25 W compact fluorescent lamp gives out as much light as a 100 W filament lamp.

A filament lamp lasts for about 1000 hours; a compact fluorescent lamp lasts for about 8000 hours, although this time is significantly shorter if the lamp is turned on and off very frequently.

A compact fluorescent lamp contains a small amount of poisonous mercury vapour.

a Why does a 25 W compact fluorescent lamp provide the same amount of light as a 100 W filament lamp but use less electricity? (2)

b Outline the advantages and disadvantages of buying compact fluorescent lamps rather than filament lamps.

In this question you will get marks for using good English, organising information clearly and using scientific words correctly. (5)

Glossary

A

Agar The nutrient jelly on which many microorganisms are cultured.
Alkali metals The elements in Group 1 of the Periodic Table, e.g. lithium (Li), sodium (Na), potassium (K).
Alloy A mixture of metals (and sometimes non-metals). For example, brass is a mixture of copper and zinc.
Aluminium A low density, corrosion-resistant metal used in many alloys, including those used in the aircraft industry.
Antibiotics Drugs that destroy bacteria inside the body without damaging human cells.
Antigens The unique proteins on the surface of a cell. They are recognised by the immune system as 'self' or 'non-self'.
Atom The smallest part of an element. All atoms contain protons and electrons.
Atomic number The number of protons (which equals the number of electrons) in an atom. It is sometimes called the proton number.
Auxin A plant hormone which controls the responses of plants to light (phototropism) and to gravity (gravitropism).

B

Bacteria Single-celled microorganisms that can reproduce very rapidly. Many bacteria are useful, e.g. gut bacteria and decomposing bacteria, but some cause disease.
Bioleaching The extraction of metals from ores using microorganisms in the process.
Blast furnace The huge reaction vessels used in industry to extract iron from its ore.
Brass An alloy of copper and zinc.
Bronze A alloy of copper and tin.

C

Calcium carbonate The main compound found in limestone. It is a white solid whose formula is $CaCO_3$.
Calcium hydroxide A white solid made by reacting calcium oxide with water. It is used as a cheap alkali in industry.
Calcium oxide A white solid made by heating limestone strongly, e.g. in a lime kiln.
Cast iron The impure iron taken directly from a blast furnace.
Cement A building material made by heating limestone and clay.
Central nervous system (CNS) The central nervous system is made up of the brain and spinal cord where information is processed.
Chemical energy Energy of an object due to chemical reactions in it.
Compound A substance made when two or more elements are chemically bonded together. For example, water (H_2O) is a compound made from hydrogen and oxygen.
Concrete A building material made by mixing cement, sand and aggregate (crushed rock) with water.
Condense Turn from vapour into liquid.
Conservation of energy Energy cannot be created or destroyed.
Contraceptive pill A pill containing female sex hormones that is used to prevent conception.
Copper-rich ores Rocks that contain a high proportion of a copper compound.
Covalent bonds The attraction between two atoms that share one or more pairs of electrons.
Culture medium A medium containing the nutrients needed for microorganisms to grow.

D

Data Information, either qualitative or quantitative, that has been collected.
Density Mass per unit volume of a substance.
Depression A mental illness that involves feelings of great sadness that interfere with everyday life.
Diffuse Spread out.
Diffusion Spreading out of particles away from each other.
Direct contact A way of spreading infectious diseases by skin contact between two people.
Displace When one element takes the place of another in a compound. For example: iron + copper sulfate → iron sulfate + copper
Double blind trial A drug trial in which neither the patient or the doctor knows if the patient is receiving the new drug or a placebo.
Droplet infection A way of spreading infectious diseases through tiny droplets full of pathogens, which are expelled from your body when you cough, sneeze or talk.

E

Effective medicine A medicine that cures the disease it is targeting.
Effector organs Muscles and glands that respond to impulses from the nervous system.
Efficiency Useful energy transferred by a device ÷ total energy supplied to the device.
Elastic potential energy Energy stored in an elastic object when work is done to change its shape.
Electrical energy Energy transferred by the movement of electrical charge.
Electricity meter Meter in a home that measures the amount of electrical energy supplied.
Electron A tiny particle with a negative charge. Electrons orbit the nucleus in atoms or ions.
Energy level (or shell) An area in an atom, around its nucleus, where the electrons are found.
Enzymes Protein molecules that act as biological catalysts. They change the rate of chemical reactions without being affected themselves at the end of the reaction.
Epidemic When more cases of an infectious disease are recorded than would normally be expected.
Evaporate Turn from liquid into vapour.
Evidence Data that has been shown to be valid.

F

Fluids A liquid or a gas.
Free electrons Electrons that move about freely inside a metal and are not held inside an atom.
FSH Follicle stimulating hormone, a female hormone that stimulates the eggs to mature in the ovaries, and the ovaries to produce hormones, including oestrogen.

G

Gravitational potential energy Energy of an object due to its position in a gravitational field. Near the Earth's surface, change of g.p.e. (in joules, J) = weight (in newtons, N) × vertical distance moved (in metres, m).
Gravitropism Response of a plant to the force of gravity controlled by auxin.
Group All the elements in a column down the Periodic Table.

H

Homeostasis The maintenance of constant internal body conditions.

I

Immune system The body system that recognises and destroys foreign tissue such as invading pathogens.
Immunisation Giving a vaccine that allows immunity to develop without exposure to the disease itself.
Impulses Electrical messages carried along the neurones.
Infectious Capable of causing infection.
Infectious diseases Diseases that can be passed from one individual to another.
Infrared radiation Electromagnetic waves between visible light and microwaves in the electromagnetic spectrum.
Inherited Passed on from parents to their offspring through genes.
Internal environment The conditions inside the body.
Ionic bond The electrostatic force of attraction between positively and negatively charged ions.

J

Joules (J) The unit of energy.

K

Kidneys Organs that filter the blood and remove urea, excess salts and water.
Kilowatt (kW) 1000 watts.
Kilowatt-hour (kW h) Electrical energy supplied to a 1 kW electrical device in 1 hour.
Kinetic energy Energy of a moving object due to its motion; kinetic energy (in joules, J) = ½ × mass (in kilograms, kg) × $(\text{speed})^2$ (in m^2/s^2).

M

Malnourished The condition when the body does not get a balanced diet.
Menstrual cycle The reproductive cycle in women controlled by hormones.
Metabolic rate The rate at which the reactions of your body take place, particularly cellular respiration.
Microorganism Bacteria, viruses and other organisms which can only be seen using a microscope.
Molecule A group of atoms bonded together, e.g. PCl_5.
Mortar A building material used to bind bricks together. It is made by mixing cement and sand with water.
Motor neurons Neurons that carry impulses from the central nervous system to the effector organs.
MRSA Methicillin-resistant *Staphylococcus aureus*. An antibiotic-resistant bacterium.

N

Natural selection The process by which evolution takes place. Organisms produce more offspring than the environment can support so only those which are most suited to their environment – the 'fittest' – will survive to breed and pass on their useful characteristics.
Nerves Bundles of hundreds or even thousands of neurons.
Nervous system See Central nervous system.
Neuron(s) Basic cells of the nervous system that carry minute electrical impulses around the body.
Neutron A dense particle found in the nucleus of an atom. It is electrically neutral, carrying no charge.
Newtons (N) The unit of force.
Nucleus (of an atom) The centre of an atom, where protons and neutrons are found. The mass and positive charge of an atom are concentrated in its nucleus.

O

Obese Very overweight, with a BMI over 30.
Oestrogen Female sex hormone that stimulates the lining of the womb to build up in preparation for a pregnancy.
Oral contraceptives Hormone contraceptives that are taken by mouth.
Ores Ores are rocks that contain enough metal to make it economically worthwhile to extract the metal.
Ovaries Female sex organs that contain the eggs and produce sex hormones during the menstrual cycle.
Ovulation The release of a mature egg from the ovary in the middle of the menstrual cycle.

P

Pancreas An organ that produces the hormone insulin and many digestive enzymes.
Pandemic When more cases of a disease are recorded than normal in a number of different countries.
Pathogens Microorganisms that cause disease.
Period The stage in the menstrual cycle when the lining of the womb is lost.

Photosynthesis The process by which plants make food using carbon dioxide, water and light energy.
Phototropism The response of a plant to light, controlled by auxin.
Phytomining The extraction of metals from ores using plants in the process.
Pituitary gland Small gland in the brain that produces a range of hormones controlling body functions.
Placebo A substance used in clinical trials that does not contain any drug at all.
Power The energy transformed or transferred per second. The unit of power is the watt (W).
Prediction A forecast or statement about the way something will happen in the future. In science it is not just a simple guess because it is based on some prior knowledge or on a hypothesis.
Product A substance made as a result of a chemical reaction.
Progesterone Female sex hormone used in the contraceptive pill.
Proton A tiny positive particle found inside the nucleus of an atom.
Puberty The stage of development when the sexual organs and the body become adult.

R

Reactant A substance we start with before a chemical reaction takes place.
Reactivity series A list of elements in order of their reactivity. The most reactive element is put at the top of the list.
Receptors Special sensory cells that detect changes in the environment.
Reduction A reaction in which oxygen is removed (or electrons are gained).
Reflex arc The sense organ, sensory neuron, relay neuron, motor neuron and effector organ, which bring about a reflex action.
Reflexes Rapid automatic responses of the nervous system that do not involve conscious thought.

S

Safe medicine A medicine that does not cause any unreasonable side effects while curing a disease.
Sankey diagram An energy transfer diagram.
Secreting Releasing chemicals such as hormones or enzymes.
Sense organs Collection of special cells known as receptors, which respond to changes in the surroundings (e.g. eye, ear).
Sensory neurons Neurons that carry impulses from the sensory organs to the central nervous system.
Shell (or energy level) An area in an atom, around its nucleus, where the electrons are found.
Smelting Heating a metal ore in order to extract its metal.
Specific heat capacity Energy needed by 1 kg of the substance to raise its temperature by 1 °C.
Stainless steel A chromium-nickel alloy of steel that does not rust.
Statins Drugs that lower the blood cholesterol levels and improve the balance of HDLs to LDL.
Steel An alloy of iron with small amounts of carbon or other metals, such as nickel and chromium, added.
Steroids Drugs that are used illegally by some athletes to build muscles and improve performance.
Stimuli A change in the environment that is detected by sensory receptors.
Synapses The gaps between neurons where the transmission of information is chemical rather than electrical.

T

Thalidomide A drug that caused deformities in the fetus when given to pregnant women to prevent morning sickness.
Titanium A shiny, corrosion-resistant metal used to make alloys.
Transformed Changed from one form into another form.
Transition metal These elements are from the central block of the Periodic Table. They have typical metallic properties and form coloured compounds.

U

Useful energy Energy transferred to where it is wanted in the form it is wanted.

V

Vaccination Introducing small quantities of dead or inactive pathogens into the body to stimulate the white blood cells to produce antibodies that destroy the pathogens. This makes the person immune to future infection.
Vaccine The dead or inactive pathogen material used in vaccination.
Viruses Microorganisms that take over body cells and reproduce rapidly, causing disease.

W

Wasted energy Energy that is not usefully transferred or transformed.
Watt The unit of power.
White blood cells Blood cells that are involved in the immune system of the body, engulfing bacteria, making antibodies and making antitoxins.
Withdrawal symptoms The symptoms experienced by a drug addict when they do not get the drug to which they are addicted.

3. The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112–116 have been reported but not fully authenticated						

* The Lanthanides (atomic numbers 58 –71) and the Actinides (atomic numbers 90–103) have been omitted.

Cu and **Cl** have not been rounded to the nearest whole number.

EXCLUSIVELY AQA ENDORSED

✔ *Written* by the experts
✔ *Checked* by examiners
✔ *Approved* by AQA

New GCSE

Continued success, inspiring all abilities....

New AQA GCSE Science is the only series that is exclusively endorsed and approved by AQA. We work closely with AQA examiners, expert authors and – most importantly – teachers, to truly understand your needs.

- **Differentiated** teaching and learning to inspire all abilities.
- Improved **accessibility** and guidance for **Quality of Written Communication**.
- End-to-end support for the new **ISA/Controlled Assessment**.
- **NEW** *kerboodle!* online learning service – **personalise** learning, track student progress and facilitate home access.
- **FREE Resources Map** and **Schemes of Work** for easy transition to the new specification.

Important note: DRAFT Sample chapters

This is sample content from the *New AQA GCSE Science A kerboodle! Interactive Student Book* and covers nine chapters, three from each of B1, C1 and P1. These chapters are DRAFT content and are written to the most recent version of the draft specifications. There may be changes made to the final version as a result of the resubmission of the specifications required by Ofqual. We are working closely with AQA on the specification development and will keep you informed with updates as the accreditation process progresses.

Teaching the new specification to your Year 9 students this year?

Nine chapters are provided within this interactive book, which will provide you with enough material to teach half of B1, C1 and P1.The corresponding online resources and teacher material are also available within *kerboodle!*

kerboodle!

Like what you see?

☎ Call Customer Support on 01242 267287

Quote code **SCISP** to receive your 20% Early Bird discount on orders of £750 or more before 31st January 2011.