Infrared radiation

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.

- Why is the ground darker than the rhinos?
- 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?

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.

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’.

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.

<table>
<thead>
<tr>
<th>Object</th>
<th>Infrared</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>A hot iron</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A light bulb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A TV screen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Sun</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   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.

A huddle test
Design an investigation to model the effect of penguins huddling together. You could use beaters of hot water to represent the penguins.

Figure 4 Penguins keeping warm

Figure 3 A solar furnace in the Eastern Pyrenees, France

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.

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

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

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.

Light, shiny surfaces reflect more radiation than dark, matt surfaces.

In general:
• Light, shiny surfaces absorb less radiation than dark matt 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 light, shiny ink.

A dark matt surface is a better absorber of infrared radiation than a light shiny surface.

Figure 1 A thermal blanket in use

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 of infrared radiation?

A thermal blanket in use

A thermal blanket in use

Figure 3 Absorbing infrared radiation

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

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 | 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 can and a metallic silver car are parked next to each other on a sunny day. Why does the temperature inside the black car rise 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, Iii radiates most?

c What are the advantages of using data logging equipment to collect the data in this investigation?

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.
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?

Energy transfer by heating

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>
<thead>
<tr>
<th></th>
<th>Flow</th>
<th>Shape</th>
<th>Volume</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>no</td>
<td>fixed</td>
<td>fixed</td>
<td>much higher than a gas</td>
</tr>
<tr>
<td>Liquid</td>
<td>yes</td>
<td>fits container shape</td>
<td>fixed</td>
<td>much higher than a gas</td>
</tr>
<tr>
<td>Gas</td>
<td>yes</td>
<td>fits container</td>
<td>can be changed</td>
<td>low compared with a solid or liquid</td>
</tr>
</tbody>
</table>

Table 1

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

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 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 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.

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

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

Did you know…?
Random means unpredictable. Lottery numbers are chosen at random.

Key points

- The particles in a solid are held next to each other in fixed positions.
- The particles in a liquid are in contact with each other. They move about at random and are much further apart than particles in a solid or liquid.

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 are in contact with each other. They move about at random.
- The particles in a gas move about randomly and are much further apart than particles in a solid or liquid.
**Conduction**

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](image)

**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.)

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.
   - b How could you carry out a test on three different lining materials?
   - Explain your choice of material.
   - 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?

**Table 1:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Starting temperature (°C)</th>
<th>Temperature after 300 s (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>paper</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>felt</td>
<td>40</td>
<td>36</td>
</tr>
</tbody>
</table>

**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.
Convection

Giders 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.

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.

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

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.

A convector heater

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

- What does the heater do to the air inside the heater?
- Why is there a metal grille on top of the heater?
- Where does air flow into the heater?

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. 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.

Figure 3 Hot water at home

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

Figure 2 Convection

Figure 4 Sea breezes

Figure 5 A convector heater

Assessment tasks

AQA Examiner’s tip

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

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.

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!
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.

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.

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. 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.

Factors affecting the rate of evaporation
What factors affect the rate of evaporation? What is evaporation? How does evaporation cause cooling? What factors affect the rate of evaporation from a liquid? What factors affect the rate of condensation on a surface?

Evaporation can be enhanced by increasing the temperature, or by creating a draught of air across the liquid's surface.

Factors affecting the rate of condensation
Factors affect the rate of condensation of a vapour on a surface. The example above shows that the rate of evaporation from a liquid is increased by increasing the surface area of the liquid. The example above shows that the rate of condensation of a vapour on a surface is increased by increasing the surface area of the liquid and increasing the temperature of the liquid. The example above shows that the rate of condensation of a vapour on a surface is increased by increasing the surface area of the liquid and increasing the temperature of the liquid. The example above shows that the rate of condensation of a vapour on a surface is increased by increasing the surface area of the liquid and increasing the temperature of the liquid.

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 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.

Figure 1 Water molecules escaping from a liquid

Figure 2 Condensation

Figure 3 A demonstration of cooling by evaporation

Figure 4 Explanation of cooling by evaporation

Figure 5 An air-conditioning unit
Energy transfer by heating

P1 1.7

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.

Why are car radiators painted black?

What happens to the rate of energy transfer when the cooling fan switches on?

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, the object’s mass and the material it is made from are important for the rate at which energy is transferred.

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

2. An electronic component in a computer is attached to a heat sink.
   - Explain why the heat sink is necessary.
   - Why is a metal plate used as the heat sink?
   - 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.

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

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
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.

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).

Using 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

- 16000 J of energy would have been needed to heat 1.0 kg of water by 4 °C.
- 3200 J was used to heat 0.2 kg of water by 4 °C.
- 1600 J was used to heat 0.1 kg of water by 4 °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.

Formula

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

Rearranging the above equation gives

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

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 45 °C.

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

Summary questions

1. 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.

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

Storage heaters

Storage heaters use off-peak electricity to store energy in special bricks.
Energy transfer by heating

Heating and insulating buildings

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.

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 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.

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Figure 2 U-values

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.

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.

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.
A liquid has component to stop it overheating.

Energy transfer in a non-metallic solid is due to 

**Why does the plate have a large surface area?**

A solar heating panel is used to heat water. Why is its
canhot in a solid or through a vacuum.

Energy transfer by heating: 

- **Conduction**
- **Convection**
- **Radiation**

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

- A solid has
  - **fixed shape** and a **fixed volume**
  - **fixed shape** but not a **fixed volume**
  - **fixed volume** but not a **fixed shape**
  - **neither a fixed shape nor a fixed volume**

**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
   - **fixed shape** and a **fixed volume**
   - **fixed shape** but not a **fixed volume**
   - **fixed volume** but not a **fixed shape**
   - **neither a fixed shape nor a fixed volume**

   b. A liquid has
   - **fixed shape** and a **fixed volume**
   - **fixed shape** but not a **fixed volume**
   - **fixed volume** but not a **fixed shape**
   - **neither a fixed shape nor a fixed volume**

   c. A gas has
   - **fixed shape** and a **fixed volume**
   - **fixed shape** but not a **fixed volume**
   - **fixed volume** but not a **fixed shape**
   - **neither a fixed shape nor a fixed volume**

   d. Fluids are
   - **solids** or **liquids**
   - **solids or liquids**
   - **liquids or gases**

   e. The particles in a solid
   - move about at random in contact with each other.
   - move about at random in contact with each other.
   - vibrate about fixed positions.

3. **In an experiment a block of copper is heated from 25 °C**
   
   Calculate the heat needed to increase the temperature
   
   **Specific heat capacity of copper = 380 J/kg °C.**
   
   **The mass of the block is 1.3 kg.**
   
   Calculate the heat needed to increase the temperature
   
   **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.
   
   b. Explain how the rate of evaporation depends on
   - the wind speed
   - the temperature
   - the humidity? (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)

---

**Summary questions**

1. **a.** Why does a matte 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.**

4. **Examination-style questions**

   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?

   **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.

---

**End of chapter questions**

**Curved mirror**

**Cooling pot**

**Figure 1 A heat sink**

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

- Why does the plate have a large surface area?

---

**Figure 2 Energy transfer in water**

- 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 convection the only cause of energy transfer in the second test?

- Which of the following conclusions about these tests is true?
  
  1. Energy transfer due to convection does not take place in water.
  
  2. Energy transfer in water is mainly due to convection.

---

**Figure 3 In this question you will get marks for using good English, organising information clearly and using scientific words correctly.**

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

- 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.
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?

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.

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\hspace{2em}electrical energy\hspace{2em}light energy\hspace{2em}thermal energy

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

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 \underline{energy} and gains \underline{energy}.
   b When an electric heater is switched on, it transfers \underline{energy} into \underline{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.

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.

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.
**Conservation of 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 changes to kinetic energy + sound + internal energy due to air resistance and friction

**Examiner’s tip**

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

**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 to maximum height to the other side at maximum height?
- Why is it difficult to mark the exact height the pendulum bob rises to?

**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 electrical 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 bounceiest.
      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.

**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.

**Examiner’s tip**

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

**Investigating energy changes**

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   - potential
   - thermal
   
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**Examiner’s tip**

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

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?

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.

Practical

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 heating the disc pads and the discs. In Formula One racing cars you can sometimes see the discs glow red hot.

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.

- 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.

<table>
<thead>
<tr>
<th>Energy transfer by</th>
<th>Useful energy</th>
<th>Wasted energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>An electric heater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A television</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An electric kettle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headphones</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
Using energy

Energy and efficiency

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:

efficiency = useful energy transferred by the device / total energy supplied to the device (×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) = 15 / 100 = 0.15
- Its percentage efficiency = 0.15 × 100% = 15%

b How much energy is wasted for every 100 J of electrical energy supplied?

c What happens to the wasted energy?

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:

= useful energy transferred by the motor / total energy supplied to the motor × 100%
= 60 J / 200 J × 100% = 0.30 × 100% = 30%

Summary questions

a The useful energy from a machine is always less than the total energy supplied to it.

b Friction between the moving parts of a machine causes energy to be wasted by the machine.

c Because energy is conserved, the energy supplied by the device is equal to the energy gained by the motor.

b 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:

- the energy wasted by the machine
- the efficiency of the motor
- 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.

Improving efficiency

Table 1

<table>
<thead>
<tr>
<th>Why machines waste energy</th>
<th>How to reduce the problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>friction between the moving parts causes heating.</td>
<td>Lubricate the moving parts to reduce friction.</td>
</tr>
<tr>
<td>the resistance of a wire causes the wire to get hot when a current passes through it.</td>
<td>In circuits, use wires with as little electrical resistance as possible.</td>
</tr>
<tr>
<td>Air resistance causes energy transfer to the surroundings.</td>
<td>Streamline the shapes of moving objects to reduce air resistance.</td>
</tr>
<tr>
<td>Sound created by machinery causes energy transfer to the surroundings.</td>
<td>Cut out noise (e.g. tighten loose parts to reduce vibration).</td>
</tr>
</tbody>
</table>

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. 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, 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.

3. 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?

4. 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 wasted energy is transferred?
   c Copy and complete the Sankey diagram below for the motor.

5. A television is designed to transform electrical energy into light and sound energy. Some energy is wasted as thermal energy.
   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 A television is designed to transform ______ energy into light and _______ energy. Some energy is wasted as _______ energy.
   b How much useful energy was transferred by the hairdryer?
   c How could the efficiency of the winch be improved?
   d A hairdryer contains an electrical heater and a fan driven by an electric motor. The hairdryer usefully transfers electrical energy into two other forms.
   e Draw and label a Sankey diagram for the light bulb.

6. 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.

7. On a building site, an electric winch and a pulley were used to lift bricks from the ground.
   a Name these two forms of energy.
   b Not all of the energy supplied to the fan is usefully transferred. Name one form of energy that is wasted by the fan.
   c Which of the following statements about the energy wasted by the fan is true?
      i It eventually becomes very concentrated.
      ii It eventually makes the surroundings warmer.
      iii It is eventually completely destroyed.
   d Is it eventually transformed into electrical energy?
   e The fan in another hairdryer uses 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?

8. 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?
   b The energy required to lift two skiers to the top of the mountain is 240,000 J.
   c The electric motor has an efficiency of 40%.
   d Which equation you use. Show clearly how you work out your answer.

9. 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.
   a 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.
   b Explain why an electric heater is the only device that can possibly be 100% efficient.
   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.
   d 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.
   i How much useful energy did the light bulb transfer in this time?
   ii How much energy was wasted by the light bulb?
   iii What is the maximum kinetic energy she has during her descent?
   iv 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.
   v Calculate the percentage efficiency of the system.
   vi Write down the equation you use. Show clearly how you work out your answer.

End of chapter questions

1. Name these two forms of energy.
2. Which of the following statements about the energy wasted by the fan is true?
3. Calculate the percentage efficiency of the system.
4. If you work out your answer.
5. What are the devices listed below transfer energy in different ways.
6. Match words A, B, C and D with the devices numbered 1 to 4.
7. 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.
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Electrical energy

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.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Useful energy</th>
<th>Energy wasted</th>
</tr>
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<tbody>
<tr>
<td>Light bulb</td>
<td>Light from the glowing filament</td>
<td>Heat transfer from the filament to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>surroundings</td>
</tr>
<tr>
<td>Electric heater</td>
<td>Energy heating the surroundings</td>
<td>Light from the glowing element</td>
</tr>
<tr>
<td>Electric toaster</td>
<td>Energy heating bread</td>
<td>Energy heating the toaster case and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the air around it</td>
</tr>
<tr>
<td>Electric kettle</td>
<td>Energy heating water</td>
<td>Energy heating the kettle itself</td>
</tr>
<tr>
<td>Hair dryer</td>
<td>Kinetic energy heating the hair driven by</td>
<td>Sound of fan motor (energy heating</td>
</tr>
<tr>
<td></td>
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<td>the motor heats the air going past</td>
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<td></td>
<td>Energy heating air flowing past the</td>
<td>it, so is not wasted; Energy</td>
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<tr>
<td></td>
<td>heater filament</td>
<td>heating the hairdryer itself</td>
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<td>Electric motor</td>
<td>Kinetic energy of object driven by the</td>
<td>Energy heating the motor and sound</td>
</tr>
<tr>
<td></td>
<td>motor</td>
<td>energy of the motor</td>
</tr>
<tr>
<td>Computer disc drive</td>
<td>Energy stored in magnetic dots on the disc.</td>
<td>Energy heating the motor that</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

How do we choose 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.

a What electrical appliance transfers:
   i sound energy into electrical energy?
   ii electrical energy into sound energy?
   iii What other electrical appliance would you need at a concert?

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.

b What does a clockwork radio need to be wound up before it can be used?
   i 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.

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.

a What electrical appliance transfers:
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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.

a What electrical appliance transfers:
   i sound energy into electrical energy?
   ii electrical energy into sound energy?
   iii 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
   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.

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.

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

Table 1

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**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 J/s).

**Power** (in watts, W) = \( \frac{\text{energy transferred (in joules, J)}}{\text{time taken (in seconds, s)}} \)

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

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

**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:

\[ \text{Efficiency} = \frac{20 \text{ W}}{80 \text{ W}} \times 100\% = 25\% \]

**Power ratings**

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

**Table 1**

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

**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!

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

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

**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.
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.

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:

\[
\text{Energy transferred (kWh)} = \text{power of appliance (kW)} \times \text{time in use (hours, h)}
\]

For example:
- A 1 kW heater switched on for 1 hour uses 1 kWh of electrical energy (= 1 kW \times 1 hour)
- A 1 kW heater switched on for 10 hours uses 10 kWh of electrical energy (= 1 kW \times 10 hours)
- A 0.5 kW or 500 W heater switched on for 6 hours uses 3 kWh of electrical energy (= 0.5 kW \times 6 hours).

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

\[
\text{energy supplied in joules} = \text{power in watts} \times \text{time in use in seconds}
\]

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)?

The kilowatt-hour is the energy transformed by a 1 kilowatt heater in 1 hour.

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 \(\times 60 \times 60\) seconds = 3 600 000 J = 3.6 million joules.
Electronic energy

Cost effectiveness matters

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.

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

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

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.

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>
<thead>
<tr>
<th>Type</th>
<th>Power in watts</th>
<th>Efficiency</th>
<th>Lifetime in hours</th>
<th>Cost of lamp</th>
<th>Typical use</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filament lamp</td>
<td>100 W</td>
<td>20%</td>
<td>1000</td>
<td>£50p</td>
<td>room lighting</td>
<td>inefficient, gets hot</td>
</tr>
<tr>
<td>Halogen lamp</td>
<td>100 W</td>
<td>25%</td>
<td>2500</td>
<td>£2.00</td>
<td>spotlight</td>
<td>inefficient, gets hot</td>
</tr>
<tr>
<td>Low-energy compact fluorescent lamp (CFL)</td>
<td>25 W</td>
<td>80%</td>
<td>15000</td>
<td>£2.50</td>
<td>room lighting</td>
<td>takes a few minutes for full brightness, disposal must be in a sealed bag due to mercury (which is toxic) in it</td>
</tr>
<tr>
<td>Low-energy light-emitting diode (LED) lamp</td>
<td>2 W</td>
<td>90%</td>
<td>30000</td>
<td>£7.00</td>
<td>spotlight</td>
<td>expensive, brightness of one halogen lamp needs several LEDs</td>
</tr>
</tbody>
</table>

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.
- Heaters can be used 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.
Summary questions

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

2. 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.

3. Which two of the following units are units of energy?
   i) joule
   ii) kilowatt
   iii) kilowatt-hour
   iv) watt
   v) joule per second
   vi) kilowatt per hour

4. 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.

5. The data below shows the electrical appliances used in a house in one evening.
   A 1.0 kW heater for 4 hours.
   B 0.5 kW television for 2 hours.
   C 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 joules.
   b) List three forms of energy that the electrical energy from the battery is transferred 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.
   a) How many kilowatt-hours of electrical energy is used by each appliance?
   b) Write down the equation you use. Show clearly how you work out your answer.
   c) How much will it cost to use the straighteners for 60 minutes each day every day?

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.

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. Which two of the following units are units of energy?
   a) J
   b) J/s
   c) kWh
   d) W

4. The diagram shows the readings on a household electricity meter at the beginning and end of one week.
   a) How many kilowatt-hours of electricity were used during the week?
   b) How much energy was transferred by the kettle?
   c) Write down the equation you use. Show clearly how you work out your answer.
   d) Which appliance uses most energy?
   e) How much would be saved each day if the motor was replaced by a more efficient 40 kW motor?

5. A student uses some hair straighteners.
   a) What useful energy transfer takes place in the hair straighteners?
   b) The hair straighteners have a power of 90 W. What is meant by a power of 90 W?
   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.
   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.
   e) 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?
   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.
A
Agar The nutrient jelly on which many microorganisms are cultivated.

Alkaline 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 A vessel used in industry to extract iron from its ore.

Bronze A alloy of copper and tin.

C
Calcium carbonate The main compound found in limestone. It is a white solid whose formula is CaCO₃.

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. In a lime kiln.

Carrier protein A molecule that binds to antigens and is transported in the bloodstream.

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 (H₂O) is a compound made from hydrogen and oxygen.

Concrete A building material made by mixing cement, sand and aggregate (crushed rock) with water.

Conserve Turn from vapour into a 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 ore A ore that contains a high proportion of a copper compound.

Covalent bond 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.

Data Information, either qualitative or quantitative, that has been collected.

Density Mass per unit volume of a substance.

Depression A mental illness that involves feeling of great sadness that interferes 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.

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.

Electric 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 A device 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.

Enzyme 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.

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. For example: iron + copper sulfate → iron sulfate + copper.

Gravitropism The 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.

Immune system The body system that recognises and destroys foreign material such as invading pathogens.

Immunisation Giving a vaccine that allows immunity to develop without exposure to the disease itself.

Impulse Electrical messages carried along the neurons.

Infectious disease A disease that can be passed on 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 (kWh) Electrical energy supplied to a 1kW 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) × speed (in m/s²).

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. PCl₅.

Molality A measure of concentration that takes into account the mass of solute and the mass of solvent.

Organism An animal that produces the hormone insulin and many digestive enzymes.

Pandemic When more cases of a disease are recorded than 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.

**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.

**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.

**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.

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

**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.

**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**
- **Atomic (proton) number**

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* 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.

Elements with atomic numbers 112–116 have been reported but not fully authenticated.
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