10 Heat and electricity

During an electrical storm at night, lightning flashes brightly. For less than a second the sky lights up as if it were the middle of the day. A short time later there is a huge crash of thunder. It's a spectacular sound and light show that all starts with electrical energy and heat. Lightning is a giant electrical spark moving between clouds and the ground or between different clouds. The flash of lightning heats the air to temperatures of up to 30 000 °C. The hot air expands, its particles crashing into the surrounding cold air particles. Thunder is the noise created by the crashing particles.

Think about heat and electricity

- How can you stop ice-cream from melting in a 230 °C oven?
- Why do dogs pant?
- What actually moves when an electric current flows?
- What is the difference between current and voltage?
- Why is it dangerous to use electrical appliances in the wet or near water?
- If a car battery is rechargeable, why doesn't it last forever?
- Why is it dangerous to use electrical appliances in the wet or near water?

In this chapter:

YOUR QUEST

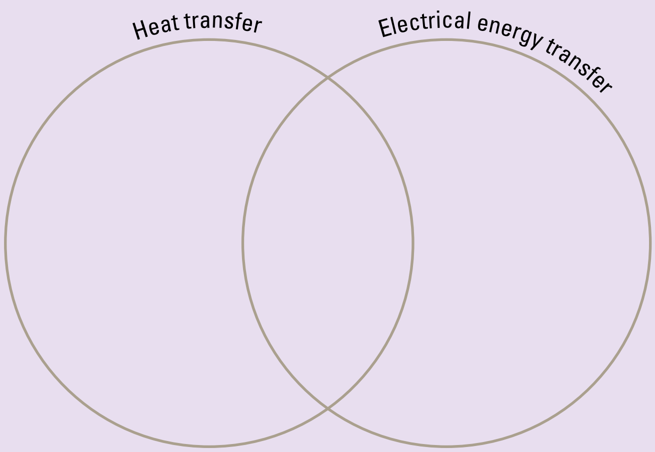
Comparing the movement of heat and electrical energy

THINK

1 Work with a partner or a small group to discuss the meaning of each of the words below. When you have agreed on the meaning of each word, write it down.

Conduction	Convection	Radiation
Current	Insulation	Energy
Metal	Charge	Vibration
Voltage	Reflection	Circuit

2 Construct a Venn diagram like the one below to distinguish between the words that are relevant to:
(a) heat transfer
(b) electrical energy transfer
(c) both heat and electrical energy transfer.



3 Describe the movement of heat when you:
(a) place a hot rock in cold water
(b) put your cold feet into a hot bath
(c) dip your hands into water that has the same temperature as your hands

4 When you open the front door to leave a heated home on a cold day, you feel cooler immediately. Is that a case of cold moving into the house or heat moving out of the house? Explain your answer.

eBook*plus* **eLesson**

Volta's pile and the age of steam
Watch a video from *The story of science* about the invention of electricity.

eles-1777

INVESTIGATION 10.1

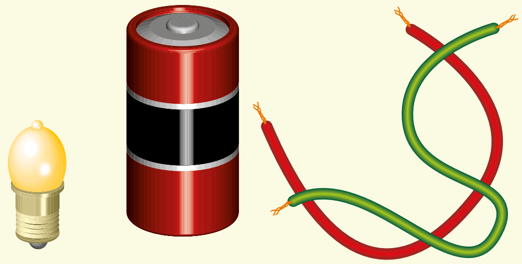
Making the right connections

AIM To connect a battery to a light globe so that it lights up

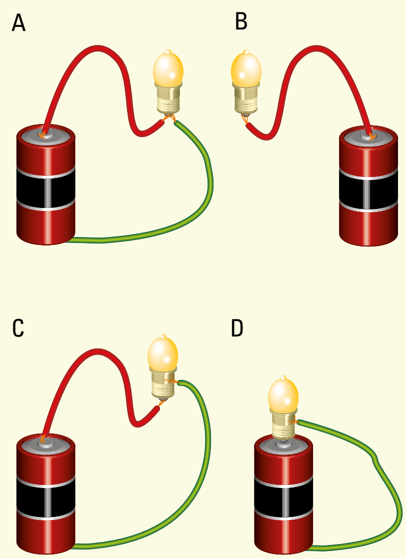
Materials:
a 2.5-volt torch light globe
a 1.5-volt battery
two connecting leads

METHOD AND RESULTS

- Connect one or two connecting leads, a 2.5-volt light globe and a 1.5-volt battery to make the globe light up.
- Try different arrangements to see whether there is more than one way to make the globe light up.



1 In which of the following electric circuits are the components correctly arranged so that the light globe will work?



2 Describe, with the aid of a diagram, any other arrangements that cause the globe to light up.

DISCUSS AND EXPLAIN

3 Draw a flowchart to show the energy transformations that take place when the globe lights up.

4 Are all the energy transformations that take place useful? Explain your answer.

Heat: Energy in transit

Heat is energy in transit from one region to another region with a lower temperature. There are three different ways in which heat can move from one place to another — by **conduction**, **convection** or **radiation**.

Conduction and convection are best explained using the particle model of matter. Radiation, however, is the transfer of electromagnetic energy and is well explained using a wave model.

Conduction

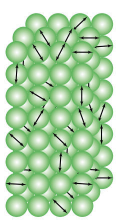
Conduction is the transfer of heat through a substance as a result of neighbouring vibrating particles. The particles in the region of high temperature are vibrating more quickly than those in the region of lower temperature and therefore have more **kinetic energy**. They collide with less energetic particles, giving up some of their kinetic energy. This transfer of kinetic energy from particle to particle continues until both regions have the same temperature.

Most solids are better conductors than liquids and gases because their particles are more tightly bound and closer together than those of liquids and gases. Metals are the best conductors of heat. The electrons of

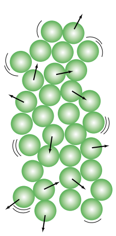
Metals are excellent conductors of heat. The plastic or wood used to make the handles of utensils are insulators and prevent conduction of heat to the user's hands. Metal handles can be very hot!

metals are more free to move than those of other solids and are therefore able to transfer their kinetic energy more readily to neighbouring electrons and atoms.

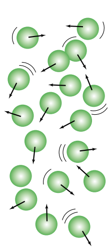
Materials that are poor conductors are called **insulators**. Materials such as polystyrene, foam, wool and fibreglass batts are effective insulators because they contain pockets of still air. Air is a very poor conductor of heat.



The particles in a solid are packed closely together. If some particles receive heat energy and begin to move faster, they collide easily with other particles nearby and pass the heat energy along.



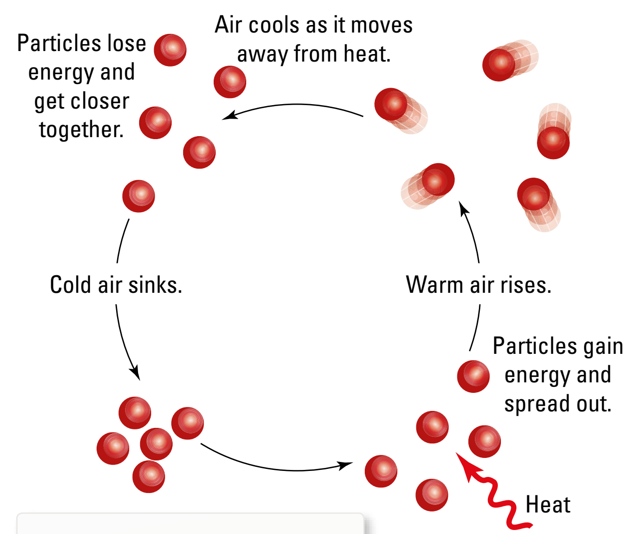
The particles in liquids are further apart than the particles in solids. When some particles receive heat energy and start to move faster, they collide with other particles. But the distance between the particles means that there are fewer collisions. So, heat is transferred by conduction more slowly in a liquid than in a solid.



The particles in a gas are far apart. Heat does not travel easily by conduction through gases.

Convection

Unlike the particles that make up solids, those of liquids and gases are able to move around. In liquids and gases, heat can be transferred from one region

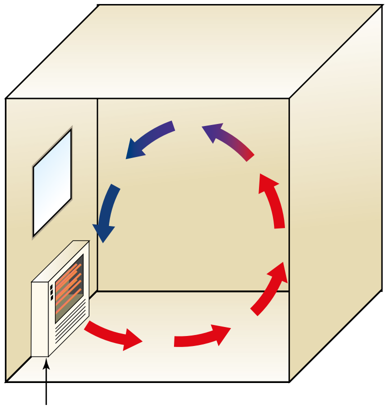


Modelling heat transfer in air

to another by the actual movement of particles. This type of heat transfer is called convection. In solids, the particles vibrate about a fixed position and convection does not occur.

The diagram on the right shows how convection takes place in air. When air is heated, the particles near the source of heat gain energy, move faster and spread out. The particles of the cooler air nearby are moving more slowly and are less spread out. This cooler air is denser and sinks, forcing the warmer, less dense air upwards. As the warmer air rises, it cools and becomes denser and eventually sinks, replacing the newly heated air. The movement of particles during convection forms a **convection current**.

Home heating systems create convection currents that move warm air around. When ducted heating vents are in the floor, warm air rises and circulates around the room until it cools and sinks, being replaced with more warm air. Powerful fans are not necessary. Gas wall heaters have fans to push warm air across the room near floor level so that it heats the entire room. Ducted heating vents in the ceiling require powerful fans to push the warm air downwards so that it can circulate more efficiently.



Convection currents circulate warm air pushed out by heaters around the room.

INVESTIGATION 10.2

Heat conduction in solids

AIM **To compare the conduction of heat through different metals**

Materials:

set of three or four metal rods, different metals but identical in size; or heat conduction apparatus

wax candle	*Bunsen burner and heatproof mat*
matches	*tripod*
ruler	*stopwatch*

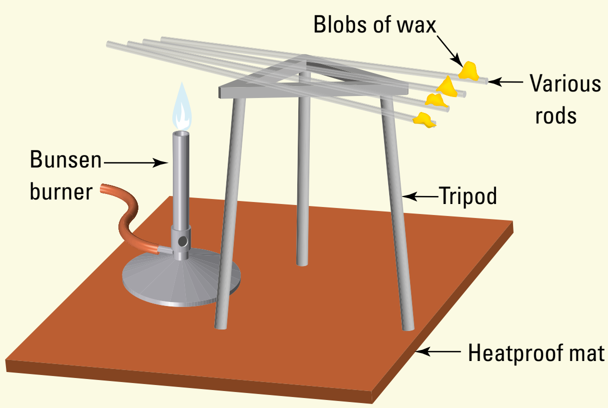
METHOD AND RESULTS

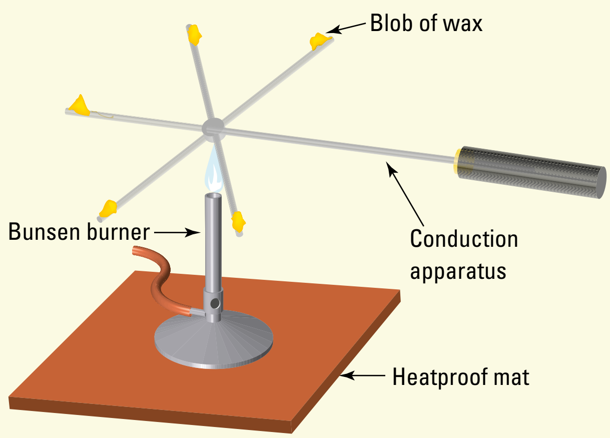
- Set up the tripod and rods or heat conduction apparatus as shown below.
- Light the candle and melt a blob of wax onto one end of each rod. Ensure that each wax blob is the same distance from the end that will be heated by the Bunsen burner flame.
- Use the blue flame of the Bunsen burner to heat the end of each rod. Start the stopwatch at the instant that heating begins.

1. Record the time taken for each blob to produce its first droplet of wax.
2. Present your data in a table and draw a bar or column graph in which to display them.

DISCUSS AND EXPLAIN

3. According to your data, which of the metals is the best conductor of heat?
4. According to your data, which of the metals is the poorest conductor of heat?
5. Compare your data with that of others in your class. Comment of the consistency of the conclusions within your class. If there was inconsistency, suggest one or more reasons for it.

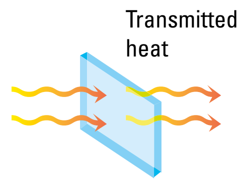




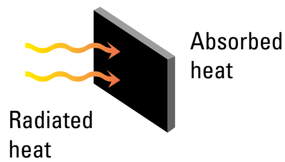
Radiation

Heat can be transferred without the presence of any particles at all, as electromagnetic radiation. Heat transferred in this way is called **radiant heat**. Heat from the sun reaches the Earth by radiation, most of it in the form of infra-red radiation. There are not enough particles between the sun and Earth for heat transfer by either conduction or convection.

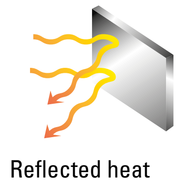
Like all electromagnetic radiation, radiant heat can be reflected, transmitted or absorbed. How much energy is reflected, transmitted or absorbed depends on the properties, including colour, of the surface.



Transmitted radiant heat
Clear objects, like glass, allow light and radiant heat to pass through them. The temperature of these objects does not increase quickly when heat reaches them by radiation.



Absorbed radiant heat
Dark-coloured objects tend to absorb light and radiant heat. Their temperatures increase quickly when heat reaches them by radiation.



Reflected radiant heat
Shiny or light-coloured surfaces tend to reflect light and radiant heat away. The temperature of these objects does not change quickly when heat reaches them by radiation.

INVESTIGATION 10.3

Radiating and absorbing radiant heat

AIM To compare the radiation and absorption of heat through black surfaces and shiny surfaces

Materials:
heater or microscope lamp
2 identical shiny, empty, soft-drink cans
matt black paint and paintbrush
2 thermometers or data logger and 2 temperature sensors

METHOD AND RESULTS

- Paint one of the cans matt black and leave the other as it is.

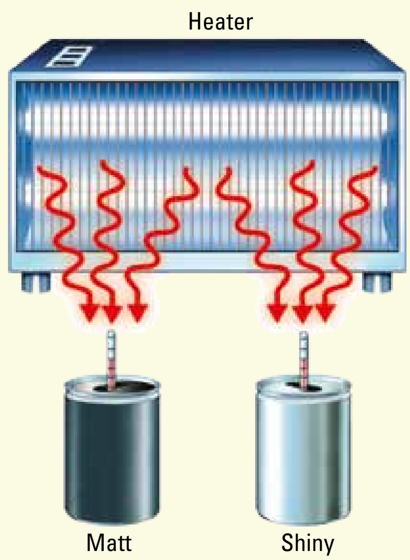
1. Construct a table or spreadsheet headed ‘Radiating heat’ in which to record the temperature every two minutes for up to 14 minutes.
2. Make a prediction about your results and write down a hypothesis.

- Pour equal amounts of hot water into each can.

3. Place a thermometer or temperature probe into each can. Measure the initial temperature of the hot water and again every two minutes.
4. Enter your data into the table or spreadsheet.

- Empty the cans and pour equal amounts of cold tap water into each can.

5. Construct a table or spreadsheet headed ‘Absorbing radiant heat’ in which to record the temperature every two minutes for up to 14 minutes.
6. Make a prediction about your results and write down a hypothesis.
7. Place a thermometer or temperature probe into each can. Measure the initial temperature of the water.

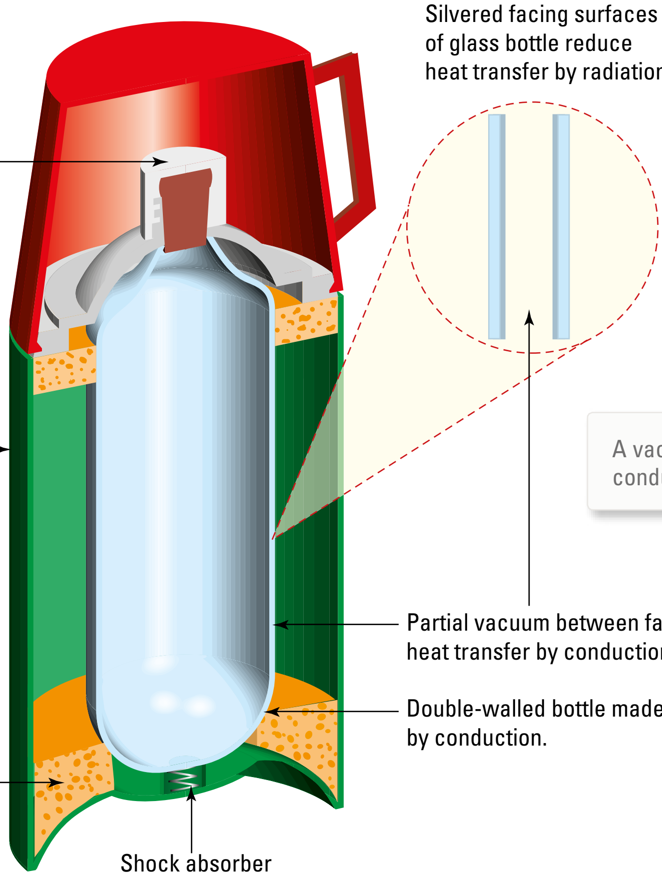


- Place the two cans at equal distances from a heater or microscope lamp.

8. Measure and record your data into the table or spreadsheet every two minutes.
9. Plot line graphs that show how the temperature changed over 14 minutes during the cooling and heating of the cans. You may wish to plot both graphs on the same set of axes.

DISCUSS AND EXPLAIN

10. Which can radiated heat more quickly?
11. Which can absorbed heat more quickly?
12. Were each of your hypotheses supported by the data?
13. Why was it important to use cans that were identical in size and shape?
14. What other variables had to be controlled during this experiment?



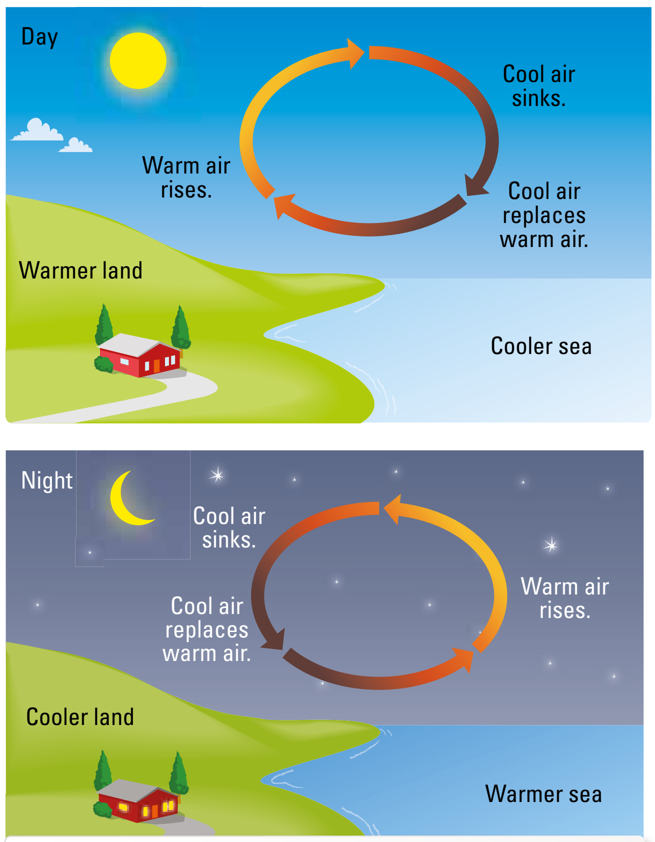
A vacuum flask reduces heat transfer by conduction, convection and radiation.

Reducing heat transfer: The vacuum flask

The vacuum flask, also known as a thermos flask, invented by British chemist Sir James Dewar, was originally designed for the cold storage of liquefied gas. However, Dewar quickly realised that it could also be used for keeping liquids warm. The vacuum flask reduces heat transfer in or out by conduction, convection and radiation.

Hot summer days by the sea

During hot summer days, radiant energy from the sun heats the land and the sea. However, as a result of the different properties of the land and water, after a few hours the land has a higher temperature than the sea. The air near the land becomes hot as a result of conduction. As this air gets hot it expands, becoming less dense than the cooler, denser air over the sea. The air over the sea rushes in towards the land, replacing the rising warm air, causing what is known as a **sea breeze**. Coastal areas usually experience less extreme maximum temperatures on hot summer days as a result of sea breezes. At night, if the sea temperature is higher than the land temperature, the convection currents move in the opposite direction, creating a flow of air towards the sea.



A sea breeze is caused by convection currents in the air during warm summer days. At night the convection currents are reversed.

HOW ABOUT THAT!

Imagine putting a scoop of ice-cream into a 230 °C oven for three minutes. That's exactly what you do when you make Bombe Alaska, a dessert with a solid ice-cream centre on a sponge cake, covered with meringue. Bombe Alaska —ice-cream and all — is baked in a preheated 230 °C oven for three minutes. Yet the ice-cream doesn't melt! The secret to this is the insulating properties of the sponge and meringue. The bombe pictured here has strawberry (pink) and orange ice-cream on top of the sponge cake. The white meringue has been cooked and has been changed to a brown colour by the heat of the oven.

Bombe Alaska, also known as Baked Alaska

UNDERSTANDING AND INQUIRING

REMEMBER

1 Which form of energy do particles transfer to each other as heat flows through a conductor?

2 Explain why solids such as polystyrene foam and wool are poor conductors of heat.

3 Explain why air near a wall furnace rises when it gets warmer.

4 What is a convection current?

5 Which form of electromagnetic radiation from the sun is responsible for most of the radiant heat reaching the Earth?

6 List three things that can happen to radiant heat when it arrives at any surface.

7 Identify the features of a vacuum flask that reduce heat transfer by:
(a) conduction
(b) convection
(c) radiation.

8 Explain, with the aid of a diagram, how a coastal sea breeze results from convection currents.

THINK

9 Suggest why metal saucepans usually have plastic or wooden handles.

10 Use the particle model of matter to explain why heat can't travel through metals and other solids by convection.

11 Why is air a poor conductor of heat?

12 When you heat water in a saucepan on a gas or electric hotplate, all of the water gets hot and not just the lower part near the heat source. How does this happen, given that water is a poor conductor of heat?

13 Why do many sportspeople wear white clothing when competing on hot summer days?

14 To which form of heat transfer do the following statements apply?
(a) Energy is transferred at the speed of light.
(b) Particles move from one place to another.
(c) No particles are required for energy transfer.
(d) This form of heat transfer is best explained by a wave model.

15 Advertisements in the media often describe all products designed to reduce heat transfer to keep homes warm in winter or cool in summer as insulators. Explain why it is incorrect to describe reflective metal foil as insulation.

CREATE

16 Create a design brief for a spacesuit to be used for walking on Mars. The spacesuit must protect the wearer from the blistering heat of day and the brutally cold nights. In your design brief, list the features of the spacesuit that will reduce heat transfer in and out by conduction, convection and radiation.

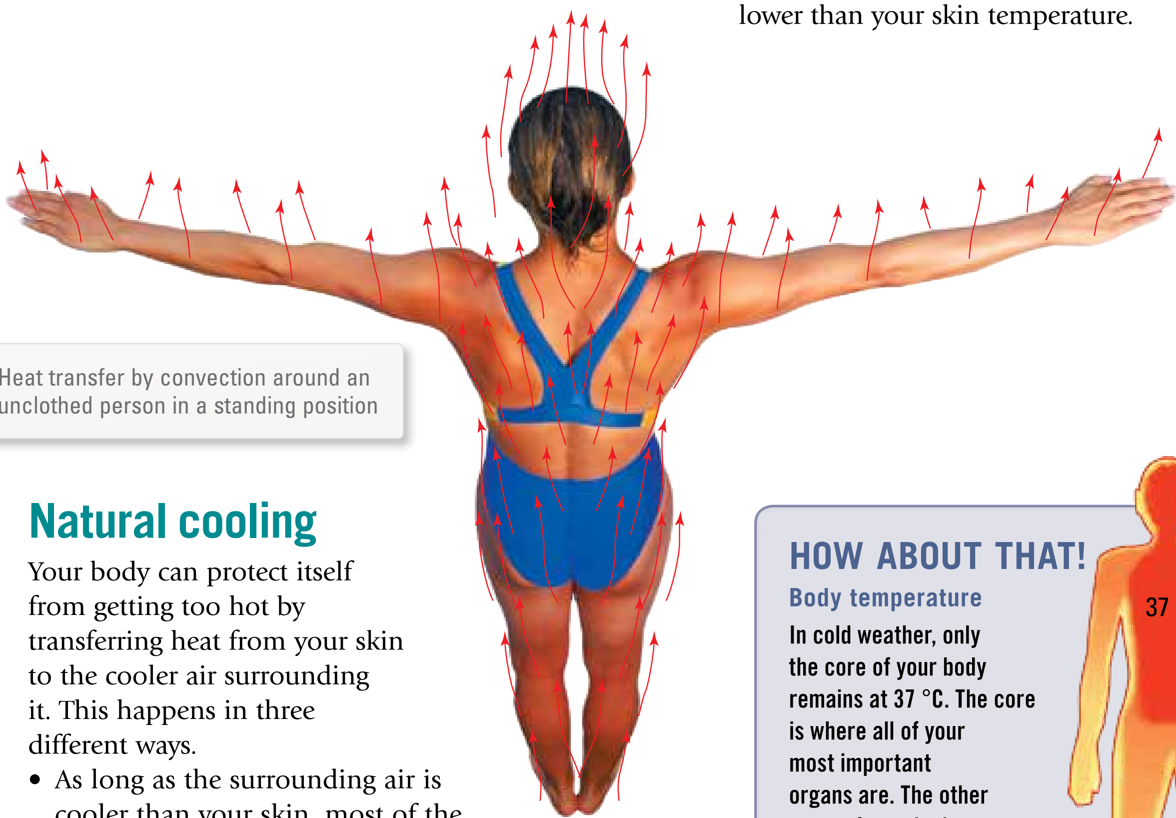
eBook*plus* work sheet 10.1 Conduction and convection

Staying cool

A healthy human body has a **core body temperature** of about 37 °C. With the right clothing and shelter, the inner parts of your body remain at this temperature almost anywhere on Earth.

The energy needed to keep your core body temperature at 37 °C is converted from the chemical energy in food. However, when you exercise, your body needs more oxygen and more energy. This extra energy is converted from food more quickly than when you are resting. Much of the converted energy causes an increase in body temperature.

In cool weather, your body is able to cool itself by transferring the extra heat into the surrounding air. However, in warm weather, it is much more difficult for your body to cool down.



Heat transfer by convection around an unclothed person in a standing position

Natural cooling

Your body can protect itself from getting too hot by transferring heat from your skin to the cooler air surrounding it. This happens in three different ways.

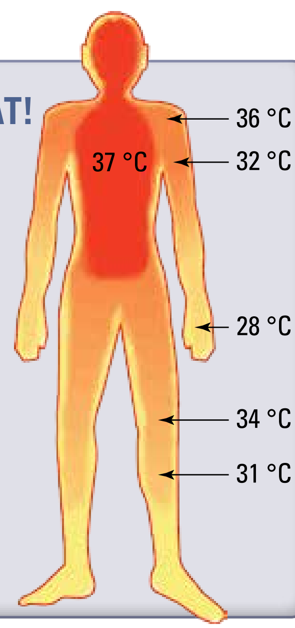
- As long as the surrounding air is cooler than your skin, most of the heat is transferred by radiation. The bigger the difference between your skin temperature and the air temperature, the more heat is radiated. When your core body temperature rises, the blood vessels beneath your skin get larger. This brings hot blood closer to your skin so that more heat is radiated away.
- Some heat is transferred from your body by convection. Heat rises from the warm layer of air just above your skin into cooler air. The photo below shows how heat is transferred by convection from an unclothed person in a standing position. By wearing light, loose-fitting clothing when you exercise, your body can still lose heat by convection. This is especially important in warm weather.
- A small amount of heat is lost by conduction from your skin to the air. The amount is small because there is a thin layer of still air above your skin. There is also an insulating layer of fat beneath your skin.

If the surrounding air is not cooler than your skin, no heat can be transferred by radiation, convection or conduction. These methods of heat transfer from your body can work only if the air temperature is lower than your skin temperature.

HOW ABOUT THAT!

Body temperature

In cold weather, only the core of your body remains at 37 °C. The core is where all of your most important organs are. The other parts of your body can be quite a lot cooler. In warm weather, the temperature of your body is more even. Most of it remains within one degree of 37 °C.



Heat transfer by evaporation

When your core body temperature increases, sweat glands under your skin produce **perspiration**. The water in the perspiration evaporates. The energy needed to change the liquid water into water vapour comes from your skin. In other words, heat is transferred from your skin to water on your skin.

When the air temperature is higher than your skin temperature, evaporation of water is the only way your body can reduce its temperature naturally. If you wear tight-fitting or too much clothing in hot weather or while exercising, you limit the evaporation of water from your skin. Your body is in danger of overheating.

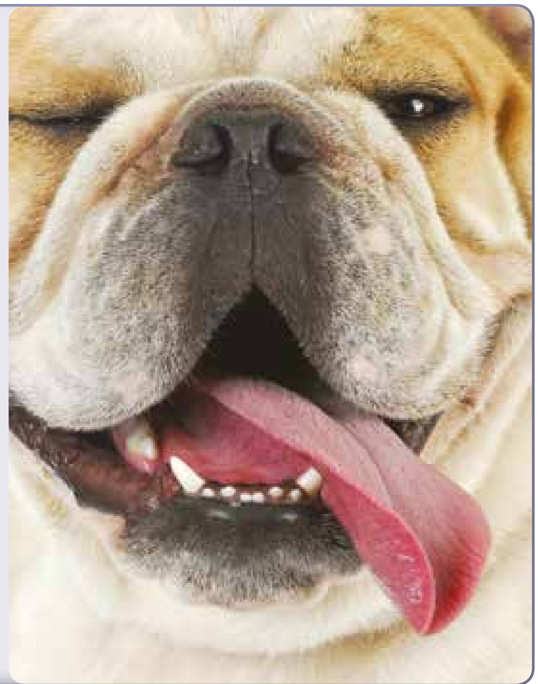
Just too hot!

In hot weather and during strenuous exercise, you need to take care. The human body does not cope well with high body temperatures. If the core body temperature reaches 39 °C, **heat exhaustion** occurs. The body feels cold and sweaty. There is a danger of fainting. When the core body temperature reaches about 41 °C, the body's natural cooling methods fail. **Heatstroke** sets in and the body's vital organs begin to suffer damage. The early signs of heatstroke include irritability, confusion and dizziness. The skin usually becomes hot and dry because perspiration stops.

One danger during hot weather, especially while exercising, is **dehydration**. Dehydration is the loss of water from the body. When evaporation is the only way for the body to cool itself, a large amount of water is lost. If the lost water is not replaced, perspiration stops and the core body temperature increases.

HOW ABOUT THAT!

Dogs have sweat glands only in their feet. These glands don't do much to help dogs reduce their body temperature. A dog controls its body temperature by sticking out its tongue and panting. Air passing over its tongue and mouth evaporates its saliva. When a dog pants, some water evaporates from its throat and lungs. The energy transferred from the dog to cause all this evaporation keeps it cool.



UNDERSTANDING AND INQUIRING

REMEMBER

1 What is the core body temperature of a healthy human body?
2 List four natural ways in which the body can transfer heat away from the skin when the core body temperature gets too high.
3 What change of state takes place on your skin as you perspire?
4 Which methods of heat transfer from your body cannot take place if the air temperature is greater than your skin temperature? Give a reason for your answer.
5 Describe two ways in which tight-fitting clothing prevents heat loss from your body while exercising in hot weather.
6 What causes heat exhaustion?
7 What are the early signs of heatstroke?
8 Hot weather is one of many causes of dehydration.
   (a) What is dehydration?
   (b) How is water lost during hot weather and while exercising vigorously?

THINK

9 Why does the skin become red during vigorous exercise?
10 List at least two ways of reducing the chances of becoming dehydrated during hot weather.
11 Antiperspirants are used to reduce perspiration and body odour. Construct a PMI chart about antiperspirants.

THINK AND CREATE

12 Imagine that you are the coach of a long-distance runner competing in a 21-kilometre race on a warm day. Make a list of 'dos and don'ts' for the runner so that dehydration, heat exhaustion and heatstroke are avoided. Present your list as a poster or PowerPoint presentation.

10.3

Electricity in transit

A bolt of lightning is clear evidence that electrical energy can move from one place to another. But to make energy useful it needs to be controlled. When you switch on a television, a computer or an mp3 player you are completing a pathway along which electrical energy flows. The pathway is called an **electric circuit**, in which electrical energy is transformed and used for lighting, heating, cooling and much, much more.

The movement of electrical energy from one place to another, whether rapidly in the form of lightning or more slowly in an electric circuit, depends on the movement of **electric charge**.

The cords to earbud headphones carry electricity, not sound. Each cord actually contains two wires. The jack that plugs into the player is composed of four wires, two per earbud.

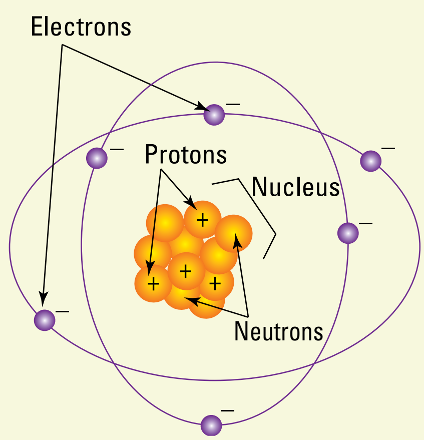
WHAT IT MEANS TO BE CHARGED

All matter is made up of atoms. At the centre of each atom is a heavy **nucleus**. Surrounding the nucleus is a lot of empty space and tiny particles called **electrons**. Electrons are constantly moving around the nucleus. Each electron carries a **negative electric charge**.

Inside the nucleus are two different types of particles. The **protons** inside the nucleus are much heavier than electrons. Each proton carries a **positive electric charge**. The **neutrons** inside the nucleus are similar to protons but carry no electric charge. The positive electric charge of a proton exactly balances the negative charge of an electron. Atoms usually contain an equal number of electrons and protons.

Any particle or substance that has more protons than electrons is said to be **positively charged**. Any particle or substance that has more electrons than protons is said to be **negatively charged**. Any particle or substance that has equal amounts of positive and negative charge is said to be **neutral**. The term 'uncharged' is also used to describe neutral particles or substances.

Substances usually become charged by the addition or removal of electrons.



A neutral atom contains an equal number of protons and electrons. (Two of the protons are hidden in this diagram.) This diagram represents a carbon atom. The number of neutrons is not always the same as the number of protons.

Static electricity

The electric charge that builds up in clouds and objects such as plastic rulers and balloons is called **static electricity**; that is, it is not moving. When enough static electrical energy builds up it can move very quickly, as it does when lightning strikes or when you get a small electric shock when you step out of a car or touch a metal door handle. Static charge can leak away from substances such as air and rubber. These substances

INVESTIGATION 10.4

Making changes

AIM **To observe and compare the flow of electrical energy through some simple circuits**

Materials:

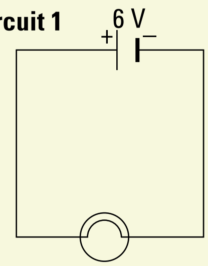
power supply (set to 6 volts)
three 6-volt light globes and holders
6 connecting leads with alligator clips or banana plugs
piece of plastic
iron nail

METHOD AND RESULTS

- In this experiment you will be setting up each of the circuits shown in the diagrams below. Draw each circuit diagram in your workbook and record your observations of the globes next to them.

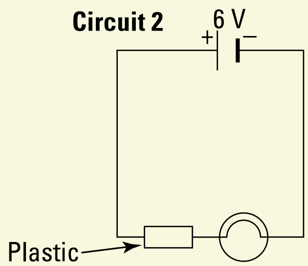
1. Set up circuit 1. Record the change that takes place in the globe.

Circuit 1



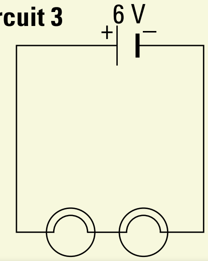
2. Set up circuit 2. Record the change that takes place in the globe when the plastic is replaced with an iron nail.

Circuit 2



- Set up circuit 3 so that both globes light up. The two globes are connected in series.

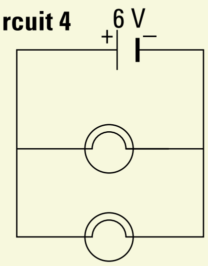
Circuit 3



3. Are the globes glowing as brightly as the globe in circuit 1?
4. Predict what will happen if you disconnect the lead between the two globes in circuit 3.
5. Disconnect the lead and record the changes that take place in each of the globes.

- Set up circuit 4 so that both globes light up. The two globes are connected in parallel.

Circuit 4



6. Are the globes glowing as brightly as the globes in circuit 1?
7. Predict what will happen if you disconnect one of the leads between the two globes in circuit 4.
8. Disconnect the lead and record the changes that take place in each of the globes.

DISCUSS AND EXPLAIN

Circuit 1

9. Explain why the change in the globe took place.

Circuit 2

10. Explain the change that took place when the piece of plastic was replaced with the iron nail.

Circuit 3

11. Explain why the globes behaved differently from the way the globe behaved in circuit 1.
12. Was your prediction about what would happen when you disconnected the lead correct?
13. Explain the change that took place when you disconnected the lead.

Circuit 4

14. Was your prediction about what would happen when you disconnected the lead correct?
15. Explain the change that took place when you disconnected the lead.

are called electrical insulators because they don't allow electrical charge to pass through them quickly.

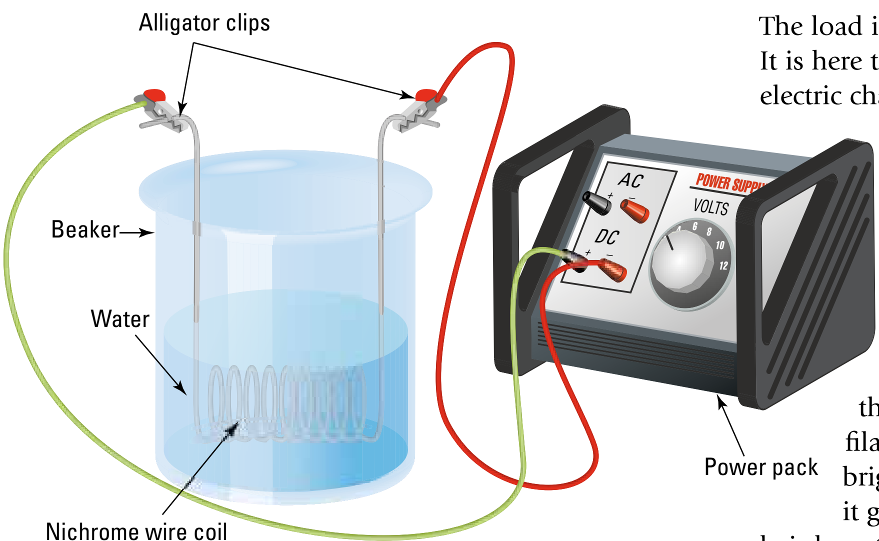
Electric circuits

All electric circuits consist of three essential items:

- a **power supply** to provide the electrical energy
- a **load** (or loads) in which electrical energy is converted into other useful forms of energy
- a **conducting path** that allows electric charge to flow around the circuit.

Where it all begins

The batteries (cells) used in torches and many other devices store chemical energy in the substances inside them. The chemical energy is transformed into electrical energy when a chemical reaction takes place inside the cell.



This electric circuit is a model of an electric kettle. The wire coil, the load, will heat up when electrical energy is passed through it.

The electrical energy that is used when you turn on a light switch or an appliance connected to a power point comes from a power station.

Current and voltage

The flow of electric charge is called **electric current**. It is a measure of the amount of electric charge passing a particular point in an electric circuit every second. Even though the electric current in wires and most electrical devices is caused by the flow of negatively charged electrons, electric current is defined as the direction of the movement of positive charge. The electric current is said to flow through the circuit from the positive terminal of the power supply to the negative terminal.

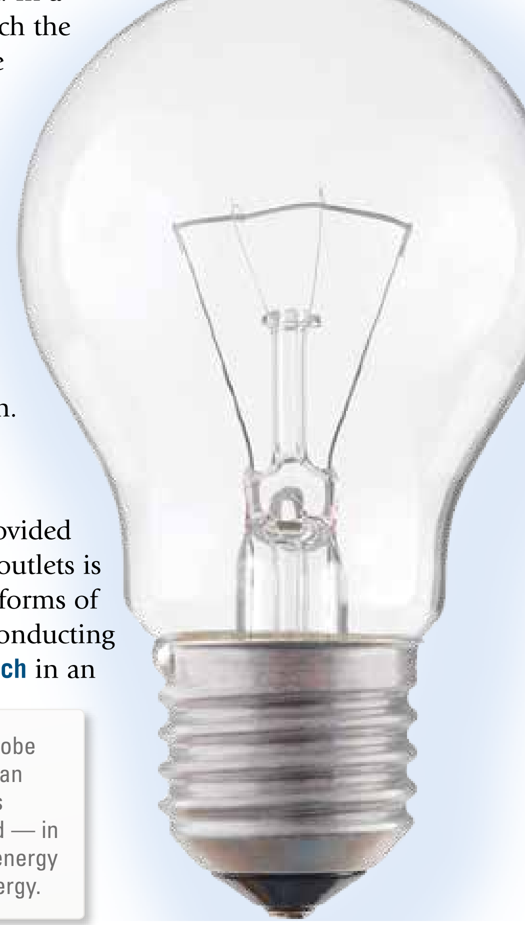
Voltage is a measure of the amount of electrical energy gained or lost by electric charge as it moves through the circuit. Voltage is also known as potential difference because it measures a change in the potential (stored) energy of charge as it moves between one place and another. When electric charge moves through a circuit, it gains electrical energy as it passes through the power supply. It loses the same amount of energy as it passes through the rest of the circuit. That is, the voltage gain across the terminals of the power supply is equal to the total voltage drop across the rest of the circuit.

Where the action is

The load in an electric circuit is an energy converter. It is here that most of the electrical energy carried by electric charge is transformed into useful forms of energy such as light, heat, sound and movement. In a simple torch the load is the **filament**, a coiled tungsten wire inside the globe. The filament glows brightly when it gets hot. In a hairdryer there are two loads: a heater and a fan.

Switched on

The electrical energy provided by batteries and power outlets is transformed into other forms of energy only when the conducting path is complete. A **switch** in an



The filament in this light globe is an example of a load in an electric circuit. The load is where energy is converted — in this case, from electrical energy into light (and thermal) energy.

electric circuit allows you to have control over whether or not the conducting path is complete.

Completing the path

A complete conducting path allows electric charge to flow through the circuit. In an efficient electric circuit, most of the electrical energy provided by the power supply is transformed in the load. However, some of the electrical energy is transformed in the conducting path, heating the path and its surroundings. The conducting paths in the electric circuits in appliances are usually made of metals such as copper so that they have little **resistance** to the flow of electric charge. The conducting path in a torch consists of copper wires covered with an insulating layer of plastic. If the connecting wires had too much resistance to the flow

INVESTIGATION 10.5

Switched-on circuits

AIM **To compare the effect of a single switch with two switches connected in parallel**

Materials:
2.5-volt globe and holder
1.5-volt battery and holder
5 connecting leads with alligator clips or banana plugs
2 tapping switches

METHOD AND RESULTS

- Connect circuit 1 as shown.

1. How can you stop the globe in circuit 1 from glowing?

- Connect circuit 2 as shown.
- Close the switch.
- If nothing happens, open the switch, check that your circuit is connected properly and try again. If nothing happens this time, replace the globe.

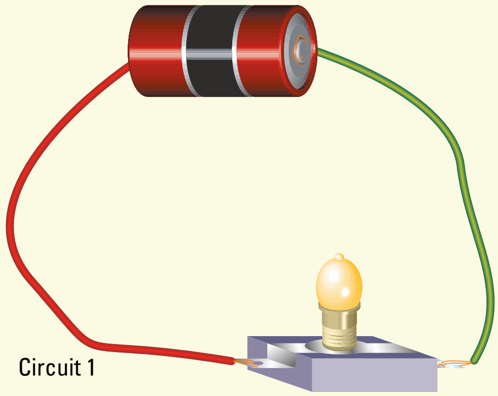
2. Describe what happens to the globe in circuit 2 when the switch is closed.

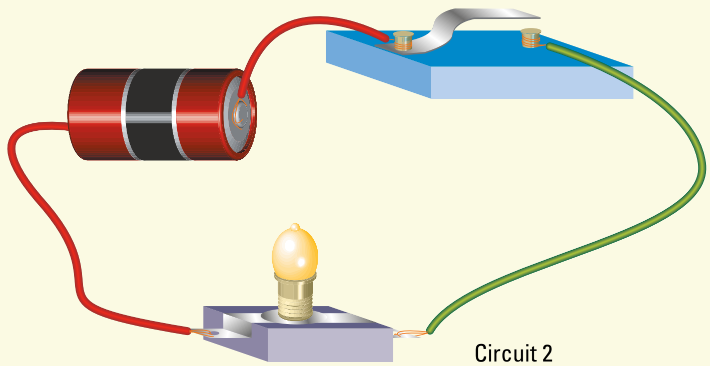
- Add a second switch as shown in circuit 3.

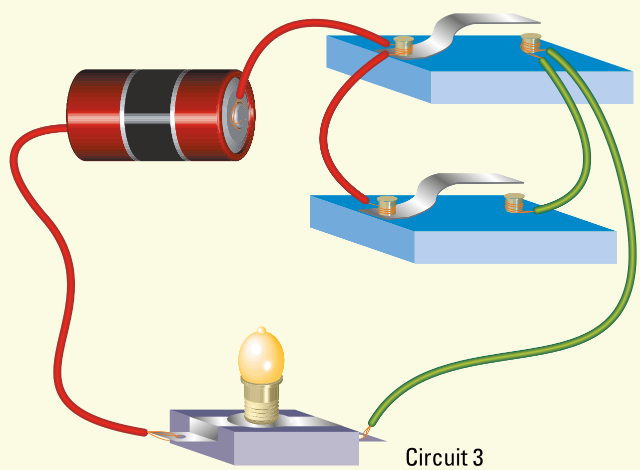
3. Describe what happens to the light globe in circuit 3 when:
   (a) neither of the switches is closed
   (b) either one of the switches is closed
   (c) both of the switches are closed.

DISCUSS AND EXPLAIN

4. Explain what happens to the light globe in circuit 3 when:
   (a) neither of the switches is closed
   (b) either one of the switches is closed
   (c) both of the switches are closed.


Circuit 1


Circuit 2


Circuit 3

of charge, a lot of electrical energy would be wasted in heating the wires, the plastic covering and the air surrounding them.

Electric maps

Maps of electric circuits need to be drawn so that people all over the world can read them. These maps are called **circuit diagrams**. Some of the standard symbols used in circuit diagrams are shown in section 10.4.

This student is sharing a large electrical charge with the Van de Graaff generator. Her hair is making a map of the electrical field around her head.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Explain the difference between the transfer of electrical energy in a bolt of lightning and the transfer of electrical energy in an electric circuit.

2 What are the three essential features of all electric circuits?

3 Contrast what electric current is a measure of with what voltage is a measure of.

4 What is the purpose of a switch in an electric circuit?

5 Why are connecting wires usually made of copper?

6 Draw a circuit diagram showing:
(a) a cell connected to two light globes connected in series
(b) a cell connected to two light globes connected in parallel.

7 Why is voltage also known as potential difference?

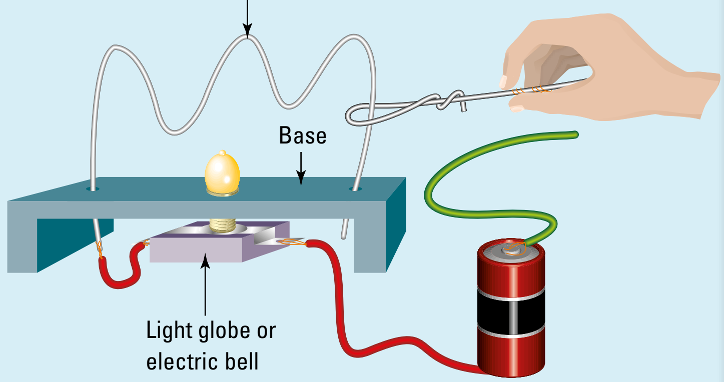
THINK

8 From which form of energy is electrical energy transformed in a television remote control?

9 Name a load that is designed to convert electrical energy into:
(a) light
(b) sound
(c) heat
(d) movement.

10 Redraw the circuit diagram in question 6(b), adding a switch that turns both light globes on or off at the same time.

11 Make a steady-hand tester. You will need: an old coathanger; a loop of thin wire; wirecutters; battery; electric bell or light globe; connecting wires; and a shirt box, shoe box or cereal packet for the base.



A steady-hand tester

The 'alarm' can be a bell hidden in the base or a globe attached to the base. Hide as much of the connecting wires as you can.

eBook*plus* work sheet 10.2 Conductors and insulators

A light in the dark

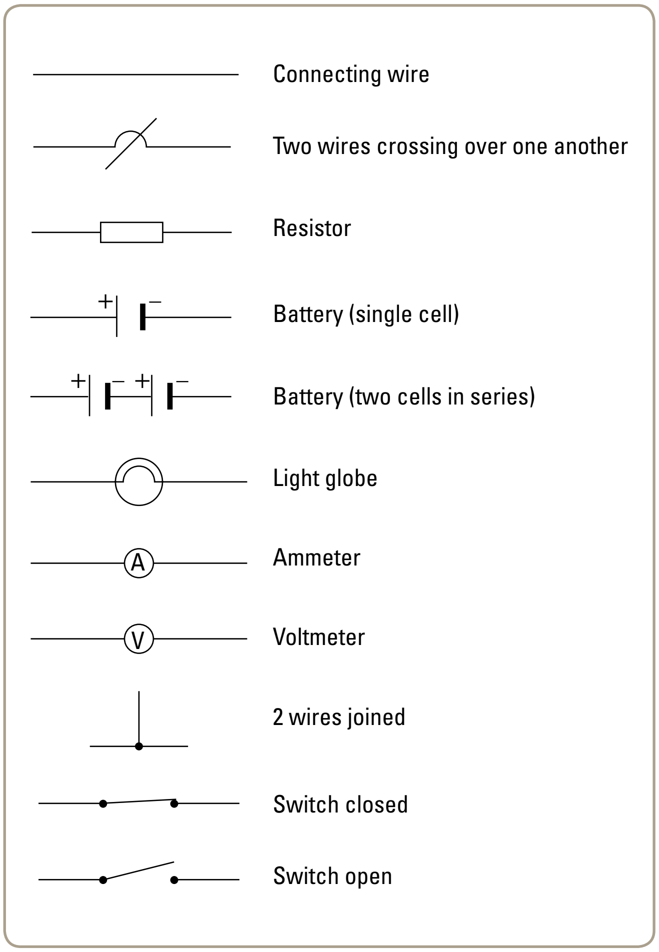
Many battery-operated devices use more than one battery. In torches, mp3 players and cordless power tools, two or more batteries are connected in series.

They are connected end-to-end as shown in the diagram in this section. It is important to ensure that the positive end of one battery is connected to the negative end of the other.

Circuit diagrams: a common language

Diagrams of electric circuits need to be drawn so that people all over the world can read them. Circuit diagrams use straight lines for connecting leads and symbols for other parts of circuits.

Some circuit diagram symbols



HOW ABOUT THAT!

Even though batteries were invented before 1800, it took until 1898 for the modern torch to be invented. This is mainly because early batteries contained a lot of liquid and were too heavy to carry around.

INVESTIGATION 10.6

What's inside a torch?

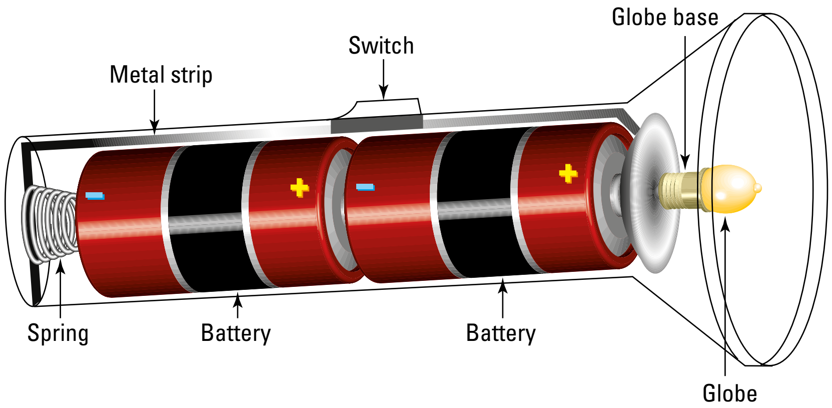
AIM To investigate the electric circuit in a torch

Materials:
torch fitted with two 1.5-volt batteries
hand lens

METHOD AND RESULTS

- Check that closing the switch makes the globe light up.
- Unscrew the end of the torch and remove the batteries. Look closely at the batteries.
- Look at the globe.
- Carefully remove the globe and examine it with a hand lens.
- Look inside the case of the torch and locate the spring and metal strip.
- Locate the metal strip and close the switch.

1. What other forms of energy is the electrical energy changed into when the circuit is closed?
2. How were the batteries connected together inside the torch?
3. What is the voltage of each battery?
4. What does the bottom of the globe touch when it is inside the torch?
5. What does the side of the globe touch when it is inside the torch?
6. Draw a diagram to show what is inside the globe.
7. Which two parts of a working torch does the spring make contact with?
8. What happens to the metal strip while the switch is being closed?
9. What does the metal strip in front of the switch touch when the switch is closed?



Inside a torch. When the switch is closed, electric current flows.

The torch circuit

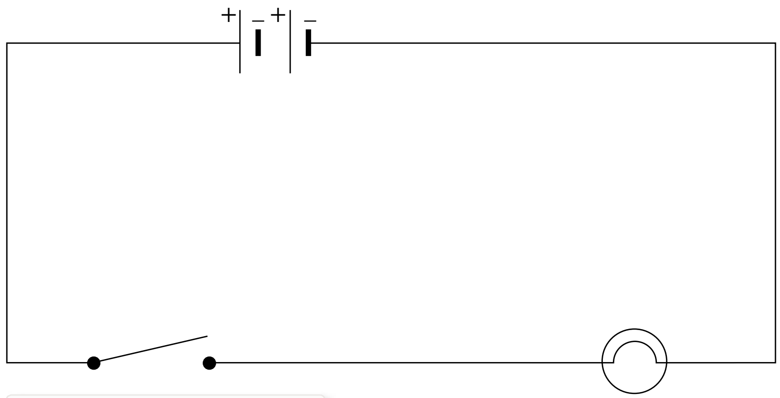
The power supply of a torch usually consists of two or more 1.5-volt batteries connected in series. When two 1.5-volt batteries are connected in series, the total voltage is 3.0 volts. Twice as much electrical energy is available to move the electric charge around the circuit.

The load in a torch circuit is the globe. When the switch is closed, electric current flows around the circuit. As electric charge passes through the globe, its electrical energy is released as heat in the filament. The filament is the coiled wire inside the globe. It is made of the metal tungsten and glows brightly when it gets hot.

WHAT DOES IT MEAN?

The word *filament* comes from the Latin term *filamentum*, meaning 'spin'.

The conducting path in a torch consists of the spring that pushes the battery against the base of the globe (or a metal globe holder) and the metal strip that includes the switch. When the switch is open, the metal strip does not make contact with the globe and the circuit is not complete.



Circuit diagram for a torch

UNDERSTANDING AND INQUIRING

REMEMBER

1 Draw a diagram to show how two batteries can be connected in series. Label the positive and negative terminals of each battery.

2 Which features of a torch provide the following parts of an electric circuit?
(a) The power supply
(b) The load
(c) The conducting path

3 Describe how a torch works. Ensure that the words 'current', 'energy' and 'circuit' appear in your description.

4 Construct a circuit diagram of a two-battery torch with a closed switch.

THINK

5 Some torches use three 1.5-volt batteries. What is the total voltage of such torches?

6 A CD player contains more than one electric circuit. The power supply provides the electrical energy for all of these circuits. Name two different parts of a CD player in which electrical energy is released as other forms of energy. These parts represent separate loads.

CREATE

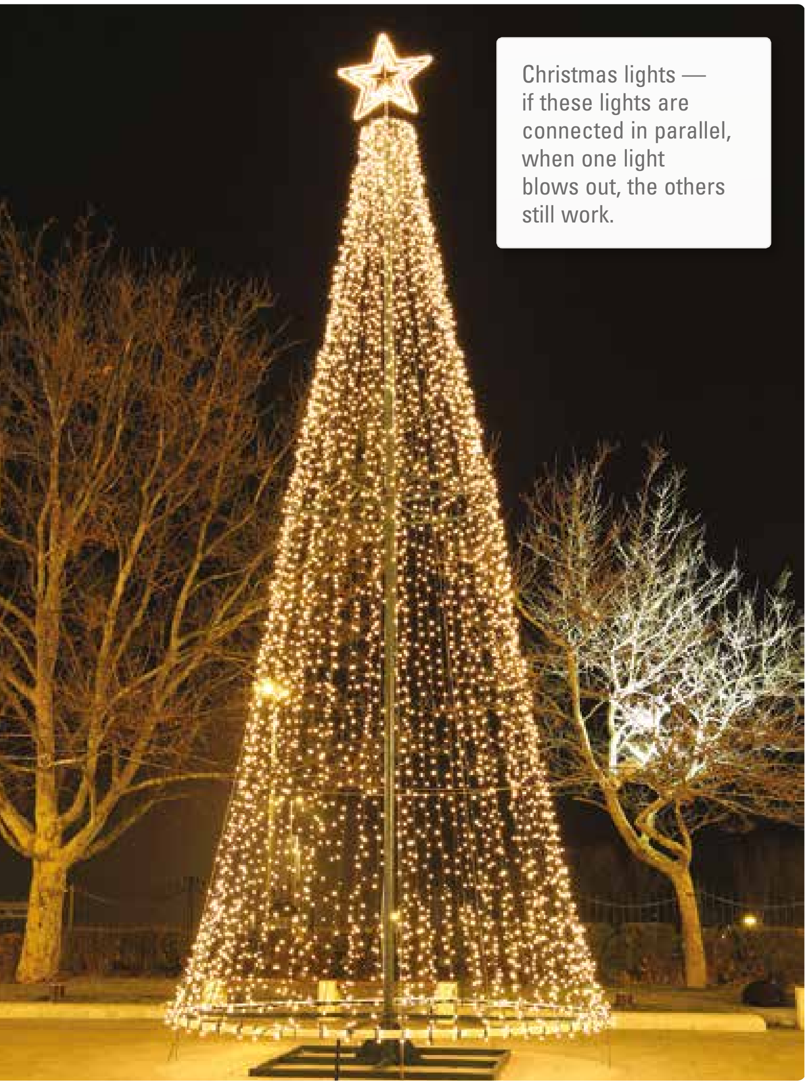
7 Construct your own model torch circuit, using the following items; a torch globe and holder; two 1.5-volt batteries and holders; connecting leads with alligator clips or banana plugs; and a switch.
Use other available materials to make your model torch circuit more realistic.

INVESTIGATE

8 Thomas Edison is credited with the invention of the electric light globe. Research and report on one of the following topics.
(a) The life and inventions of Thomas Edison
(b) The first electric light globe and how light globes have changed since their invention
(c) How the invention of the light globe changed the way people lived

Series and parallel circuits

The parts of the torch circuit shown in section 10.4 — the batteries, the switch and the globe — were all connected one after the other. This type of circuit is a **series circuit**. Series circuits are usually easy to connect. However, if any one part of the circuit is faulty, the connecting path is broken and nothing in the circuit will work. For example, if the Christmas tree lights in the photo below were connected in series, a single faulty globe would cause all of the globes to stop glowing.



Christmas lights — if these lights are connected in parallel, when one light blows out, the others still work.

eBookplus eLesson

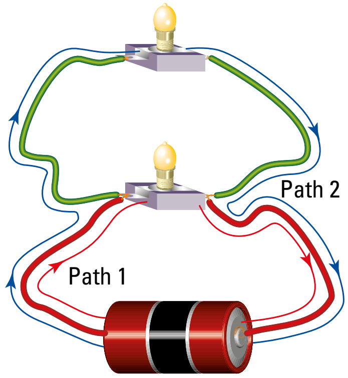
The hydraulic model of current

Learn how you can model the flow of current in a circuit using pipes, taps, water and a pump.

eles-0029

In parallel: side by side

In a **parallel circuit**, each component is connected in a separate conducting path. This means that if one part of the circuit is faulty, the other parts will still work. If the Christmas tree lights shown in the photograph were connected in parallel, if one globe was faulty the other globes will still glow. Their conducting paths would not be affected.



A parallel circuit has more than one conducting path. If one of the components is faulty, its conducting path is broken. The other conducting paths are still intact and all other components will still work.

Bright lights

The brightness of light globes in electric circuits depends on how quickly energy flows through the globe. There are two factors that affect how quickly the energy flows.

- The amount of energy each electron flowing through the globe has. The voltage across the globe is a measure of this.
- The number of electrons passing through the globe each second. The electric current passing through the globe is a measure of this.

Identical globes in a series circuit have the same brightness because they share the voltage equally and all globes have the same electric current passing through them. Identical globes in a parallel circuit have the same brightness because they all have the same voltage across them and they equally share the electric current passing through the power supply.

The lights in your home are connected in parallel. Each light has the same voltage across it. Each electron gets the same amount of energy from the power supply. But different globes, bulbs and fluorescent tubes allow different amounts of electric current through. Because the brightness depends on both voltage and electric current, the brightness of the lights can differ.

These lights are connected in parallel. Why?

INVESTIGATION 10.7

In a line or side by side

AIM To compare series and parallel circuits

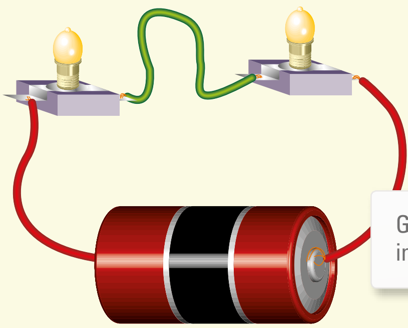
Materials:

three 2.5-volt or 3.0-volt torch globes
6 connecting leads

Part A: Series circuits

METHOD AND RESULTS

- Connect one globe and the battery together with wire leads so that the globe lights up.
- Add a second globe in series with the first globe as shown in the diagram below.
- Remove one globe from its holder.
- Replace the globe that was removed, and then remove the other one.



Globes connected in series

1. Draw a circuit diagram to represent the circuit that you have connected.
2. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
3. What effect does the removal of one globe have on the other globe when the battery is connected?
4. Does it matter which globe is removed?

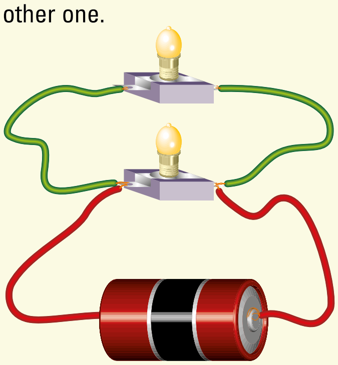
DISCUSS AND EXPLAIN

5. What would be the effect on the other globes if a third globe were added in series? Test your prediction.
6. Can electric current flow in this series circuit when either globe is removed?
7. Would it be sensible to have all of the ceiling lights in your home connected in series? Give a reason for your answer.

Part B: Parallel circuits

METHOD AND RESULTS

- Connect the two globes, battery and wire leads as shown in the diagram below.
- Remove one globe from its holder.
- Replace the globe that was removed, and then remove the other one.



Globes connected in parallel

8. Draw a circuit diagram to represent the circuit that you have connected.
9. How does the brightness of the two globes compare with the brightness of a single globe connected to the same battery?
10. What effect does the removal of one globe have on the other globe?
11. Does it matter which globe is removed?
12. Outline whether the removal of one globe has any effect on the other globe.
13. What would be the effect on the other globes if a third globe were added in parallel? Design a circuit to test your prediction.

DISCUSS AND EXPLAIN

14. Can electric current flow in this parallel circuit when either globe is removed?
15. Would it be sensible to have all of the ceiling lights in your home connected in parallel? Give a reason for your answer.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Explain, in words and without the use of a diagram, the difference between a circuit with two light globes in series and a circuit with two light globes in parallel.

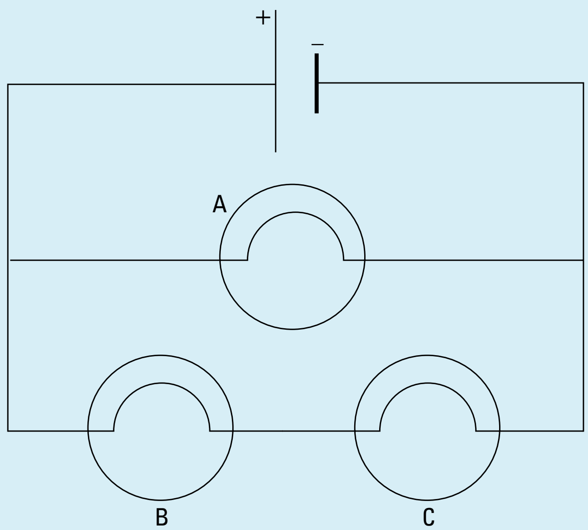
2 Copy and complete the following sentences, by choosing the correct word from the pair of words in italics.
   (a) When light globes are connected in *series/parallel*, the same electric current flows through each globe. The globes share the voltage of the power supply.
   (b) When light globes are connected in *series/parallel*, the electric current splits to be shared by the globes. Each globe uses the same voltage.

THINK

3 Draw a circuit diagram of each of the circuits shown in Investigation 10.7. Make sure that you include the switch.

4 In a small shop, the six light globes are in parallel. One switch is used to switch all of the lights on or off at once. Draw a circuit diagram of this circuit.

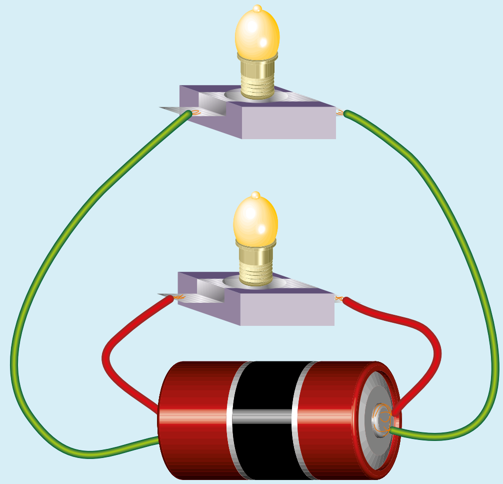
5 Examine the circuit diagram shown below.



   (a) If the filament of globe A breaks, do globes B and C remain lit or do they stop working also?
   (b) If the filament of globe B breaks, which globe or globes (if any) remain lit?
   (c) If the filament of globe C breaks, which globe or globes (if any) remain lit?

6 In a house, six light globes are in parallel. However, the lights are in separate rooms. This means that a separate switch is needed for each globe. Draw a circuit diagram of this circuit.

7 Examine the circuit shown below.
   (a) If the two globes are identical, how much of the current that flows through the battery flows through each globe?
   (b) In what way is this circuit similar to the one in part B of Investigation 10.7?
   (c) In what way is this circuit different from the one in part B of Investigation 10.7?



Is this really the same circuit as the one in part B of Investigation 10.7?

INVESTIGATE

8 To see a direct comparison between the flow of water and a DC circuit, use the **DC water analogy** weblink in your eBookPLUS.

eBook*plus*

CREATE

9 Design a circuit with two switches and an electric bell, so that the bell rings when either one (or both) of the two switches is closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.

10 Design a circuit with two switches and an electric bell, so that the bell rings only when both switches are closed. Draw a picture and circuit diagram of your circuit. Invent your own symbol for the bell. If a bell is not available, use a light globe instead.

work sheets
10.3 Simple circuits
10.4 Series and parallel circuits

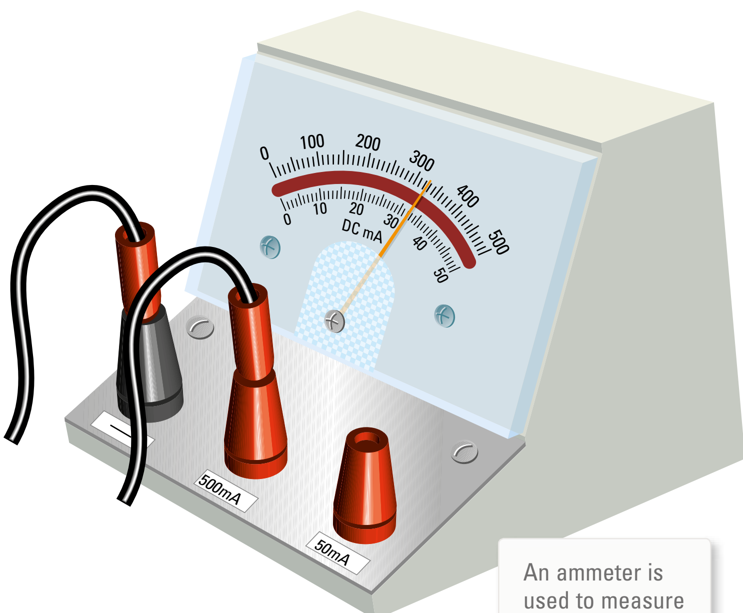
Scale and measurement: Made to measure

Like the currents of water in rivers and the sea, electric current can be measured.

Water currents in a river or the sea can be measured by determining the amount of water that passes a particular point every second. Likewise, the size of the electric current in an electric circuit can be measured by determining the amount of electric charge passing a particular point in an electric circuit every second.

Using an ammeter

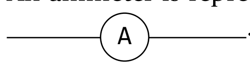
An **ammeter** is used to measure the size of electric current flowing in an electric circuit. An ammeter measures electric current in amperes (A) or in one-thousandths of an ampere, which are called milliamperes (mA).



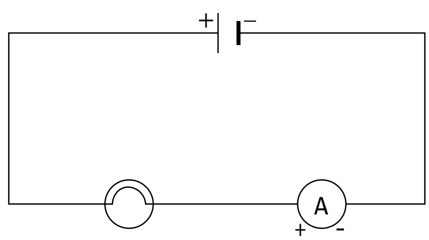
An ammeter is used to measure electric current.

Most ammeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using ammeters.

- The positive terminal of the ammeter should always be connected in series so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured current in your circuit is smaller than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.
- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal. (The top scale of the ammeter on the left is used because the lead is connected to the 500 mA terminal.)
- An ammeter is represented by the symbol



- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.



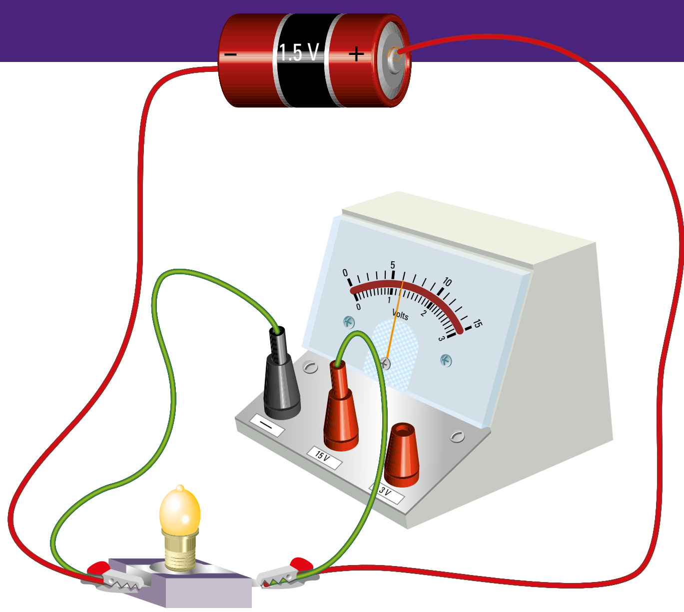
Circuit diagram showing how an ammeter is used to measure the electric current through a light globe

Using a voltmeter

A **voltmeter** is used to measure the voltage gain across the terminals of a power supply or voltage drop across parts of an electric circuit. Voltage is (not surprisingly) measured in volts (V).

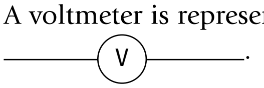
Like ammeters, most voltmeters used in school laboratories have one (black) negative terminal and two or more (red) positive terminals. Remember the following points when using voltmeters.

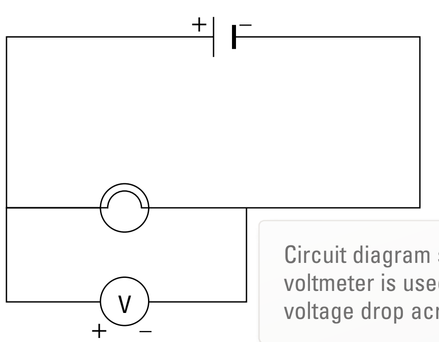
- A voltmeter should be connected in parallel with the part of the circuit across which the voltage is being measured. The positive terminal should always be connected so that it is closer to the positive terminal of the power supply than the negative terminal of the power supply.
- Use the positive terminal with the highest value first. If the measured voltage in the circuit is smaller



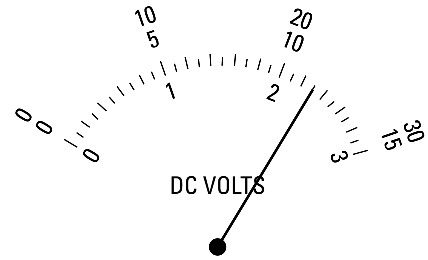
A voltmeter is used to measure the voltage gain or drop across two parts of an electric circuit. This voltmeter is being used to measure the voltage across the light globe.

than the value shown on one of the other terminals, you may change the connection to the positive terminal with the smaller value.

- The scale has at least two sets of numbers on it. Use the set that matches the connected positive terminal.
- A voltmeter is represented by the symbol .
- Always read a voltmeter from directly in front to avoid parallax error.



Circuit diagram showing how a voltmeter is used to measure the voltage drop across a light globe



There is always a degree of error when reading a scale like this.

Errors of measurement

No matter how much care you take with your measurements, there will always be errors because of limitations of your equipment. In addition, when you are reading scales such as those on a ruler, a mercury or alcohol thermometer, an ammeter or a voltmeter, you always have to make an estimate. You should be able to read a scale to about one-tenth of the smallest division marked on it.

For example, on the 3-volt scale of the voltmeter shown above, the smallest division is 0.1 volt. With care, the scale can be read with an uncertainty of about 0.01 volt. The reading appears to be 2.30 volts, but because of the thickness of the needle and the difficulty in making an estimate it could be read as 2.31 volts or 2.29 volts.

Random errors

Errors that occur due to estimation when reading scales are called **random errors**. Random errors also occur when the quantity being measured changes randomly. For example, when the temperature of the water in a saucepan is being measured, it may increase or decrease slightly due to the convection currents in the water.

Systematic errors

Errors that are consistently high or low due to the incorrect use or limitations of equipment are called **systematic errors**. Parallax errors caused by consistently reading the scale of an ammeter or voltmeter from one side instead of directly in front are systematic errors. An incorrect zero reading when there is no current or voltage, or uneven scales, are also systematic errors.

Reducing errors

Random errors can be reduced by repeating measurements numerous times and calculating an average. But this is not always possible or practical. Such errors can never be totally eliminated. Some systematic errors can be eliminated by knowing how to use the equipment correctly. If a measuring instrument does not read zero when it should, the error can be eliminated by adding or subtracting the ‘zero error’. But there will always be systematic errors, because no scale or measuring instrument is perfect.

INVESTIGATION 10.8

Probing a simple circuit

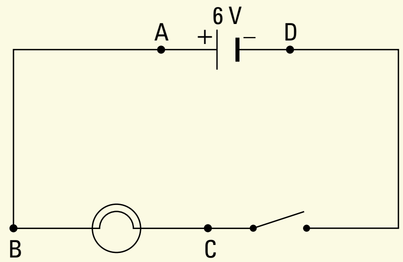
AIM **To investigate the current and voltage within an open and closed circuit**

Materials:

power supply (set to 6 volts)
6-volt light globe and holder
6 connecting leads with alligator clips or banana plugs
very long connecting lead (at least 2 m long)
switch
ammeter
voltmeter

METHOD AND RESULTS

1. Set up the circuit shown in the diagram below. You should be able to set it up using only three connecting leads. Make a copy of the table below in which to record your measurements.



Probing a simple circuit

Part A

- Use the ammeter to measure the electric current at each of the points A, B, C and D.

2. Record your measurements in the table.

CAUTION Check that the ammeter is connected properly before closing the switch. Ask your teacher if you are not sure.

- Remove the ammeter from the circuit.

3. With the switch closed, use the voltmeter to measure the voltage across:
   – the power supply (across points A and D)
   – the light globe (across points B and C)
   – the switch (across points C and D)
   – one of the connecting leads (across points A and B).

DISCUSS AND EXPLAIN

4. Is there any difference between the amount of current travelling through the points A, B, C and D?
5. How does the voltage across the terminals of the power supply compare with the voltage across the light globe when the switch is closed?
6. Where is most of the electrical energy generated by the power supply lost?

Part B

7. With the switch open, use the ammeter to measure the electric current at each of the points A, B, C and D.

- Before you connect the ammeter, make a prediction of the electric current at each of the four points.

8. With the switch open, use the voltmeter to measure the voltage across:
   – the power supply (across points A and D)
   – the light globe (across points B and C)
   – the switch (across points C and D)
   – one of the connecting leads (across points A and B).

- Before you connect the voltmeter, make a prediction of the voltage across each of the four items.

DISCUSS AND EXPLAIN

9. Were your predictions correct?
10. Why has the voltage across the switch changed so much?
11. Explain how a voltage drop can occur even though the circuit is not closed. (*Hint:* Think about what voltage measures.)

Currents and voltages around a simple circuit

	Using the ammeter		Using the voltmeter	
	Location in circuit	**Electric current (mA)**	**Item**	**Voltage (V)**
Switch closed	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	
Switch open	A		Power supply	
	B		Light globe	
	C		Switch	
	D		Connecting lead	

UNDERSTANDING AND INQUIRING

REMEMBER

1 Which physical quantity is measured by:
(a) an ammeter
(b) a voltmeter?

2 Explain how an ammeter must be connected in an electric circuit and state which terminal of the ammeter must be connected closest to the positive terminal of a battery.

3 Describe how a voltmeter must be connected to the part of a circuit across which the voltage is to be measured.

4 Describe two causes of random errors that occur when reading scales to measure any physical quantity.

5 Describe one way in which random errors can be reduced.

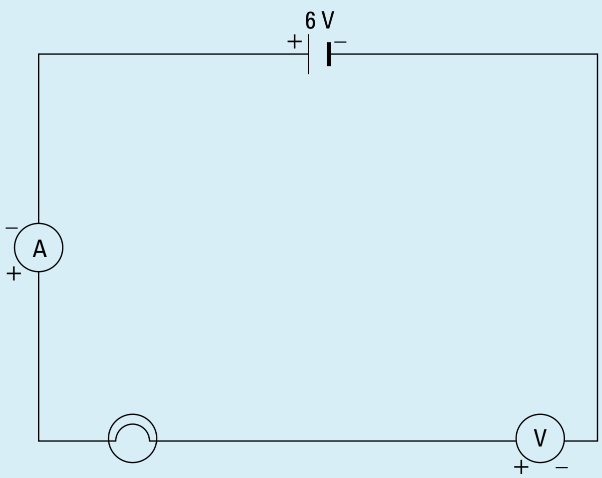
6 Describe two causes of systematic errors when using a voltmeter or ammeter.

THINK

7 Explain why voltmeters and ammeters have two or three scales.

8 Express an electric current of 0.350 A in mA.

9 Identify two errors in the circuit shown below.



10 Explain why the voltmeter in Investigation 10.8 must be connected in parallel with the light globe.

11 When using an ammeter, you are advised to use the positive terminal with the highest value scale first. If you can choose between a 50 mA and a 500 mA scale, which one should you connect first? Explain your answer.

12 (a) Why can't you accurately read the electric current measure on the ammeter illustrated at the start of this section?
(b) Estimate the reading.

13 Is a parallax error a random or systematic error? Explain your answer.

14 Can random errors be eliminated by using digital measuring instruments?

15 Explain why it is never possible to totally eliminate errors when measuring physical quantities.

16 Read the measurement on the ammeter below accurately.

INVESTIGATE

17 Research and report on the life and contributions to the investigation of electricity of either André-Marie Ampère or Alessandro Volta.

eBook*plus* work sheet 10.5 Ammeters and voltmeters

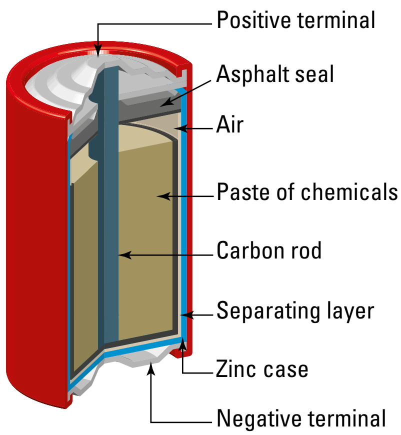
Electricity in a packet

The great thing about batteries is that they are light and portable. They are used mostly in devices that need to be moved about. Imagine the disadvantages if you could only get electricity for a torch, a mobile phone or an mp3 player by plugging it into a power point.

Batteries are also used in devices such as clock radios and DVD players as a backup in case of power failure.

A battery is made up of two or more **cells** connected in series. However, in everyday language the word battery is used for a single cell. The batteries used in a torch are actually single cells. An electric cell consists of two **electrodes** and a substance through which electric charge can flow. When the two electrodes are joined together by a conducting path, a **chemical reaction** takes place inside the cell, releasing electric charge and allowing current to flow.

Dry cells



A general-purpose dry cell

The general-purpose cells used in torches, clocks, smoke detectors and toys are filled with a paste of chemicals. The two electrodes are:

- a central rod of carbon, which is attached to the positive terminal
- a zinc case, which is in contact with the negative terminal of the cell.

When a conducting path is provided between the two terminals of the cell, a chemical reaction takes place between the paste and the zinc case. This releases electric charge, allowing an electric current to flow around the circuit. A separating layer stops the chemicals from reacting while the cell is not in use.

These general-purpose cells are called **dry cells** because the **electrolyte** (the substance inside the cell through which electric charge moves) is not a liquid.

Other types of dry cell work in the same way but use different electrodes or electrolytes.

HOW ABOUT THAT!

Have you ever experienced a sharp pain in your mouth when a piece of aluminium foil, probably from a sweet wrapper, contacts a filling? The cause of the pain is an electric cell that you have accidently created in your mouth. The aluminium foil acts as the negative electrode giving up electrons to the filling, with your saliva acting as the electrolyte. The metal in your filling acts as the positive electrode. Contact between the aluminium foil and the filling short-circuits the cell, causing a weak electric current to flow between the electrodes. You feel this as a sharp pain.

Alkaline cells contain an electrolyte that allows a greater electric current to flow. They are ideal for heavy-duty torches, battery-operated shavers, portable CD players and digital cameras.

Mercury cells produce a voltage that is much steadier than other dry cells. Their steady output makes them ideal for pagers, hearing aids, watches, calculators and measuring instruments.

Fruity cells

Citrus fruits such as lemons, oranges and grapefruit can be used to make a battery. When a conducting path is provided between different metals inserted into the fruit, a chemical reaction takes place with the acids and a small electric current flows.

Different types of batteries

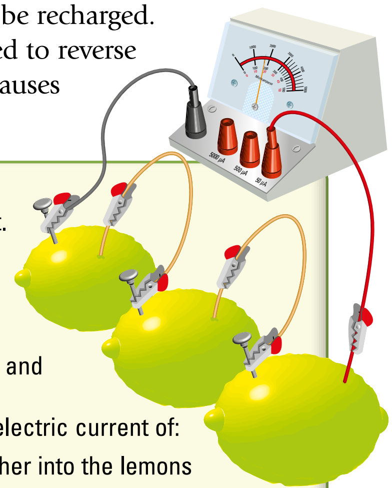
Car batteries

Car batteries consist of six cells connected in series. Each cell has two lead electrodes, one of which is coated with a paste of lead dioxide. The electrodes are surrounded by a sulfuric acid solution. When the battery is in use, a chemical reaction occurs between the electrodes and the sulfuric acid. One of the products of the reaction is lead sulfate. Once the engine is running, the chemical reaction is reversed and the battery recharges. The lead sulfate is converted back to lead and lead dioxide. After a few years, the lead sulfate builds up on the electrodes and becomes so hard that the reverse reaction cannot take place. The battery cannot be recharged and needs replacing.

HOW ABOUT THAT!

The very first working battery, made by Alessandro Volta more than 200 years ago, was a tall pile of silver and zinc discs with pieces of cloth soaked in salty water between the discs. This structure became known as a voltaic pile.

Nickel–cadmium cells, such as those used in mobile phones, can also be recharged. A battery charger can be used to reverse the chemical reaction that causes electric current to flow.



INVESTIGATION 10.9

A lemon battery

AIM To use lemons to create a battery

Materials:

3 lemons
3 galvanised nails
three 5 cm lengths of uninsulated copper wire
microammeter
4 connecting leads

METHOD AND RESULTS

- Squeeze all three lemons to break up some of the pulp inside.
- Insert a galvanised nail and a piece of copper wire into one of the lemons. The nail and wire should be about 3 cm apart.
- Use connecting leads to connect the negative terminal of the microammeter to the nail and the positive terminal to the copper wire.

1. Record the electric current.
2. Add a second lemon in series and record the electric current again.
3. Add a third lemon in series and record the electric current.

- Investigate the effect on the electric current of:
  - pushing the electrodes further into the lemons
  - changing the distance between the nail and the copper wire in each lemon.

DISCUSS AND EXPLAIN

4. What is the electrolyte in this lemon battery?
5. How did the adding of a second and third lemon in series affect the electric current?
6. How did changing the depth of the electrodes and the distance between them affect the electric current?

UNDERSTANDING AND INQUIRING

REMEMBER

1. What is the difference between a cell and a battery?
2. What takes place inside a cell to cause an electric current to flow?
3. What substances are the electrodes of a general-purpose dry cell made of?
4. How do alkaline cells differ from general-purpose dry cells?
5. If a car battery can be recharged, why can't it last for ever?

THINK

6. Make a list of all the devices you can think of that use batteries.
7. What substance makes up the electrolyte in a car battery?
8. Explain why mercury cells are ideal for watches, hearing aids and measuring instruments.
9. Why does a car battery need replacing sooner if it is not used very often?

IMAGINE

10. Imagine that batteries were no longer available. Consider each of the devices you listed in question 6, and state:
    (a) what could replace the battery
    (b) how you would be affected if the battery could not be replaced.

eBook*plus* work sheet 10.6 Testing batteries

Driving on batteries

What sort of car do you expect to be driving thirty years from now? Will it be just a newer, sleeker, lighter version of the cars you see on the road today? How much will petrol cost: $2 per litre or $20 per litre? Most medium-sized cars have petrol tanks that hold between 50 and 80 litres. How much will it cost to fill the tank? Will you have trouble breathing the polluted air in traffic-clogged cities?

eBook*plus* **eLesson**

The Australian International Model Solar Challenge
Learn about the exciting annual event where Australian high school students compete by building and racing model cars and boats that are powered by solar energy.

eles-0068

Changing times

It is unlikely that you will be driving a car with an engine powered by petrol. There are several reasons for this:

- Petrol is made from oil and the world's oil supply is rapidly decreasing. At the same time, the amount of oil being used is increasing. It has been predicted that the world's oil reserves will run out in less than fifty years.
- Petrol is becoming more expensive. This is partly due to attempts by politicians to conserve the world's oil reserves. As the cost of petrol increases, alternative fuels become more attractive. LPG (liquefied petroleum gas) is already increasing in popularity as a fuel for cars.
- Petrol-driven car engines cause air pollution. Gases released from car exhausts include carbon monoxide (a poisonous gas), carbon dioxide (a major cause of the 'greenhouse effect' and a probable cause of climate change) and nitrogen oxides (which lead to smog and acid rain).

The Tesla Roadster is a high performance electric car now available in Australia. It can accelerate from 0 to 100 km/h in 4 seconds, has a top speed of 200 km/h and can travel 350 km before the batteries need recharging.

Electric cars

One of the most attractive alternatives to the petrol-driven car is a car powered by rechargeable batteries. Electrical energy from the batteries is used to drive a motor which turns the wheels. The batteries can be recharged while the driver is at home or at work.

Electric cars have three main benefits:

1. Their use will reduce the demand for oil. The world's oil reserves will last longer.
2. They do not release exhaust gases. This would reduce air pollution in large cities.
3. They are very quiet.

An additional benefit is that electric cars can be designed so that their batteries can be fully or partially charged by solar energy.

There are also some drawbacks to electric cars:

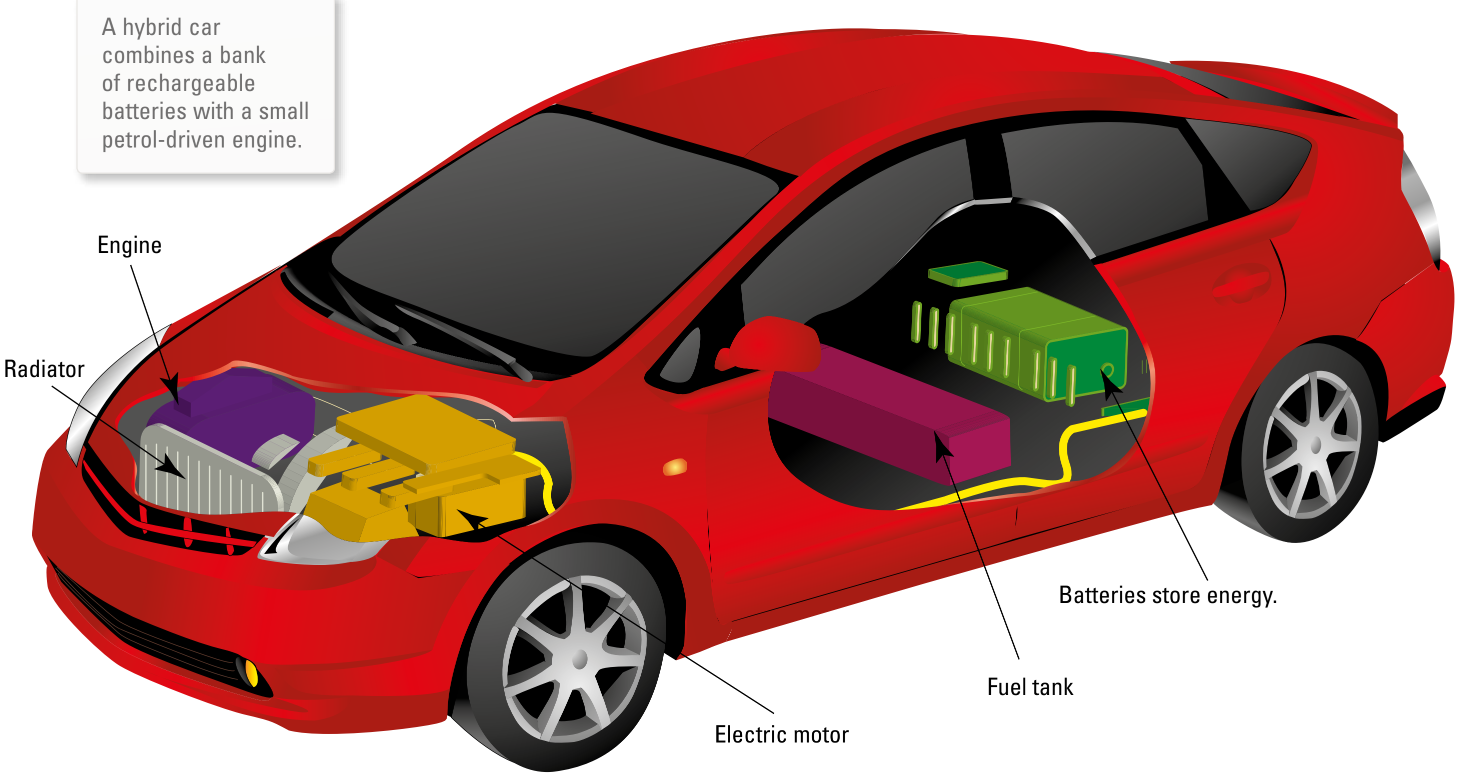
1. Electric cars can travel only about 160 kilometres before the batteries need recharging. A tank of petrol would allow most cars to travel 500–800 km before refuelling.
2. The batteries, which are very expensive, need replacing after a few years.
3. Electric cars do not accelerate quickly and can usually reach speeds of only 100 km per hour.
4. Electric cars are more expensive to buy than petrol-driven cars.
5. If everyone owned electric cars, power stations would need to supply more energy for recharging batteries from power points. Although air pollution in cities would be reduced, the air pollution around the power stations would be increased.

Solving the problems

Some of the disadvantages of electric cars will be overcome as the need to replace petrol-driven cars becomes more urgent.

- Automotive engineers are using scientific knowledge, together with computer techniques and models, to design lighter cars. They are also designing car bodies and tyres to reduce the friction caused by the air and road surfaces. These changes will reduce the amount of energy needed to keep cars running. Batteries will last longer.
- Electric cars that have been converted from petrol-driven cars need at least 12 standard lead–acid car batteries (connected in series) to run at normal speeds. These batteries are very heavy. Lighter, smaller and more powerful batteries are currently being developed.
- As more electric cars are made, the cost of each car will decrease. Also, as petrol becomes more expensive, the higher cost of electric cars will be less of a problem.

A hybrid car combines a bank of rechargeable batteries with a small petrol-driven engine.



New car designs, better batteries and decreasing costs make electric cars a very likely alternative to petrol-driven cars.

The hybrid car

The hybrid car combines a bank of rechargeable batteries with a small petrol engine. It provides most of the benefits of a totally electric car. In the car illustrated on the previous page, the petrol engine generates energy to recharge the batteries while the car is being driven. In some hybrid cars, the petrol engine is connected directly to the motor that turns the wheels. This means that less energy is required from the batteries. The exhaust fumes of hybrid cars still contribute to air pollution, but to a much lesser extent than current petrol-driven cars.

Hybrid cars, such as Toyota's Prius and Camry, are gaining popularity in Australia as the increased price of petrol puts pressure on car owners to use less of it. Hybrid car manufacturers are struggling to keep up with demand.

In Australia, the CSIRO is working with car manufacturers to produce lighter and more compact lead–acid batteries that will require less frequent recharging.

HOW ABOUT THAT!

Battery-powered electric cars are not new. In fact, before 1900 there were more electric cars than petrol-driven cars. However, petrol-driven cars were more powerful and could travel for longer distances without having to stop. Using petrol was also cheaper than replacing and recharging batteries. By 1930, electric cars had been replaced almost entirely by petrol-driven cars.

An early electric car

UNDERSTANDING AND INQUIRING

REMEMBER

1 List three benefits of electric cars.

2 State five disadvantages of electric cars at the current time.

3 What is a hybrid car?

THINK

4 Why are electric cars likely to become popular after being ignored for over 60 years?

5 Suggest why most electric cars are currently able to reach speeds of only 100 kilometres per hour.

6 Which disadvantages of electric cars do hybrid cars partially or entirely overcome?

7 Advertisements for hybrid cars highlight their advantages and sometimes make claims without evidence.
(a) List some disadvantages of hybrid cars.
(b) What type of evidence would you expect from automotive engineers before purchasing a hybrid vehicle?

8 Do you think the government should force car manufacturers to stop making petrol-driven cars and replace them with electric or hybrid cars? State reasons for your opinion.

INVESTIGATE

9 Research and report on how solar cars work. Include in your report a discussion about the possibility of solar cars replacing petrol-driven cars on Australia's roads.

IMAGINE

10 If you could buy an electric car for the same price as a petrol-driven car of the same make and model, which would you choose? Why?

CREATE

11 Draw a diagram of a car of the future. Label the features of the car that will reduce the amount of energy needed to make it go fast.

A question of resistance

Have you ever had to push your way through a crowd of people to get somewhere quickly? Frustrating, isn't it? It slows you down and saps your energy. Well, if the electrons moving in an electric circuit had feelings, they would understand how you felt.

Pushing through the atoms

The negatively charged electrons moving in an electric circuit have to make their way past the atoms in the connecting leads and devices that make up the circuit. Electrical **resistance** is a measure of how difficult it is for electrons to flow through part of a circuit. The resistance to the flow of electric charge limits the electric current, just as the resistance of a narrow and crowded corridor limits the number of students that can pass through in a given time interval. Electrical resistance also determines how much energy is lost by electric charge as it moves through a circuit.

The value of resistance

Conductors have very little resistance. They allow large electric currents to flow with little loss of energy. **Insulators** have a very large electrical resistance. They allow very little electric current to flow.

The letter R is used to represent resistance and its unit is the ohm (Ω). The value of the resistance of part of an electric circuit is defined by the following formula, where V is the voltage drop in volts and I is the electric current in amperes.

$$R = \frac{V}{I}$$

A torch globe carrying an electric current of 200 mA with a voltage drop of 3 volts therefore has a resistance of:

$$R = \frac{V}{I} = \frac{3}{0.2} = 15\Omega.$$

When resistance is constant

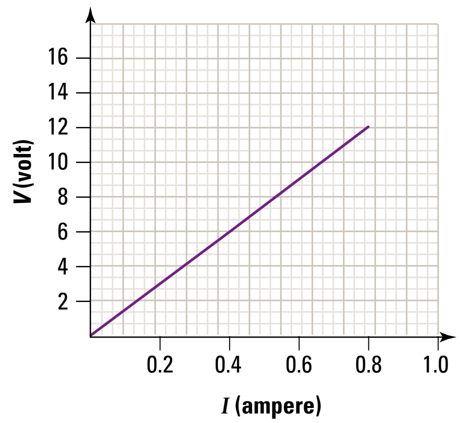
In 1827, a German physicist, Georg Simon Ohm, discovered that the electric current in metallic conductors was proportional to the voltage drop across the conductor. That is, if the voltage was doubled, the current doubled. If the voltage was tripled, the current tripled. This discovery has become known as **Ohm's Law**.

Materials that obey Ohm's Law are said to be **ohmic**. Metals and carbon are ohmic materials as long as the temperature remains fairly constant. The filament in a light globe is not ohmic.

One way of working out whether a material is ohmic is to draw a graph of voltage drop versus electric current. Recall that resistance is defined as:

$$R = \frac{V}{I}$$
$$\therefore V = RI$$

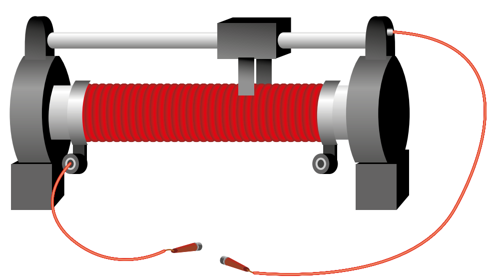
Graph of voltage drop (V) versus electric current (I) for an ohmic conductor



If the material is ohmic, R is constant. A graph of V versus I yields a straight line.

Controlling the flow

When you turn down the volume of a radio or television, you are changing the voltage across and current flowing through parts of the electric circuits inside. The volume dial or sliding knob is part of a **variable resistor**.



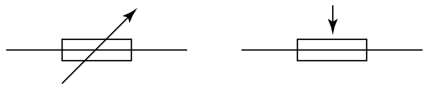
This variable resistor consists of coils of wire touched by a slider. The slider is connected to the coil, and controls the number of coils through which the current flows and, therefore, the resistance.

Resistors are used in electric circuits to control the voltage and current. They can have a fixed resistance or can be variable like those in volume controls.

Three different types of carbon resistors are illustrated on page 381. The two can-shaped resistors on the right are a type of variable resistor used in volume dials.

Taking a dimmer view of things

A variable resistor can be used in a circuit like the one in Investigation 10.11 to control the voltage across the light globe and the electric current flowing through the light globe. As the resistance of the variable resistor increases, the total resistance in the entire circuit increases. This increase in resistance causes a decrease in the amount of current flowing through the circuit.



There are several symbols that can be used to represent variable resistors.

In addition, the amount of available electrical energy transformed in the globe also decreases. As the resistance of the variable resistor increases, more electrical energy is lost in heating the resistor and the surrounding air. Consequently, the globe glows less brightly because not only does less electric charge pass through it every second, but each electric charge has less energy to heat the globe's filament.

A range of carbon resistors

INVESTIGATION 10.10

Changing resistance

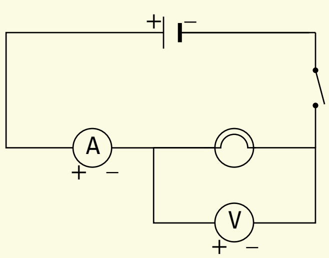
AIM **To investigate the relationship between voltage and resistance of a light globe**

Materials:

power supply (variable)
9-volt light globe and holder
6 connecting leads with alligator clips or banana plugs
switch
ammeter
voltmeter

METHOD AND RESULTS

- Set up the circuit shown in the diagram on the right and leave the switch open.



1. Construct a table like the one below in which to record your measurements of the electric current flowing through the light globe, the voltage drop across the globe and the calculated resistance.

- Set the power supply to 2 volts.

2. Close the switch and quickly read the meters, recording the electric current and voltage drop in your table. Ensure that the electric current is recorded in amperes (not milliamperes).

- With the switch closed, set the power supply to 4 volts.

3. Quickly measure and record the electric current and voltage displayed on the meters.
4. Set the power supply to 6 volts (again not opening the switch) and quickly measure and record the electric current and voltage displayed on the meters.
5. Calculate the resistance of the globe for each of the three power supply settings and record them in your table.
6. Plot a graph of voltage drop (*V*) versus electric current (*I*) for the light globe.
7. Repeat the experiment, constructing a new table in which to record your data. This time, however, start with the power supply set to 6 volts. Then decrease it to 4 volts and then 2 volts.
8. Plot a second graph of the voltage drop versus electric current on the same set of axes as the first graph in a different colour.

DISCUSS AND EXPLAIN

9. Does the resistance increase or decrease during the first part of the experiment, when the power supply setting is being increased?
10. How is the change in resistance different during the second part of the experiment, when the power supply setting is being decreased?
11. What changing property of the filament do you think caused the resistance of the light globe to change?
12. Explain any difference between the shape of the first graph and that of the second graph.

The characteristics of a light globe

Power supply setting (volts)	Electric current (amperes)	Voltage drop (volts)	Resistance (ohms)
2			
4			
6			

INVESTIGATION 10.11

Making the change

AIM To investigate the effect of a variable resistor on a light globe connected with it in series

Materials:

power supply (set to 6 volts)
6-volt light globe and holder
variable resistor
6 connecting leads with alligator clips or banana plugs
ammeter and voltmeter

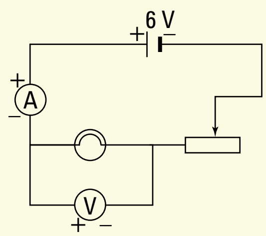
METHOD AND RESULTS

1 Construct a table in which you can record five sets of measurements of voltage across the light globe and electric current flowing through the light globe.

- Set up the circuit shown in the diagram below. The variable resistor is connected in series with the light globe. Move the sliding part of the variable resistor so that the voltage drop across the light globe is at a maximum.

2 Record the voltage and current shown on the meters.

- Move the sliding part of the variable resistor to four different positions, gradually reducing the voltage across the light globe.



Controlling current and voltage with a variable resistor

3 Record the voltage and current in your table for each position.

- Adjust the variable resistance so that the globe is at its brightest.
- Move the voltmeter so that it measures the voltage across the variable resistor.

4 Take note of the voltage.

- Adjust the resistance to make the globe dimmer and dimmer.

5 Take note of how the voltage across the variable resistor changes.

DISCUSS AND EXPLAIN

6 What would you expect the resistance of the variable resistor to be when the voltage drop across the light globe is at a maximum?

7 What happens to the electric current flowing through the light globe as the resistance of the variable resistor increases?

8 What happens to (a) the voltage across the light globe and (b) the brightness of the globe as the resistance of the variable resistor increases?

9 When the globe is at its brightest, what is the voltage across the variable resistor?

10 How does the voltage across the variable resistor change when the globe is made dimmer?

11 What would you expect the sum of the voltage across the light globe and the voltage across the variable resistor to be?

UNDERSTANDING AND INQUIRING

USING DATA

Answer these questions about the ohmic conductor described by the graph of voltage drop versus electric current at the beginning of this section.

1 What is the voltage drop across the conductor when the electric current is 1.0 ampere?

2 What electric current (in mA) flows through the conductor when the voltage drop across it is 6 volts?

3 Calculate the resistance of the conductor.

4 Explain how you know that the conductor is ohmic.

REMEMBER

5 Why does very little current flow through insulators?

6 What does Ohm's Law say about the relationship between electric current in and voltage across metallic conductors?

7 Which two properties of a working electric circuit change when the resistance of a variable resistor changes?

8 What happens to the electric current flowing through a light globe when the resistance of a variable resistor in series with the globe increases?

THINK

9 What is the voltage drop across a 100 Ω resistor when the electric current flowing through it is measured at 250 mA?

10 The electric current flowing through a light globe is measured to be 200 mA when the voltage across the globe is 1.5 volts. When the voltage is increased to 3.0 volts, the current is measured to be 360 mA.
(a) What is the resistance of the light globe when the electric current is 200 mA?
(b) Is the light globe ohmic?
(c) If the light globe were ohmic, what would happen to the electric current flowing through that light globe if the voltage across it were doubled?

INVESTIGATE

11 Take a close look at a variable resistor and explain what causes its resistance to increase when a slider is moved or the dial turned.

12 Use the **Ohm's Law** weblink in your eBookPLUS to learn more about Ohm's Law and the relationships between voltage, current and resistance.

eBook*plus* work sheet **10.7** Ohm's Law

Electricity at home

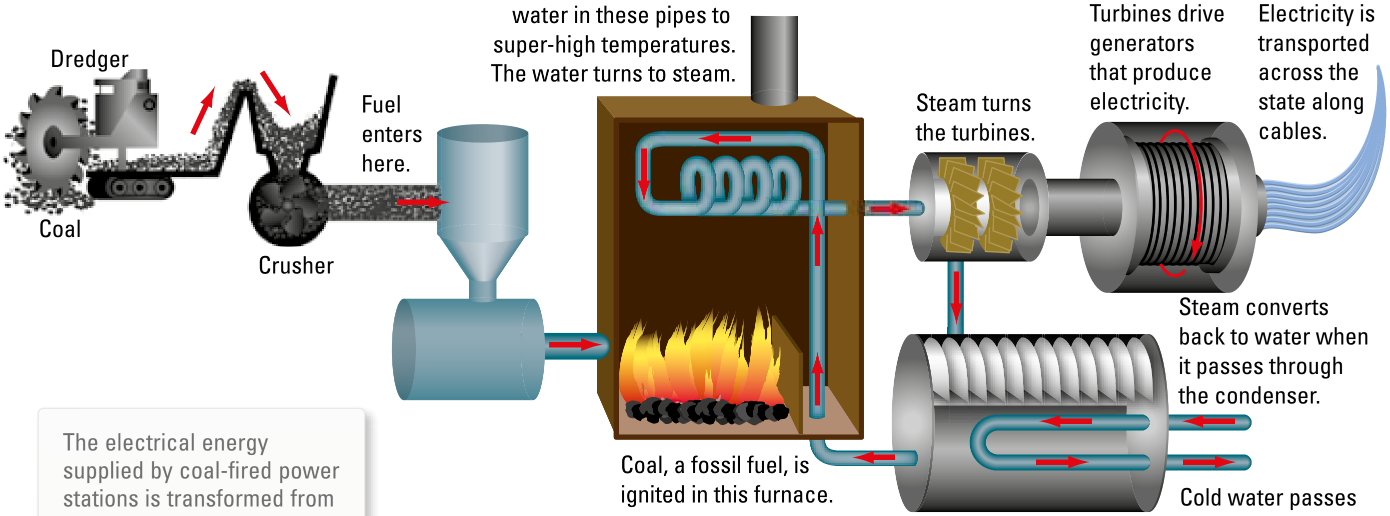
When you are at home, most of the electrical energy you use is obtained simply by plugging a lead into a power point and flicking a switch or two. However, the electric current that flows from power points is not quite the same as the electric current that flows through a battery.

A 500 MW superheated steam turbine generator during construction

The electrical energy provided when you plug an appliance into a power point can be transformed from stored chemical energy. This happens when the power station providing the energy burns coal or another fossil fuel to generate electricity. The chemical energy in the fuel is used to boil water, which forms steam and turns the blades of turbines. The turbines are like giant fans. In many parts of Europe, the USA and Japan, water is heated with the energy released in nuclear reactions. In hydro-electric power stations, the electrical energy is transformed from the gravitational potential energy produced when water falling from a great height turns the turbines in the power station. About 90 per cent of Australia's electrical energy is generated by coal-fired power stations. Most of the remaining 10 per cent is provided by hydro-electric power stations. A very small number of Australian power stations use gas as a fuel.

WHAT DOES IT MEAN?

The term *hydro* in hydro-electric comes from the Greek word *hydor*, meaning 'water'.



The electrical energy supplied by coal-fired power stations is transformed from chemical energy.

AC or DC — what's the difference?

The electric current supplied by a cell or battery is called **direct current** (DC). It flows in one direction only. The electric current provided to your home by power stations is called **alternating current** (AC). It changes direction about one hundred times every second. In household lights and appliances, electrical energy is transformed into other forms of energy as electrons move backwards and forwards.

Alternating current, rather than direct current, is supplied by power stations because it is easier and cheaper to generate. It is also easier and cheaper to distribute widely over large distances. In Australia, electricity is supplied to homes at a voltage of 240 volts.

It's in the box

The electric cable that carries alternating current to your home holds two wires. When the **main switch** in your home's meter box is open, current doesn't flow through the wires in the cable. The circuit is not complete. When the main switch in your meter box is closed, electric current is able to flow through these wires. However, it flows only when other switches inside your house (such as light and appliance switches) are closed. When the main switch is open, the current also flows through the meter in your meter box.

Why there are three

Power points have three sockets. When you plug in an electrical device and switch on the power, alternating current flows between the top two sockets through the appliance. The third socket, called the **earth socket**, is connected to a metal pipe in the ground.

If an electrical device has an uninsulated metal casing, its plug has three pins. The bottom pin is connected by a wire to the metal casing. This pin fits into the earth socket. If there is a fault in the appliance, and the metal casing becomes 'live', electric current flows to the ground, rather than through the body of a person touching the metal. Appliances with two-pin plugs are 'double insulated' to make them safe. Any metal on the outside of these appliances is insulated with plastic. This prevents electric current from flowing from the metal to the wiring inside.

Hand-held electric appliances like this hairdryer are double insulated.

Stepping down

Many of the electrical devices that you plug into power points are not designed to use a 240-volt power supply. For example, devices like computer printers and electronic games require voltages of 9 volts or 12 volts. A **transformer**, usually attached to the lead, is plugged into the power point. The transformer reduces the voltage from 240 volts to the 9 volts or 12 volts required.

Some devices that use DC current, such as mobile phone battery chargers, are plugged into power points. The black box that is plugged in contains a transformer, which 'steps down' the voltage, and another circuit, called a **rectifier**, that changes the alternating current into direct current.

Some electrical devices require less than the 240 volts supplied by power points. A transformer is used to 'step down' the voltage.

Keeping circuits safe

The appliances and lights in your home are all connected in parallel. There are normally two separate parallel circuits in a house, one for the lights and one for the power points. If too many appliances or lights are turned on at once, the total current is too large and a **fuse** or **circuit breaker** can open the main circuit and stop the flow of current. A set of fuses or circuit breakers can be found in your meter box at home. A fuse is a short piece of wire that melts if the current gets too high. A circuit breaker is a special switch that opens automatically if the electric current gets too high.

Safety switches

Fuses and circuit breakers open circuits before they overheat. But they work too slowly to stop people from getting an electric shock if a short circuit causes a dangerously high current. Safety switches (also known as residual current devices) can turn off the power much more quickly — in less than one-thirteenth of a heartbeat — thus reducing the risk of death due to electric shock in the home.

The switch on the left is a safety switch. The other switches are circuit breakers.

Take care!

The 240-volt AC household power supply can kill. If you tamper with working appliances or electrical wiring, it is possible that electric current will flow through your body. Electrocution — death from electric shock — can be caused by electric currents as low as 0.05 amperes flowing through your body.

One of the biggest causes of electrocution in the home is the use of damaged cords and plugs. If appliance cords and plugs are frayed or damaged, exposing the smaller plastic covered wires inside, the appliance should be replaced or taken to a qualified repairer.

The bathroom can be a very dangerous place in which to use electrical appliances. Tap water contains charged particles (ions) due to substances dissolved in it. It is therefore a good conductor of electric current. Appliances like hair dryers, radiators and electric shavers should never be used when there is water in the basin or bath, or when there is water on the floor. If a working appliance was to fall into some water, you could be electrocuted if you came in contact with the appliance, either by accidentally touching it or by trying to pick it up.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What do the letters AC and DC stand for?

2 Explain why devices like electronic games and computer printers have heavy transformers attached to their leads or plugs.

3 What should be done when appliance cords or plugs become frayed or damaged?

4 Why does extra care need to be taken when using electrical appliances in the bathroom?

5 What important roles do both fuses and circuit breakers play?

6 Explain how circuit breakers are different from fuses.

THINK

7 What form of energy is the electrical energy for a streetlight most likely to have been transformed from in:
(a) Melbourne
(b) Hobart?

8 Why do power points have three sockets even though many appliances have plugs with only two pins?

INVESTIGATE

9 On the back of a mobile phone battery charger is printed 'Input: AC240V 50Hz'. Find out what '50Hz' means.

10 Use the **DC/AC** weblink in your eBookPLUS to see animations comparing how AC and DC currents flow around a simple circuit.

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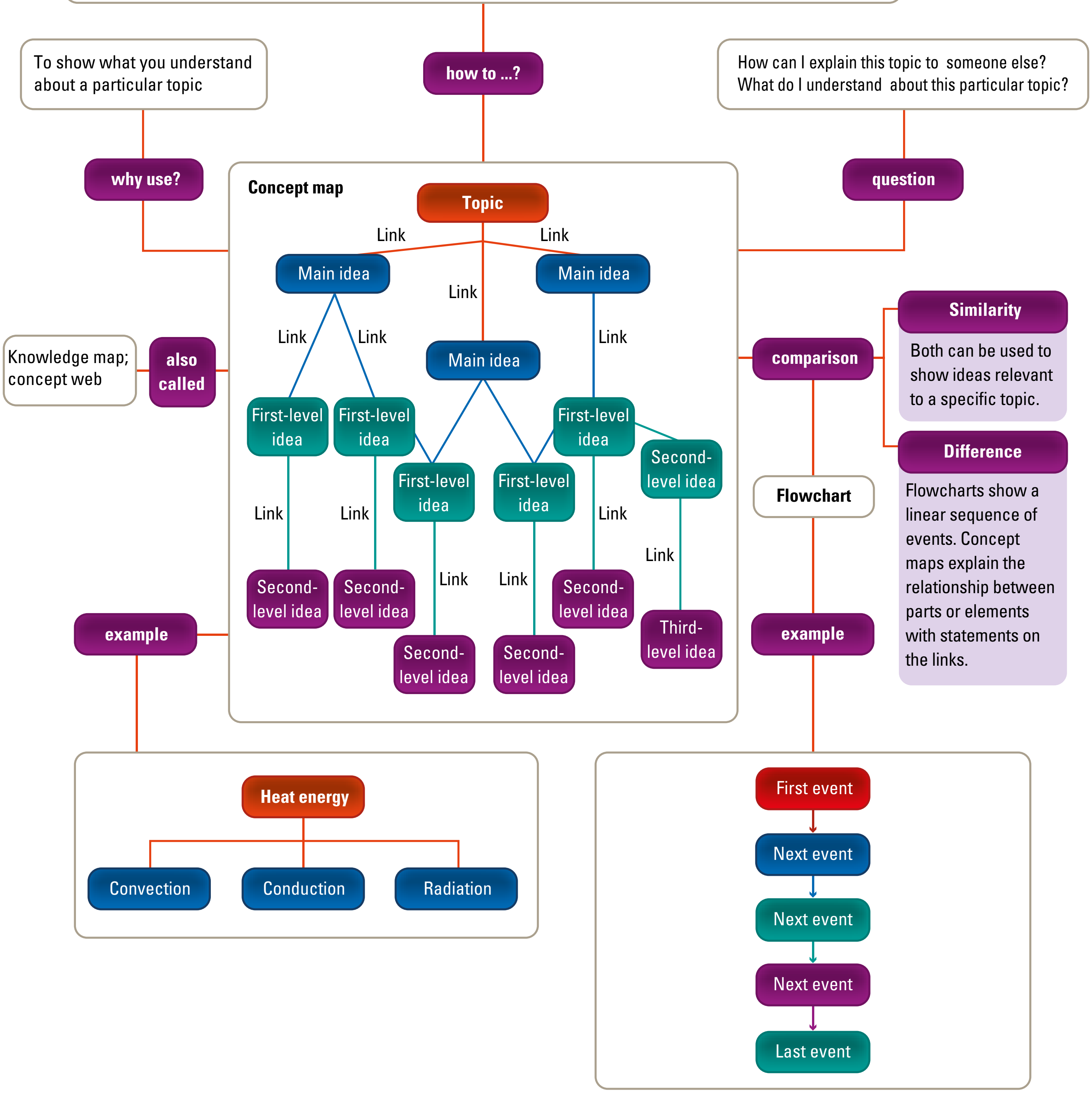
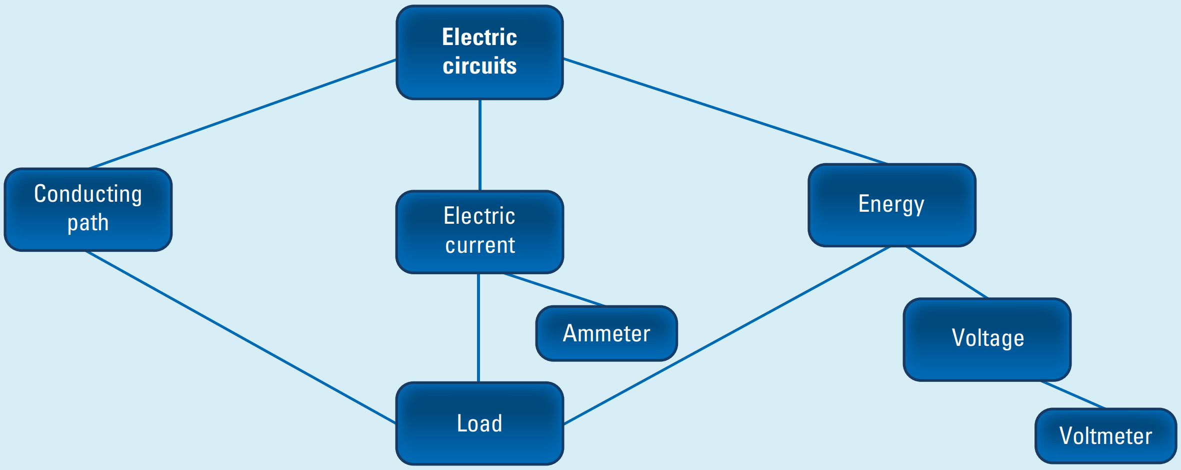
Concept maps and flowcharts

1. On small pieces of paper, write down all the ideas you can think of about a particular topic.
2. Select the most important ideas and arrange them under your topic. Link these main ideas to your topic and write the relationship along the link.
3. Choose ideas related to your main ideas and arrange them in order of importance under your main ideas, adding links and relationships.
4. When you have placed all of your ideas, try to find links between the branches and write in the relationships.



UNDERSTANDING AND INQUIRING



THINK AND CREATE

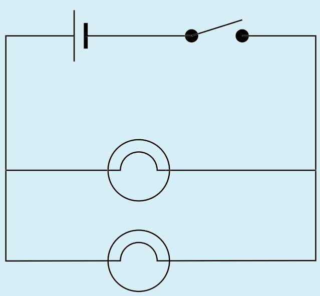
1 The incomplete concept map above represents some of the key ideas related to electric circuits. This concept map is just one way of representing ideas about matter and how they are linked. Copy and complete the concept map by writing suitable links between the ideas.

2 Write each of the ideas included in the concept map above and each of the terms in the box at right on a small piece of paper such as a 'sticky note'. Create a concept map of your own by arranging the ideas on an A3 sheet of paper. Write links in light pencil at first in case you want to make changes to your arrangement.

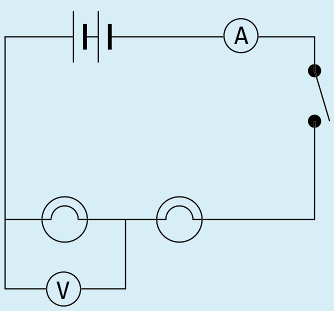
3 Use sticky notes and A3 paper to create a concept map for the topic of household electricity. Use the ideas in the box at right and add as many other ideas as you can.

4 Create two separate flowcharts that show, step by step, how to connect each of the circuits below so that the light globes glow.

(a)



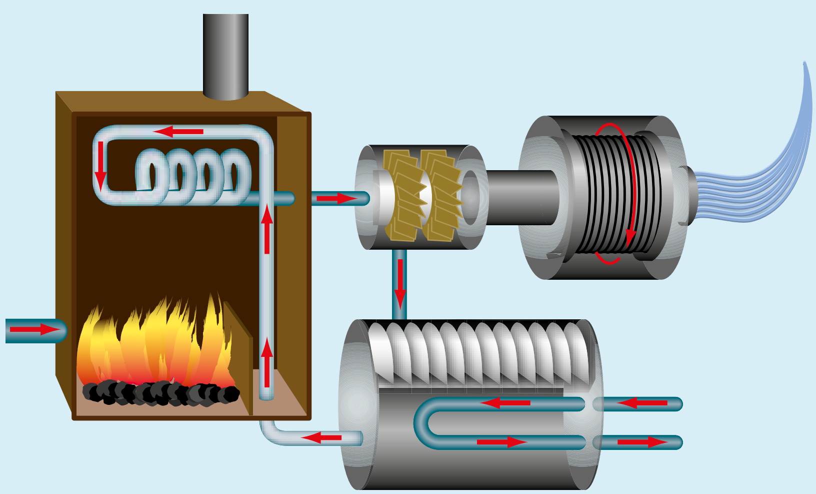
(b)



Electric circuit ideas		
resistance	circuit diagram	filament
in parallel	switch	Ohm's Law
in series	electrons	load
power supply	potential difference	power supply

Household electricity ideas		
alternating current	main switch	appliances
electric power	transformer	voltage
in parallel	rectifier	safety
direct current	electrical energy	circuit breaker

5 Create a flowchart to show how electricity is produced from fossil fuels.



STUDY CHECKLIST

HEAT TRANSFER

- ☐ describe, compare and explain the transfer of heat by conduction, convection and radiation
- ☐ use the particle model to explain heat transfer by conduction and convection
- ☐ contrast the properties of conductors and insulators
- ☐ investigate the radiation and absorption of radiant heat
- ☐ explain sea breezes in terms of radiation, conduction and convection

ELECTRIC CIRCUITS

- ☐ distinguish between static electricity and the flow of electric current in a closed circuit
- ☐ explain energy transfer in an electric circuit
- ☐ relate electric current to the flow of electric charge in a closed circuit
- ☐ relate voltage to the energy gained or lost by electric charge as it moves through an electric circuit
- ☐ draw and interpret electric circuit diagrams
- ☐ distinguish between series and parallel circuits
- ☐ correctly use an ammeter and voltmeter
- ☐ appreciate the errors associated with reading scales and distinguish between random and systematic errors

CELLS AND BATTERIES

- ☐ compare the advantages of alkaline and mercury cells over general-purpose dry cells
- ☐ describe the operation of rechargeable batteries
- ☐ define electrical resistance and explain how it affects the electric current flowing through a circuit
- ☐ distinguish between conductors and insulators
- ☐ distinguish between ohmic and non-ohmic conductors

ELECTRICITY AT HOME

- ☐ distinguish between alternating and direct currents
- ☐ explain why household power points have three sockets
- ☐ describe the role of fuses and circuit breakers
- ☐ describe the role of transformers and rectifiers as they are used in household appliance leads

SCIENCE AS A HUMAN ENDEAVOUR

- ☐ use a scientific understanding of heat transfer to explain how humans maintain a safe body temperature
- ☐ investigate the contributions of Alessandro Volta and André-Marie Ampère to the study of electricity
- ☐ evaluate claims made in the media about the benefits of hybrid cars
- ☐ describe the dangers of tampering with electrical wiring, damaged cords and plugs and using electrical appliances near water

eBook plus DIGITAL RESOURCES

ANSWERS for this chapter can be found online in your eBookPLUS.

Online section

This section of the chapter can be found online in your eBookPLUS.

10.11 Thinking tools: Concept maps and flowcharts (eBook plus ONLINE ONLY)

Individual pathways

Activity 10.1	Activity 10.2	Activity 10.3
Revising heat and electricity	Investigating heat and electricity	Investigating heat and electricity further
doc-8458	doc-8459	doc-8460

FOCUS activity

Access more details about focus activities for this chapter in your eBookPLUS. doc-10634

eLessons

The Australian International Model Solar Challenge

Learn about the exciting annual event where Australian high school students compete by building and racing model cars and boats that are powered by solar energy.

Searchlight ID: eles-0068

The hydraulic model of current

Learn how you can model the flow of current in a circuit using pipes, taps, water and a pump.

Searchlight ID: eles-0029

Volta's pile and the age of steam

Watch a video from *The story of science* about the invention of electricity.

Searchlight ID: eles-1777

LOOKING BACK

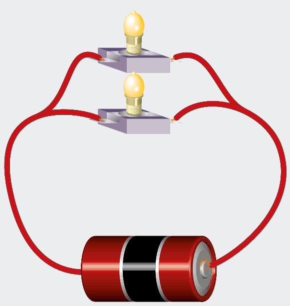
Link to assessON for questions to test your readiness **FOR** learning, your progress **AS** you learn and your levels **OF** achievement. **www.assesson.com.au**

1 Match each term with its correct description.

Word	Description
Static electricity	A material that allows current or heat to flow through it
Electron	Positively charged particle in the nucleus of an atom
Proton	The build-up of charge on an object
Current	A material that does not allow current or heat to flow through it easily
Voltage	Particle in an atom with a negative charge
Conductor	A path that has no breaks in it
Closed circuit	The energy supplied to move electrons around a closed circuit
Insulator	The flow of electrons around a closed circuit

2 Which of the following circuits are parallel circuits and which are series circuits?

(a)



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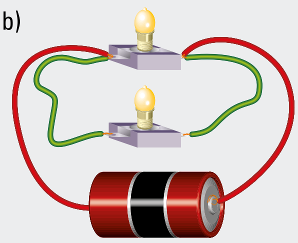

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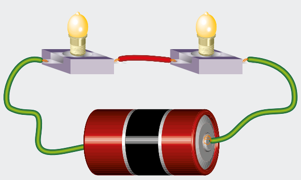

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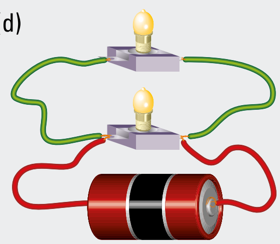


3 Use symbols to draw a circuit containing a light globe in series with an ammeter, a battery and a switch.

4 Using either a particle or a wave model, briefly describe how heat is transferred from one region to another by:
(a) conduction
(b) convection
(c) radiation.

5 Identify the main method or methods by which heat is transferred to the human body by:
(a) a gas wall furnace
(b) the sun
(c) holding a hot plate
(d) an open fireplace
(e) walking on hot coals.

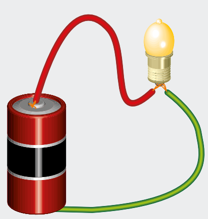
6 Explain why cooks often cover meat with aluminium foil instead of plastic.

7 Explain why solids such as polystyrene, foam, wool and fibreglass batts do not conduct heat as well as most other solids.

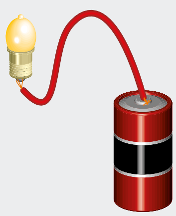
8 (a) Heat is always transferred from a region of high temperature to a region with a lower temperature. Explain how your body is able to keep its core temperature at 37 °C even when the air temperature is greater than 37 °C.
(b) Explain how the wearing of light, loose-fitting clothes protects your body from overheating in hot weather.
(c) Why do your blood vessels get larger in hot weather?

9 In which one or more of the following arrangements will the globe light up?

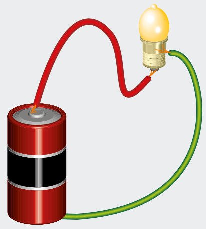
A



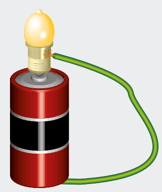
B



C



D

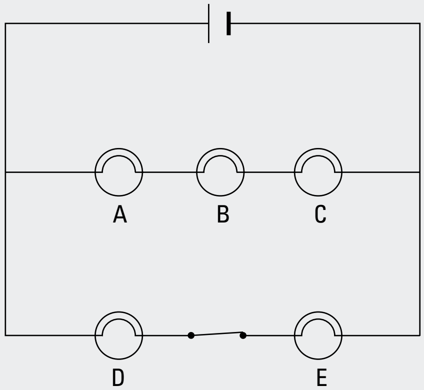


10 Write down the meanings of each of the following terms based on what you have learned from this chapter. When you have finished, and if you completed question 1 in the *Your Quest* section at the beginning of this chapter, compare your answers with those that you agreed on at that time.

(a) Conduction
(b) Convection
(c) Radiation
(d) Current
(e) Insulation
(f) Energy
(g) Metal
(h) Charge
(i) Vibration
(j) Voltage
(k) Reflection
(l) Circuit

11 Which of the physical quantities electric current and voltage is a measure of a change in energy?

Questions 12–18 refer to the circuit diagram below. The light globes, labelled A–E, are identical to each other.



Circuit diagram for questions 12–18

12 Which two or more of the light globes are connected:
(a) in series with globe A
(b) in parallel with globe A?

13 If the voltage across globe C was measured to be 4 volts, what is the voltage across:
(a) globe A
(b) the terminals of the power supply
(c) globe E?

14 If the electric current flowing through globe B was measured to be 200 mA and the electric current flowing through globe D was measured to be 300 mA, what is the electric current flowing through:
(a) globe A
(b) globe E
(c) the power supply?

15 If the filament in globe B was to break, which of the light globes would remain glowing?

16 If the switch in the circuit was opened, which light globes would stop glowing?

17 How could you make all of the light globes stop glowing without opening the switch or turning off the power supply?

18 The voltage across globe C is measured to be 4 volts and the current flowing through it is 200 mA.
(a) What is the electric current flowing through globe C, in amperes?
(b) What is the resistance (in ohms) of globe C while this current is flowing?

19 Complete the table below by writing down the missing quantity, unit or abbreviation.

Electrical quantities and their units

Quantity	Unit	Abbreviation
Voltage	Volt	
Electric current		A
	Ohm	

20 Draw a circuit diagram that shows how a voltmeter and ammeter are used to measure the voltage across and current flowing through a single light globe connected to a 6-volt power supply. Label the positive and negative terminals of the power supply and each meter with + and – symbols.

21 What is the electric current being shown on the ammeter below if the positive lead is placed in the:
(a) 500 mA terminal
(b) 5 A terminal?

22 Describe an example of
(a) a random error and
(b) a systematic error when the scale on the ammeter in question 21 is read.

23 Differentiate between an electric cell and a battery.

24 In what way does a conductor that obeys Ohm's Law behave differently from one that doesn't? Sketch a graph to support your answer.

25 How does increasing the resistance of a variable resistor in series with a power supply and a lamp affect the:
(a) electric current in the lamp
(b) voltage across the variable resistor
(c) voltage across the lamp?

26 Explain the basic difference between alternating current and direct current.

27 Describe the purpose of a circuit breaker in household electric circuits.

28 The mobile phone charger shown in the figure on the right contains a transformer and a rectifier. What is the purpose of the:
(a) transformer
(b) rectifier?

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Go-Go Gadget online shop

SEARCHLIGHT ID: PRO-0110

Scenario

We use the term *technology* to describe the application of science to develop devices, machines and techniques to make some aspect of our lives easier. Televisions, satellites and the internet are all pretty obvious examples of technology, but small devices such as the automatic cat-flap and the humble vegetable peeler are also forms of technology. Small or specialised pieces of technology such as these are often referred to as *gadgets*. Every year, patents for thousands of such gadgets are issued to inventors. Some of them, like the NavMan, are immediate successes, while others — for example, a combination shoe-polisher and toothpick — don't make it into mass production. So what happens if you need a device to do a particular job but no-one has ever made one?

This is just what you and your partners were thinking when you decided to open the Go-Go Gadget online shop. Once established, clients would browse designs for gadgets that you have already developed or ask you to design something new for them that will do the job they need done. Maybe the client wants a hamster wheel that can drive a coffee-grinder or a signalling device that will tell a cat-owner whether their cat has come inside through the cat-flap or is still outside. They just tell you what they need and you design it for them! You then ship them the design, the parts they need to assemble it and an instruction brochure.

To get the business started, you decide to take out a business loan with the bank. The bank manager is intrigued with the idea but wants some assurance that you know what you are doing before they hand over the money.

Your task

As part of your presentation to the bank, you and your business partners are to develop a design for one of the following clients.

- Taylor wants a snooping-parent device that will warn her when one of her parents is coming up the hallway that leads to her bedroom. This device will give her a silent signal so she has time to turn off her computer and open her homework books before they open the door and catch her playing computer games or surfing the net instead of working.
- Heisenberg has an office on the top floor of his house. His cat, Schrödinger, can enter the house through a cat-flap in the door downstairs. When Heisenberg is locking up the house when going out or to bed, it would save a lot of time if he could know whether the cat is already inside the house. He needs a device that is connected to the cat-flap that sends a signal to Heisenberg upstairs indicating whether the cat has come in or gone out the cat-flap.
- Felicity often works until late at night and doesn't get time to exercise her dog by taking her out for a walk. She can use her computer at work to turn on switches in her apartment, and wants a device that will allow her to exercise her dog by remote control without the dog leaving the apartment.

You will then create the following to submit to the bank in support of your loan application.

1. A brief overview (approximately 300 words) of why there is a market for the services of your online shop. To support your argument, you should include references to gadgets that have been successfully developed.
2. A brochure for the gadget you have designed that includes:
   - a diagram of your design
   - a list of parts that are included in the package sent with the brochure
   - instructions on assembly/installation of the gadget
   - a troubleshooting guide to solve problems.

Process

Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the Start Project button to set up your project group.