

7



Electrical energy

By the end of this chapter you will be able to ...

Science Understanding

- investigate factors that affect the transfer of energy through an electric circuit
- describe the differences between series and parallel circuits in terms of voltage, current and resistance
- use laboratory equipment to investigate the relationship between current and voltage in an electric circuit

Science as a Human Endeavour

- discuss Cathy Foley's career with superconductors

Science Inquiry Skills

- draw circuit diagrams using the correct symbols

LITERACY FOCUS

alternating current (AC)
ammeter
circuit diagram
direct current (DC)
earth wire

electrical resistance
electric cell
electric circuit
electric current
electric generator

electromagnet
fuse
magnetic field
parallel circuit
series circuit

short-circuit
solenoid
voltage
voltmeter
volts

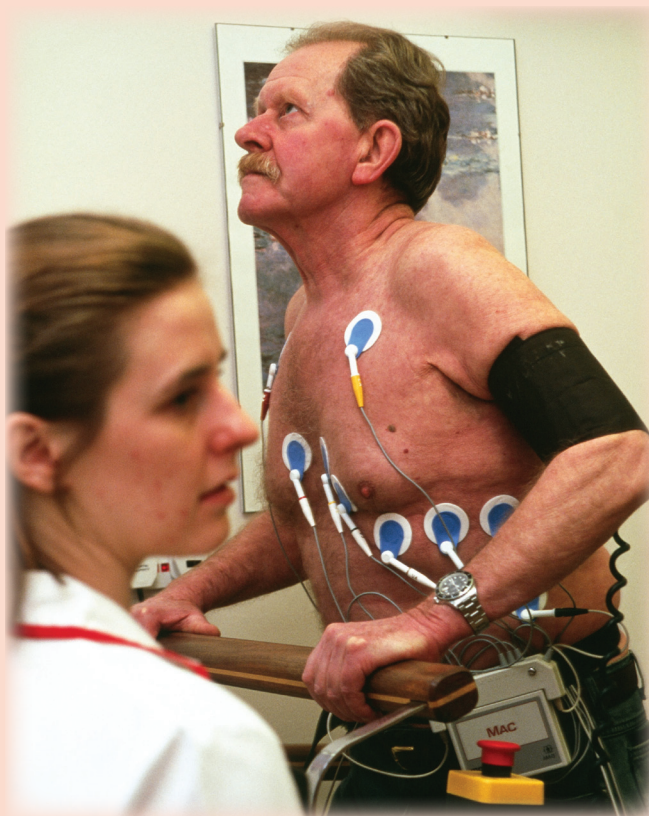
Focus for learning

You use electricity every day. It is supplied to your home, and you just have to flick a switch to turn on a light or an electrical appliance. You can even carry electricity with you in batteries to power watches, torches, CD players, mobile phones and laptops.

Electricity is not just found in our homes and in batteries. It also occurs naturally. Electricity can build up in storm clouds and be released as a flash of lightning.

Electric eels live in South American rivers. They grow up to 2 m long and can produce enough electricity to kill or stun any fish nearby. The dead or stunned fish are then easy to catch.

Your brain and nerves produce electric signals which control your body and keep you alive. For example, your heart needs these signals to keep it beating. If there is a problem with your heart, the doctor does an ECG (electrocardiogram). This shows whether the electrical activity in the heart is normal.

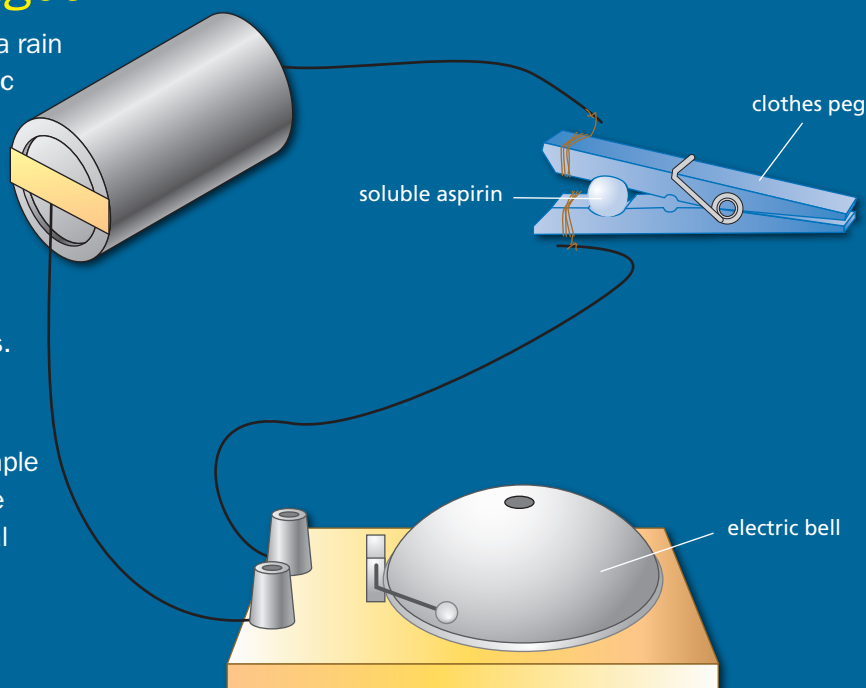


PROBLEM SOLVING

Making an electrical gadget

Caitlin and Trang have made a rain alarm using a battery, an electric bell, a clothes peg, a soluble aspirin and bits of wire. When enough rain falls, the aspirin dissolves, letting the peg close. This connects the wires and lets electricity flow from the battery, causing the bell to ring. Make this rain alarm and see how it works.

Using what you have learnt, design another useful gadget, like the rain alarm, using wires, switches, bulbs and other simple electrical devices. As you work through the chapter you will learn more about electrical gadgets and how to connect them.



7.1 What is electricity?

INVESTIGATION

1 Battery, bulb and switch

Aim

To investigate different ways of connecting a battery, bulb and switch.

Risk assessment and planning

Don't leave the battery connected, as the wires may become hot. This will flatten the battery and you may burn your fingers.

Apparatus

- 1.5V torch battery
- torch bulb (2.5V)
- 4 connecting wires with alligator clips
- 2 switches

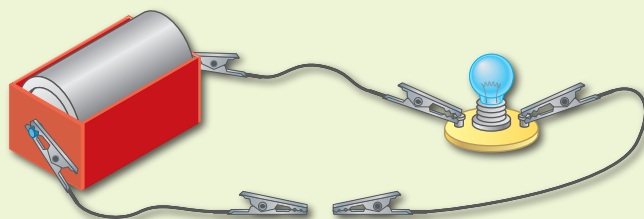
Method

Part A: Lighting a bulb

- 1 Use the battery and one connecting wire to make the bulb glow.
 - * When you have done this, draw a simple diagram of how you connected the battery and bulb.
- 2 See if you can find other ways of making the bulb glow. For example, does reversing the connections make any difference?
 - * Which parts of the bulb do you need to connect for it to glow?
 - * Which parts of the battery do you need to connect?
- 3 How can you make the bulb glow using two connecting wires? Does the bulb have to be touching the battery?
 - * Draw diagrams of each circuit you build.

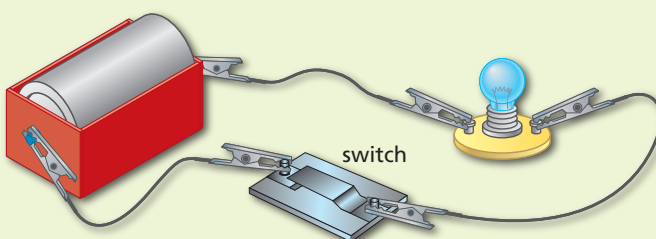
Part B: Using a switch

- 1 Use three connecting wires to connect the battery and bulb as shown top right.



* How can you make the light go on and off?

- 2 Now connect the switch between the alligator clips. Have a close look at the switch to see how it works. You may need to check the back of it.



- 3 Use the switch to turn the bulb on and off.
 - * Explain how the switch works.
 - * Does it matter where you connect the switch?
 - * Does it matter which way round the switch is connected?
 - * What happens when you unscrew the bulb from its holder?
 - * Does it make any difference if you reverse the connections to the battery?

Conclusion

Write a sentence or two saying what you have found out about batteries, bulbs and switches.

Electric circuits

In Investigation 1 you should have noticed:

- 1 You need to connect both ends of the battery to the bulb before it will glow. These metal connection points are called *terminals*. The top of the battery is positive (+) and the bottom is negative (-).
- 2 The bulb has to be connected the right way. The metal side of the bulb is one terminal, and the

metal spot on the bottom is the other. One wire must be connected to each terminal. You can't have two wires connected to one terminal.

- 3 For the bulb to glow, there must be a closed path joining the battery and the bulb. This is called an **electric circuit**. If there is a gap in the circuit the bulb goes off. A switch is a convenient way to open and close the circuit.

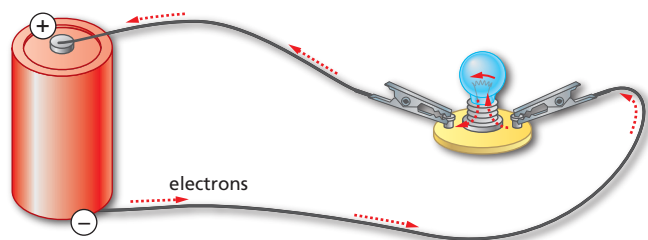
The connecting wires in a circuit are made of metal, which allows the electricity to move through them. The atoms in the metal have positive nuclei, with negative electrons around them. In metals these electrons are free to move from one atom to the next. As one electron leaves an atom, another replaces it. In this way there is a movement of electrons through the metal. This movement of electrons in a wire is called *current* electricity. It is different from *static* electricity, where the electric charges don't move.

Imagine your class is in a narrow corridor. If you pass a ball along from one person to the next this is like an electron moving along a wire. You can also think of the electron as someone surfing the mosh pit.

Electric current

Now you know that electricity is a movement of electrons through a metal, you can explain the electric circuit in Investigation 1. The battery acts like a pump, pushing electrons out of the battery's negative terminal. Because the electrons are negatively charged they are attracted towards the positive terminal of the battery and skip from atom to atom through the metal connecting wires.

If the electrons meet a light bulb they continue to move through the fine metal wire (called a filament) inside the bulb. As they move through this filament they cause it to heat up and glow. The electrons then continue moving from atom to atom on their way to the positive terminal of the battery, and the circuit is complete. This continuous movement of electrons in a wire is called an **electric current**. If there is a break anywhere in the circuit the movement of electrons stops and the bulb does not glow.



Measuring electric current

Electric current is measured using an **ammeter** (AM-eat-er), which is similar to the current detector you can make in Inquiry 1. It counts the number of electrons passing through it per second. The electric current is measured in **amperes** (abbreviation *amps*, symbol A) or milliamperes (1000 mA = 1 A).

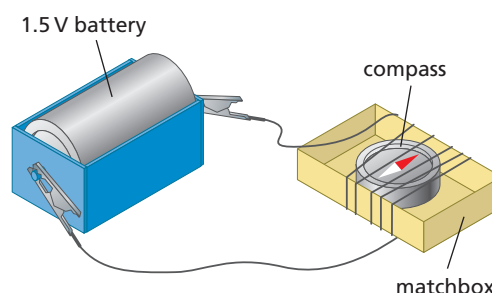
INQUIRY

1

Making a current detector

You will need: 1.5 V battery, small magnetic plotting compass, connecting wire about 1 m long with alligator clips, empty matchbox

- 1 Place the compass in the tray of a matchbox. Wind the connecting wire around the compass in the box, as shown. Connect one end to the battery.
- 2 Rotate the matchbox so that the needle is parallel with the wire and points north–south.



- 3 Briefly touch the other end of the connecting wire to the other terminal of the battery. What happens?

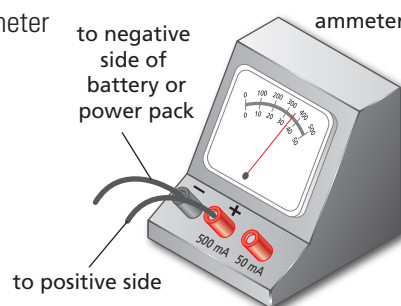
INQUIRY

2

Using an ammeter

When using an ammeter, the red positive terminal is always connected to the positive side of the battery or power pack. The black negative terminal is connected to the negative side. There may be more than one positive terminal, as in the photo below. If you connect to the 50 mA terminal, the ammeter measures from 0 to 50 mA on the bottom scale. If you connect to the 500 mA terminal, it measures from 0 to 500 mA on the top scale. Always connect to the terminal with the largest scale. This will prevent you from damaging the ammeter with too large a current. You can then change to the more sensitive scale if you need to.

Connect an ammeter into the electric circuit you set up in Investigation 1. Measure the electric current.



2 Conductor or insulator?

Aim

To test various materials to see whether they are conductors or insulators.

Conductors allow electricity to move through them, that is, they allow electrons to move from atom to atom.

Insulators do not conduct electricity, that is, they make it very difficult for electrons to move through them.

Risk assessment and planning

For each object listed below, you will record the material it is made of, how brightly the bulb glows and the ammeter reading. Design a suitable data table for this.

Apparatus

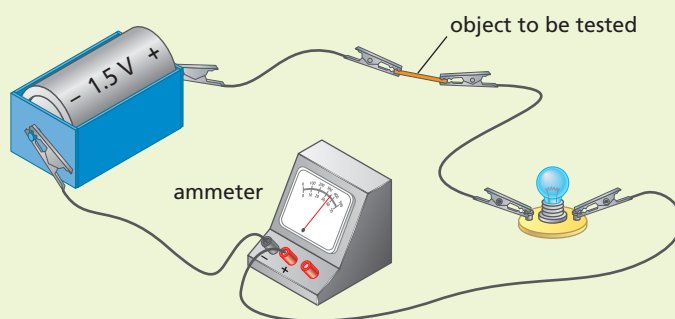
- metal objects, e.g. paperclips, coins, aluminium foil
- objects made of plastic, wood, rubber, glass, paper, string
- connecting wires of various lengths (Test the insulation on the outside, and the wire inside.)
- the graphite in a lead pencil (Sharpen both ends.)
- ammeter (0–500 mA)
- 2.5 V bulb
- 1.5 V battery

Method

- 1 Set up a circuit as shown, but with no object between the alligator clips.
- 2 Touch the alligator clips together to make sure the bulb and circuit work.

* Record the electric current on the ammeter.

- 3 Connect one of the objects between the alligator clips.



* Record how brightly the bulb glows, and the ammeter reading.

- 4 Test each of the other objects and record your results.
- 5 Is your skin a conductor or an insulator? Does it make any difference how far apart the alligator clips are, or whether your skin is wet or dry?

Results

- 1 Why is it necessary to have an ammeter in the circuit?
- 2 How do you know from this experiment whether a material is a conductor or an insulator?
- 3 List the materials tested, from the best conductor to the worst conductor (best insulator). Explain your order.
- 4 Some materials didn't make the bulb glow, yet they gave a reading on the ammeter. Explain this.

Conclusion

From the results, write a conclusion about which types of materials are conductors and which are insulators.

Conductors and insulators

Conductors are usually metals, but not all metals conduct electricity equally. The best conductors are silver, copper, gold, aluminium and steel. The reason they are good conductors is that the electrons are only weakly attracted to the nuclei of the atoms, so they are free to skip from atom to atom, forming an electric current. Metals are also good conductors of heat.

The best insulators are plastic, rubber, wood, glass, porcelain and air. This is because in these materials, the electrons are strongly attracted to the nuclei of their atoms and are not free to move.

Connecting wires are made of copper or aluminium, but they are covered in plastic to prevent electric current from escaping into other conductors such as metal appliances or your body. This is also why electrical appliances have plastic cases and plastic handles. The handles of screwdrivers and pliers are often coated with plastic insulation, and electric plugs, sockets and switches are all made of plastic. The wires on power lines are made of aluminium or steel, but they have glass or porcelain insulators to stop any electric current from escaping down the pylons and into the ground.

Resistors and resistance

Electrical resistance is a measure of how difficult it is for electrons to move through an object. Resistance is measured in *ohms* (symbol Ω). Conductors have a low resistance and insulators have a high resistance. To help you understand this, think about moving along a crowded corridor. The more people there are in the way, the greater the resistance to your movement, and the longer it takes to get through.

As electrons move through a conductor they collide with atoms. This causes the atoms to vibrate more, raising the temperature of the conductor. Some substances—such as platinum, nichrome, tungsten, iron and carbon—offer a lot of resistance, even though they allow the current to pass. These substances can be used to make *resistors*. A resistor with a small resistance lets a large current flow through it, and one with a large resistance lets only a small current through it. This is why resistors are used in electric circuits to control the flow of electric current. In a circuit with a large resistance, only a small current will flow. In a circuit with a small resistance, a large current will flow.

Current flowing through resistors produces heat and this is why appliances such as TV sets become warm when they are operating. Electric stoves, toasters, bar heaters, hair dryers and irons all contain long coils of wire which resist the movement of electrons. They get hotter and hotter as more current flows through them, until they become red-hot. The coiled filament of a light bulb is made of tungsten. Because it has a high resistance it gets so hot it becomes white-hot and glows brightly.

INQUIRY

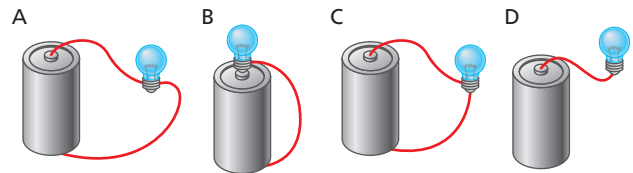
3 Resistance wires

You will need: 240V light bulb, hand lens, toaster

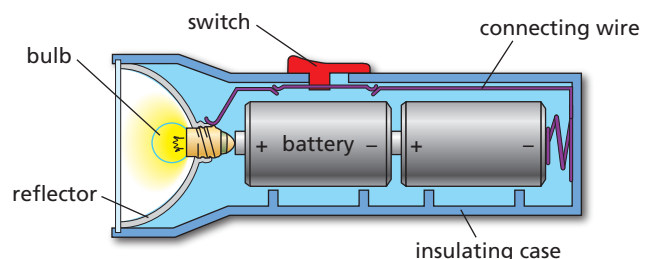
- Look carefully at the light bulb and draw an accurate diagram of it. Use the hand lens for a closer look at the filament—the resistance wire that glows when the bulb is plugged in.
 - Why do you think the filament is coiled?
 - Describe how the light bulb works.
- Examine an old toaster, bar heater or hair drier with its cord cut off. If possible, remove the casing so that you can see the resistance wires used for heating.
 - Draw a diagram of the appliance showing how it works.

Over to you

- What is an electric current?
- What is the difference between a conductor and an insulator?
 - Give two examples of each.
- Copy and complete these sentences.
 - A path for electricity is called a _____.
 - A _____ lets you open and close a circuit.
 - The movement of electrons in a wire is called an electric _____.
 - Substances which do not allow an electric current to flow through them are called _____.
 - Metals are _____ because they allow an electric current to flow through them.
 - The more current there is flowing around a circuit, the _____ a bulb glows.
 - If the resistance in a circuit increases, the current _____.
 - A conductor has _____ resistance, while an insulator has _____ resistance.
- In which of these circuits will the bulb glow? For the other set-ups, explain *why* the bulb won't glow.



- How do you measure electric current in a circuit? Name the unit used to measure current.
- The wires in an appliance are plastic coated, but this coating has to be removed from the wire at the point where it is connected to a part of the circuit. Why is this?
- Why does a wire become hot when an electric current flows through it?
- Use the diagram below to explain how a torch works. In your explanation make sure you use the terms *electric current* and *electric circuit*. You might want to make a model torch as your chapter problem.



SCIENTISTS AT WORK

Cathy Foley and superconductors

Cathy Foley became interested in science when she was in primary school and she entered several science

competitions. However, she thought she had to be as clever as Einstein to become a scientist. After doing her HSC she decided to become a science teacher, but at university she changed her mind and went on to study physics. Then in

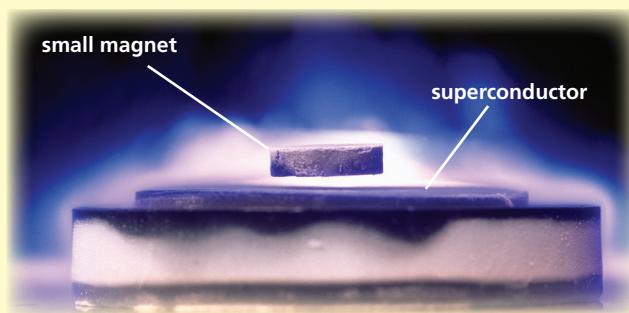


1987 she attended a conference in New York that started a revolution in *superconductors*.

If certain materials called superconductors are cooled to very low temperatures, they lose all resistance to the flow of electricity. In electric power lines there is always some loss of energy as heat, due to the resistance of the metal in the wires. If these wires could be made cheaply from superconductors, no energy would be lost and billions of dollars could be saved.

The problem was that to produce a superconductor, a temperature of -270°C was needed. This could only be obtained using liquid helium, which is very expensive and difficult to work with. The big breakthrough in superconductors came in 1986 when two scientists in Switzerland discovered a ceramic compound that became a superconductor at only -200°C . This meant that liquid nitrogen could be used for cooling. Liquid nitrogen is cheaper and easier to use than liquid helium.

As well as having zero resistance, superconductors have a remarkable magnetic property. When liquid nitrogen is poured over a piece of superconducting material and a small magnet held above it, the magnet magically floats in the air!



Because of their unique properties, it is predicted that superconductors could revolutionise our methods of transportation. Powerful electromagnets can be made by winding superconductors into coils and passing electricity through them. These could be used to propel trains which float on air. This technology is called maglev (*magnetic levitation*) and a test train in Japan has reached a speed of 581 km/h. It has even been suggested that maglev could be used to build a space elevator to carry people and materials into space.

It was in this exciting new area of superconductors that Dr Foley chose to work. Dr Foley is now head of a research team at CSIRO in Sydney. She is working with tiny superconductors called SQUIDs, which can detect extremely weak magnetic fields. Dr Foley's team has developed a SQUID system operating at -200°C to explore for minerals in the hot Australian desert. They are also researching other uses for their new superconductor technology. For example, they can use it to detect defects in the heartbeat of a foetus, something that cannot be done any other way. They can also monitor adult hearts without using electrodes, check for unwanted metal fragments in food, and detect nuclear submarines.

Dr Foley loves the challenge of working with materials about which little is known, and developing tests and techniques that have never been tried before. However, she feels that science must provide real world solutions which help people. Having studied nuclear physics, she is aware that scientific research can lead to such things as weapons of mass destruction. This is why she is a member of Scientists for Global Responsibility, a group which encourages discussion about the ethics of scientific research, not just the possible benefits.

★ Use the internet to find out more about superconductors.

7.2 Batteries and bulbs

INQUIRY

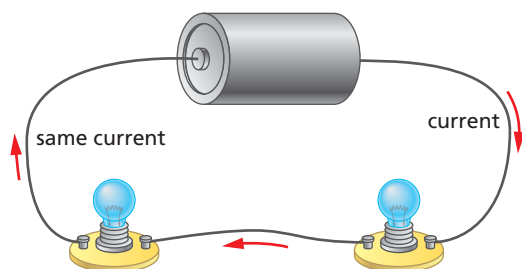
4 Connecting bulbs

You will need: 1.5V battery, three 2.5V bulbs, connecting wires

- 1 See if you can light two bulbs using one battery and as many wires as you like. This can be done in more than one way, and gives different results. Remember, don't leave the battery connected for any longer than necessary.
 - Draw a diagram of each way you find to connect the bulbs.
 - How many different ways did you find to connect two bulbs and one battery? Look at your drawings and check other people's results.
 - What is different about the way the bulbs are connected? Discuss this with other students.
- 2 For each way you connect the bulbs, note how brightly they glow. Do they glow as brightly as with one bulb only?
- 3 Also check what happens when you unscrew one of the bulbs in each set-up.
- 4 Can you light three bulbs using one battery? Are there different ways of doing this too? Does the brightness of the bulbs change? Explore this and report your findings to the class.

Series circuits

In Inquiry 4 you probably found that there are different ways to connect two bulbs in an electric circuit. One way in which they can be connected is one after the other in a line, without any branches, as shown. This is a **series circuit**, with the bulbs connected in series.



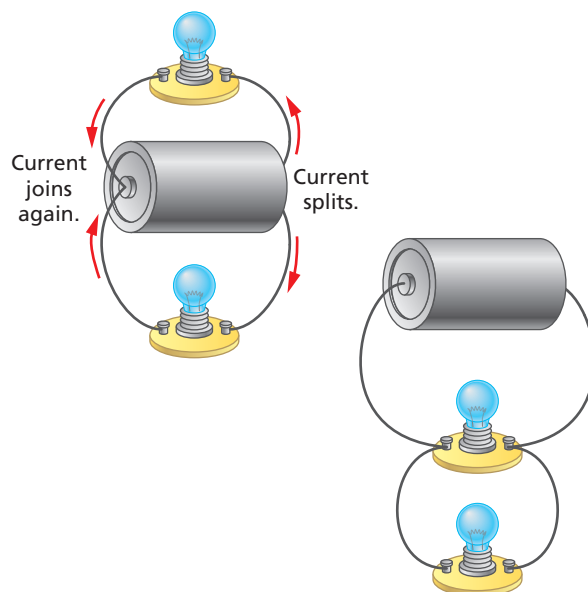
The two bulbs are connected in series.

In this type of circuit there is only one path for the current to flow: from the battery, through the first bulb, through the second bulb, and back to the battery. If you disconnect (unscrew) one of the bulbs the circuit is broken, no current flows and the other bulb goes out. Different parts of the circuit cannot be used separately because there is only one path for the current.

The battery has to push the current through two bulbs, so there is twice as much resistance in the circuit and only half the current. This is why each bulb is dimmer than it would be by itself. If you add a third bulb, each bulb is even dimmer.

Parallel circuits

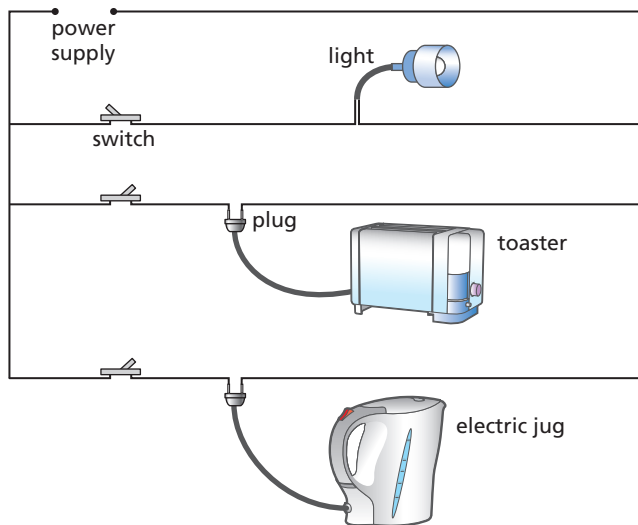
Two bulbs can also be connected in a circuit with branches, as shown. This is a **parallel circuit**. Notice that there are two different paths for the electric current. Somewhere in the circuit, the current splits. If the bulbs are the same, then half the electrons go into the top circuit and half into the bottom circuit. Each electron passes through only one bulb, so it meets less resistance than in the series circuit where it has to pass through two bulbs. Each bulb glows as brightly as if it was the only bulb in the circuit. If you disconnect one bulb the other still glows, because the current can still flow through the unbroken branch of the circuit. This is a much more useful type of circuit, because each branch can operate independently. Parallel circuits are used in the wiring of a house.



Two different ways of connecting two bulbs in parallel

House wiring

Look at the simplified diagram of house wiring. The toaster, the light and the electric jug are connected in three different parallel circuits. Each circuit has a switch so you can turn each appliance on and off without affecting the others. If they were connected in series they would have to be all on or all off.



INQUIRY

5 Connecting batteries

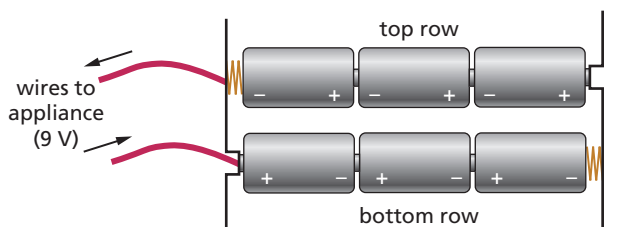
You will need: two 1.5V batteries, two 2.5V bulbs, connecting wires

- 1 Connect two batteries and a bulb in series. If the bulb doesn't glow, reverse the connections to the batteries. When the circuit is working, draw it, and mark the positive and negative terminals on the batteries.
 - Why do the batteries have to be connected in a particular way?
 - Does the bulb glow more brightly than with one battery only?
- 2 Now connect the batteries in parallel. Draw the circuit that works.
 - Check with other students. Did they connect up the circuit the same way as you?
 - Does the bulb glow more brightly than with one battery?
 - Which way would you connect the batteries in a torch—in series or in parallel? Explain your answer.
- 3 Construct a circuit containing two batteries and two bulbs so that the bulbs glow as brightly as possible. When you have solved this problem, draw the circuit and explain why you connected it the way you did.

Voltage

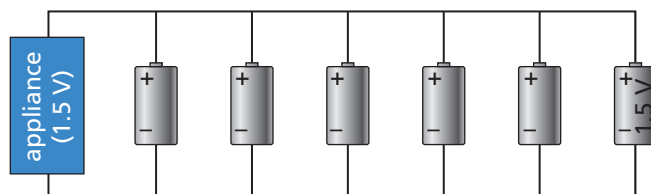
The **voltage** of a battery is a measure of how much 'push' the battery can give to the electrons in a circuit. It is measured in **volts (V)**, using a **voltmeter**. A torch battery has a voltage of 1.5 volts (1.5V). A 9V battery can push a larger current through a circuit than a 1.5V battery can.

Suppose you have bought a digital radio that needs six 1.5V batteries. The batteries have to be connected in series so that the top positive terminal of one touches the bottom negative terminal of the next. In this example there are two rows of three batteries, one row on top of the other as shown. The batteries are in series, so the electrons in the circuit receive a push from each battery. The total voltage is $1.5V \times 6 = 9V$.



When putting batteries into an appliance you must be careful to put them in the right way round.

If six batteries are connected in parallel, the electrons in the circuit receive a push from one battery only, so the total voltage is only 1.5 volts.



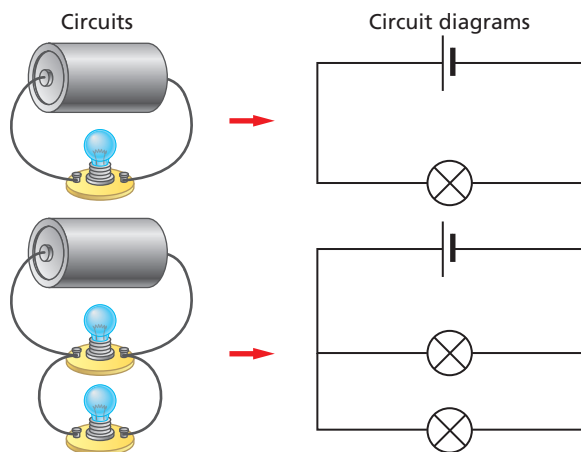
SKILL



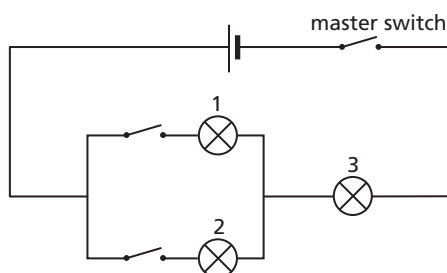
Using circuit diagrams

In the last few activities you probably found that drawing electric circuits with batteries, bulbs and switches takes time. Also, not all batteries, bulbs and switches are the same. For this reason, symbols have been developed for the parts of electric circuits. These symbols are shown below.

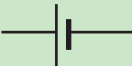
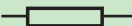
Using these symbols, you can draw plans of electric circuits called **circuit diagrams**. To keep the diagram neat and compact, circuit diagrams are usually drawn in a rectangular shape—with straight lines and right-angle bends. For example, two simple circuits can be drawn as shown. Note that it doesn't matter where the symbols go, so long as they are in the right pattern—series or parallel. For example, in the series circuit you could put the bulb on any side of the rectangle—it doesn't change how the circuit works.



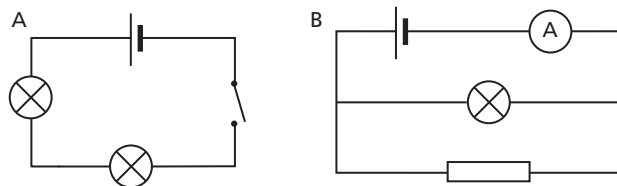
Quite complicated circuits can be drawn using circuit diagrams. For example, in the circuit below, bulbs 1 and 2 are connected in parallel, but they are in series with bulb 3, the battery and the master switch. Bulbs 1 and 2 can be switched on and off independently. And because the master switch is connected in series, it turns all three bulbs on and off.



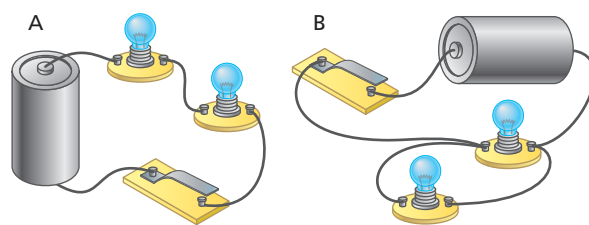
Electric symbols

	connecting wire	
	or 	light bulb
	battery (The long thin stroke is positive and the short fat stroke is negative.)	
	power pack (variable power supply)	
	or 	resistor
	variable resistor	
	switch	
	ammeter	
	voltmeter	

- 1 List the equipment needed to set up each of these circuits.



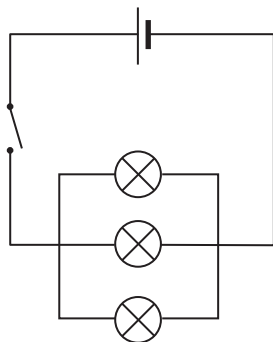
- 2 Draw a circuit diagram for each of the following circuits.



- 3 Draw a circuit containing a battery in which two bulbs in series are connected to a third bulb in parallel.

Over to you

- Use diagrams to explain the difference between a series circuit and a parallel circuit.
- A torch bulb is connected to a battery. Will the brightness of this bulb increase, decrease or remain the same when:
 - an identical bulb is connected in series with it?
 - an identical bulb is connected in parallel with it?
- Look at the parallel circuit below.



- Does the current flowing through the circuit pass through all three bulbs when the switch is closed?
- With three bulbs working, one is removed from its socket. Three students predict what will happen:

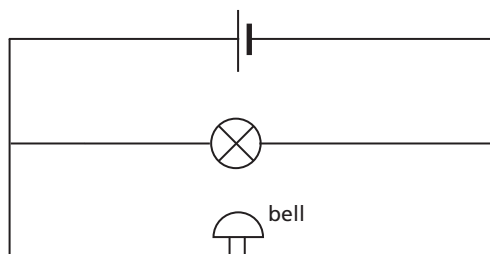
Coen: *The other bulbs will go out.*

Kalani: *The other bulbs will glow brighter than they did before.*

Monique: *The two remaining bulbs will glow just as brightly as they did before.*

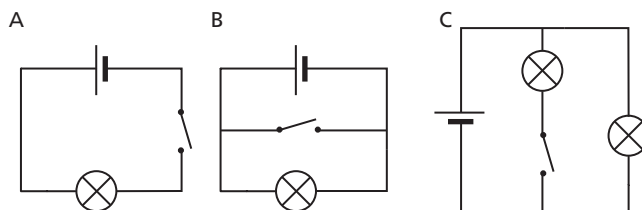
Who is correct? Why?

- Copy the circuit diagram below and add:
 - a switch that will turn the light on and off without affecting the bell
 - a second switch that will turn off the light and the bell.

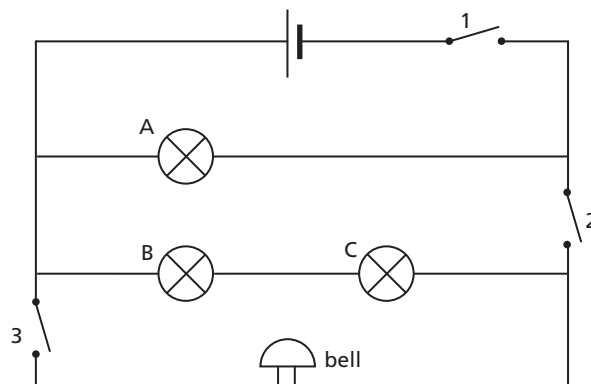


- In some types of Christmas tree lights, if one bulb blows then all the others go out. In other types, if one bulb blows the rest stay on. Explain this difference.

- What will happen in each of these circuits when the switch is closed?



- Consider the circuit shown below. What will happen when:
 - switch 3 is open, but switches 1 and 2 are closed?
 - switch 1 is open, but switches 2 and 3 are closed?
 - switch 2 is open, but switches 1 and 3 are closed?



- How would you connect two 1.5 V batteries to produce a total voltage of:
 - 3 V?
 - 1.5 V?

PROBLEM SOLVING

Have you started on your electrical gadget yet? If not, here are some ideas: model torch (Over to you, page 147), model electric kettle (Thinking skills, page 165),

lighthouse, model house, front door bell, burglar alarm, street lights, boom gates, buzzer for quiz show, alarm clock, mousetrap.

You now know how to connect electrical devices in series and in parallel. You also know how to use switches to control electric circuits. Checking through pages 144–151 may also give you some ideas for your gadget.

7.3 Current and voltage

INVESTIGATION

3 Current and voltage

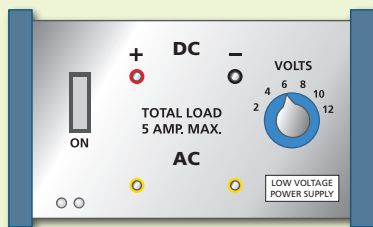
Aim

To use an ammeter and a voltmeter to measure the current and voltage in series and parallel circuits.

Risk assessment and planning

In this investigation you will be using a power pack instead of a battery. Follow these safety rules.

- High voltages will blow the light bulbs. So don't turn up the voltage higher than you are told to, or higher than the voltage marked on the bulbs provided.
- Don't touch the power pack with wet hands or use it on a wet surface. Why?
- Always use the DC (direct current) power outlet on the power pack.
- When you have connected the power pack into a circuit, get the teacher to check it before you start.
- Turn on the switch in the circuit only when you are taking a measurement.



A power pack

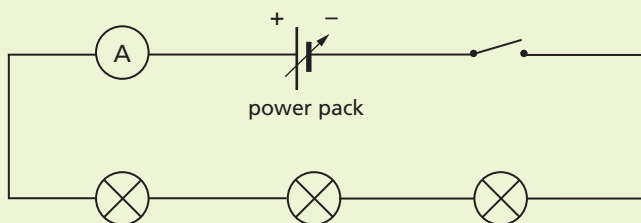
Apparatus

- 50 cm length of nichrome wire
- three 6 V bulbs in holders
- 7 connecting wires
- voltmeter
- power pack
- ammeter
- switch

Method

Part A: Measuring current and voltage

- 1 Connect the power pack, switch, ammeter and three bulbs in a series circuit, as shown. Set the power pack to 6 V DC.

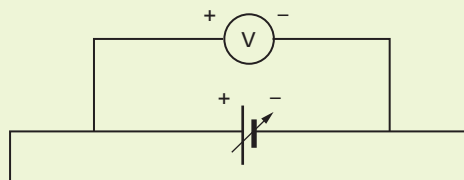


- 2 Close the switch and measure the current. Draw the circuit and record the current in amps on your diagram.

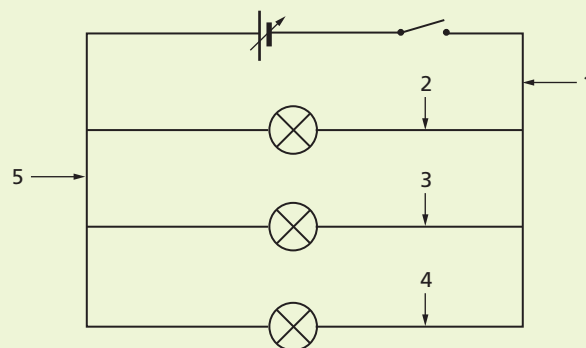
- 3 Connect the ammeter at different places in the circuit and record the results on your diagram.
- 4 Connect the voltmeter in parallel across the power pack terminals as shown. Its positive terminal must be connected to the positive side of the power pack and its negative terminal to the negative side.

If there is more than one positive terminal on the voltmeter, use the one with the highest value first. Use the scale on the voltmeter that matches the connected positive terminal.

- * Record the voltage on your diagram.



- 5 Connect the voltmeter across one of the bulbs and record the voltage. Do this for each bulb.
- * What pattern can you see in the voltages?
- 6 Rearrange the circuit so that the three bulbs are in parallel, as shown.



- 7 Use the ammeter to measure and record the current at points 1, 2, 3, 4 and 5 in the circuit.
- 8 Use the voltmeter to measure and record the voltage across the three bulbs.
- * What pattern can you see in the voltages?

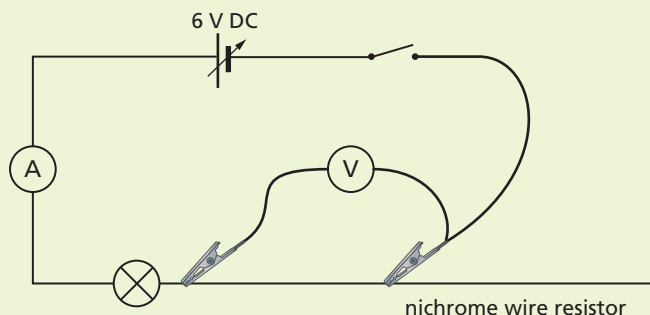
Conclusion

Write a short paragraph summarising what you found out about the current and voltage in a series circuit.

Do the same for a parallel circuit.

3 *continued***Part B: Nichrome wire resistor**

- 1 Connect up the circuit as shown, with the power pack on 6VDC. Fasten the alligator clips onto the 50 cm length of nichrome wire as close to each other as possible.
- 2 Turn on the switch. Observe the brightness of the bulb and the ammeter reading.
- 3 Investigate what happens as you move the alligator clips apart on the nichrome wire.
- 4 Write a paragraph summarising what you found out about the current in the circuit and explaining why this happened. In your explanation, the word *resistance* should be used.



- 5 Measure the voltage across the bulb and across the alligator clips as you move them apart. What happens? How can you explain this?

Current and voltage

A battery can be thought of as an electron pump. In the battery the electrons gain enough energy to move around a closed circuit. As they move through a resistor such as a light bulb, they collide with the atoms of the resistor, and the energy of the electrons is converted to light and heat. When the electrons return to the battery their energy is renewed for another trip around the circuit. The amount of energy carried around the circuit and converted to light and heat is the same as that given to the electrons by the battery.

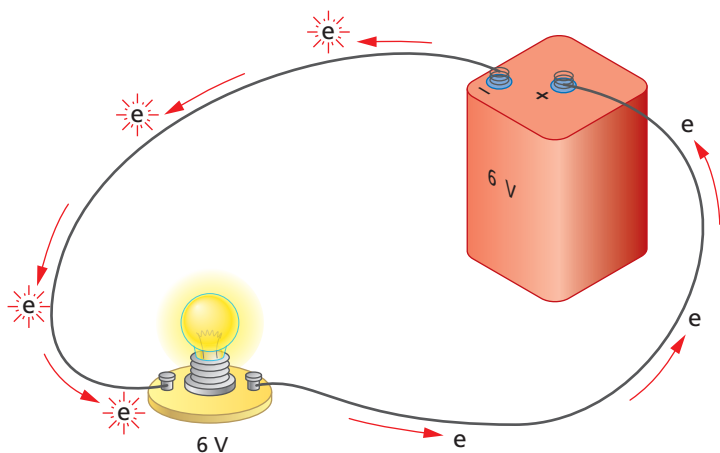
The electrons have much more electrical potential energy when they leave the battery than when they return to it. They have the 'potential' to cause

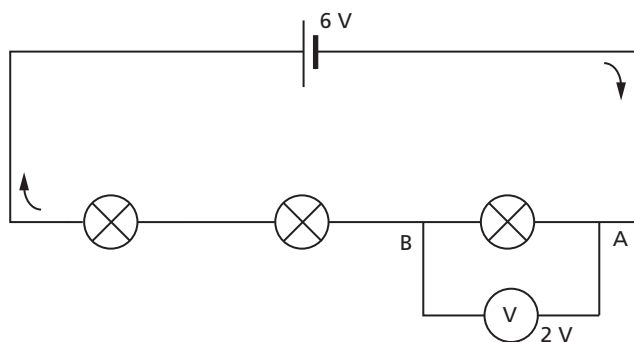
changes in the circuit. This difference in the energy of the electrons leaving and returning to the battery is called the *potential difference* or voltage of the battery. It is a measure of the push of the battery.

As the electrons move around an electric circuit containing a bulb, their potential energy is converted to light and heat energy. After the electrons have passed through the bulbs they have little energy until they return to the battery. If there is a break anywhere in an electric circuit, no current flows. The potential difference is the difference in energy between the two terminals of the battery, or the energy given to the electrons by the battery.

Series circuits

Consider a circuit with three identical bulbs in series (see next page). The current (moving electrons) has to pass through all three bulbs and is the same throughout the circuit. There is a voltage drop across each bulb, and the total voltage drop is the same as the voltage of the battery. For example, consider the circuit shown at the top of the next page, which contains a 6V battery and three identical bulbs. Each electron gains 6V of energy in the battery. This voltage is divided equally among the three bulbs and drops by 2V as it passes through each bulb. A voltmeter connected as shown would measure 2V. This is the potential difference between A and B.



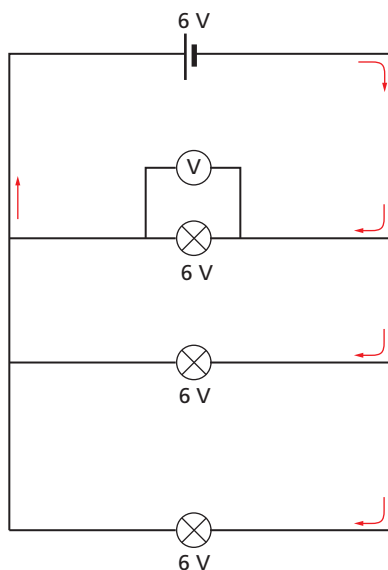


In a series circuit, current passes through each resistor in turn and the voltage is shared between them.

Parallel circuits

In the parallel circuit shown below, the current splits into three. The current that flows through each branch will depend on the resistance. The greater the resistance, the smaller the current that flows. On the other side of the circuit the currents join up again. The voltage drop across each bulb (resistor) is the same and is the same as the voltage of the battery.

For example, if it is a 6V battery, each electron leaves the battery with 6V of energy. As each electron passes through a bulb, it loses all of this 6V of energy. A voltmeter connected as shown would measure a potential difference of 6V.



In a parallel circuit the voltage is the same across each resistor and the current is shared between them.

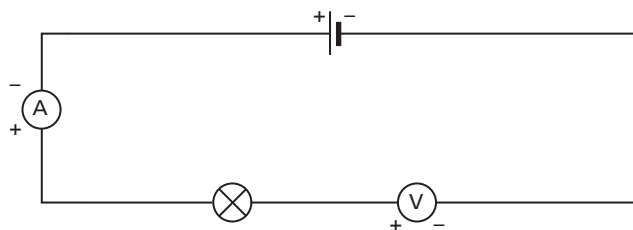
Variable resistors

In Part B of Investigation 3 you were able to alter the electric current in a circuit by moving the alligator clip along the nichrome wire. The greater the length of wire, the greater the resistance, and the smaller the current. This is an easy way to control the brightness of the bulb.

The piece of nichrome wire is a variable resistor called a *rheostat*. The brightness of a light in a house can be controlled using a rheostat, called a dimmer switch. There are also dimmer switches to control the brightness of the dashboard lights in cars. Model cars have a rheostat in their controllers. Push the control and more current flows to the motor, making it go faster.

Over to you

- Copy and complete the following sentences.
 - Voltage is measured in _____.
 - In a series circuit, the same _____ flows through all parts of the circuit.
 - If you increase the voltage in a circuit, the current _____.
 - If you increase the resistance in a circuit, the current _____.
 - A _____ is an electrical device whose resistance can be changed.
- What is the difference between electric current and voltage? In your explanation you should talk about electrons.
- After a battery has gone flat, where is all the energy that was once stored in it?
- A 6V battery is connected in series with two bulbs. Predict the voltage drop across each bulb.
- What happens to a light bulb when the resistance of a variable resistor in series with it is increased, as in Part B of Investigation 3 (page 154)? Why?
- There are two errors in the way this circuit has been connected to measure the current and voltage across the bulb. What are they? Redraw the circuit correctly.



7.4 Electromagnets

Hans Christian Oersted (ER-sted) was a professor of science at Copenhagen University in Denmark. In 1820 he arranged a science demonstration for friends and students in his home. He was showing them that a wire becomes hot when an electric current is passed through it. To his surprise, he noticed that every time he switched on the electric current, the needle of a magnetic compass on the table moved slightly. He didn't say anything about this at the time. Instead, he repeated the experiment many times until he was sure that he had discovered a link between electricity and magnetism.

A magnet has a magnetic field around it. You can see what this magnetic field looks like by putting a

plastic sheet on top of a magnet and sprinkling iron filings over it. You can also use iron filings to show that there is a circular magnetic field around a wire carrying an electric current.

With a single wire, the magnetic field is weak, but if you make a coil from the wire, the field is much stronger. Such a coil carrying an electric current is called a **solenoid**. It has a magnetic field like a bar magnet.

In 1825 a British inventor, William Sturgeon, discovered that he could make the magnetic field of a solenoid even stronger by putting a piece of iron (called a core) inside the solenoid. He wrapped a wire around a horseshoe-shaped piece of iron and connected it to a battery. He was then able to lift 4 kg of iron with his **electromagnet**.

4 Electromagnet

Aim

To demonstrate Oersted's discovery, and to make an electromagnet.

Risk assessment and planning

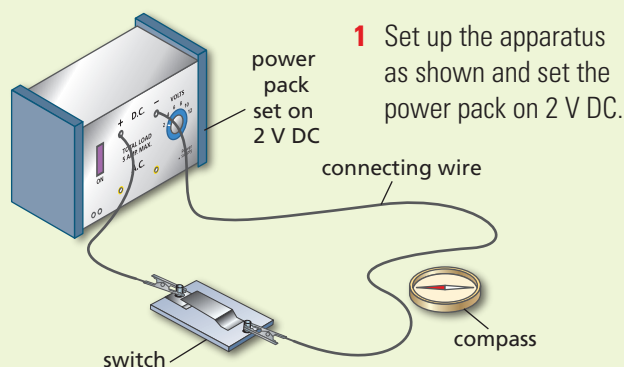
Review with your teacher the rules for using a power pack.

Apparatus

- staples, tacks or small nails
- power pack
- cardboard tube
- switch
- connecting wires
- large iron bolt
- adhesive tape
- small compass

Method

Part A



- 1 Set up the apparatus as shown and set the power pack on 2 V DC.

- 2 Turn the switch on briefly, then turn it off. Did the compass needle move?

- 3 What happens if you:

- reverse the connections to the power pack?
- move the compass further away from the wire?
- increase the voltage?

Part B

- 1 Wind the connecting wire around the cardboard tube to make a coil. Use tape to stick the wire to the tube.
- 2 Put the compass inside the tube and close the switch. Is the magnetic field inside the coil stronger or weaker than the field around the wire in Part A?

Part C

- 1 Make an electromagnet by winding a long piece of connecting wire around the iron bolt.
- 2 Test both ends of the electromagnet with the compass. **Your magnet may get warm, so don't leave it connected for long.**
- 3 Test the strength of the electromagnet by seeing how many staples, tacks or small nails you can pick up.
- 4 How could you make your electromagnet stronger? Make some predictions and test them.

Conclusion

- 1 What advantages does an electromagnet have over an ordinary magnet?
- 2 How did you make the electromagnet stronger?

Uses of electromagnets

Electromagnets have two advantages over ordinary magnets: they can be made much stronger, and they are easily turned on and off. Electromagnets have many uses. For example, they are often attached to cranes and used to lift scrap metal. They are also used to separate iron and steel from other rubbish. Some road-cleaning machines use electromagnets to pick up bits of metal that could puncture tyres.



Maglev train

The photo below shows a maglev train in China that can travel at speeds over 500 km/h, floating on a magnetic field. There are electromagnets containing superconductors on the track and underneath the train. Like poles repel each other, pushing the train up above its tracks. The high speeds are possible because of the train's streamlined shape and because there is almost no friction between the train and the track.



Metal detectors

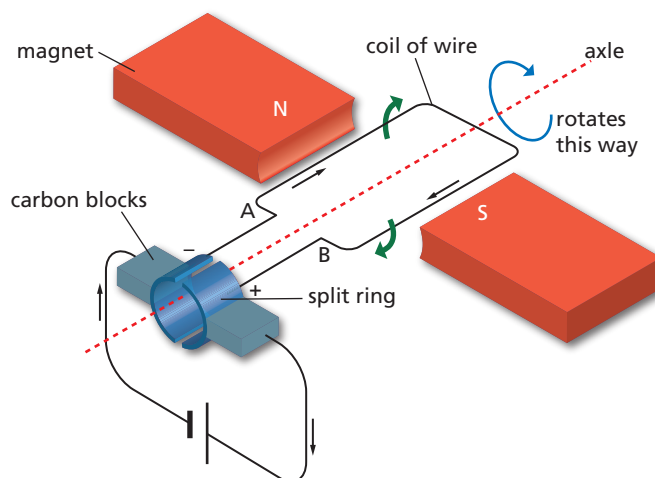
The metal detectors you have to walk through at airports contain a solenoid, which has a magnetic field. When you walk through, anything metallic you are carrying changes this field. This change can be detected by the officer monitoring the equipment.

Have you ever approached a red traffic light when there are no other cars about and the light changes to green? This is because there is a solenoid buried in the road. You may have noticed the cuts in the bitumen in the shape of a rectangle. When a metal car passes over the solenoid, the magnetic field changes. This produces an electric current that causes the traffic lights to change.

How an electric motor works

When an electric current flows in a wire in a magnetic field, a force is produced which can make the wire move. This is sometimes called the *motor effect*. Scientists and engineers have used this effect to build the electric motors that are so important in our lives. These range from the small motors which spin the CD in a CD player to the powerful motors that move electric trains.

The diagram below shows a simple motor. It consists of a pair of magnets and a coil of wire that rotates on an axle between the poles of these magnets. The ends of the coil are connected to a split ring that rubs against two carbon blocks. This allows an electric current from the battery to flow into the coil without tangling the wires.



A simple electric motor

In the position shown, an electric current flows into the coil through side A, which is pushed upwards. At the same time, side B is pushed downwards. This causes the coil to spin in a clockwise direction. The coil rotates to the vertical position and continues past this position. Because the coil has now turned over, the current flows into the coil through side B, which is pushed upwards. This keeps the coil moving clockwise. So the motor has converted electrical energy to kinetic energy.

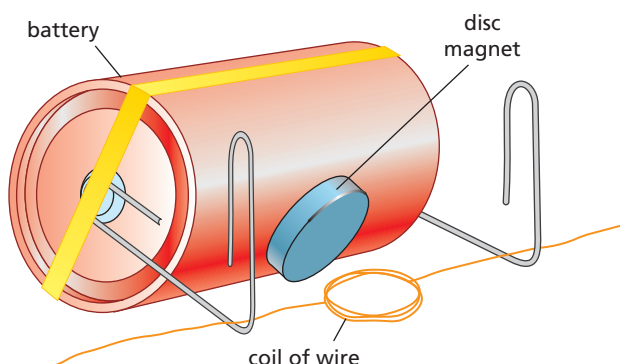
In a real motor there are many turns of wire in the coil. Also, the magnet may be an electromagnet.

INQUIRY

6 Electric motor

You will need: 1.5V battery, 2 paperclips, disc magnet, 60 cm enamelled copper wire, marking pen, sandpaper, rubber band

- 1 Make a coil from the copper wire by winding it around a marking pen. Tie the ends neatly as shown so that about 10 cm sticks out each end.
- 2 Use the sandpaper to remove the enamel from the same side of each end piece (*one side only*).
- 3 Bend the paperclips as shown and secure them to the battery using the rubber band.
- 4 Place the disc magnet on the side of the battery.
- 5 What happens when you place the coil between the paperclips as shown?

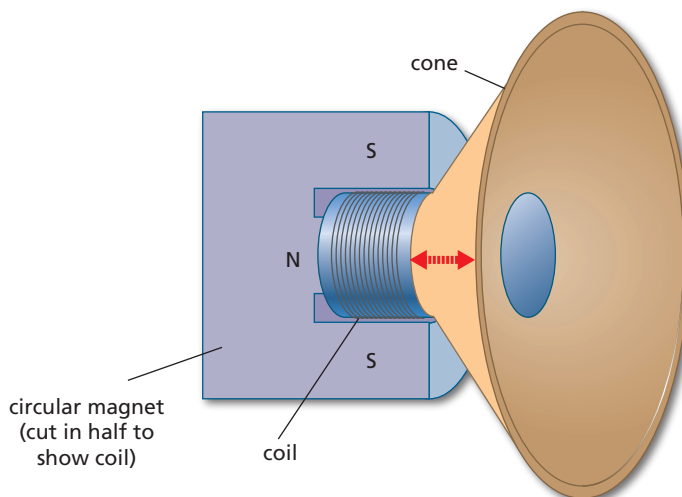


■ Try to explain how your motor works.

How a loudspeaker works

A loudspeaker also uses a magnetic field to produce movement. It consists of a cardboard cone, with a coil of wire wound around its base. The coil fits snugly between the poles of a cylindrical magnet. An

alternating current from a microphone is fed into the coil. A current in one direction makes the coil move outwards, and a current in the other direction makes it move inwards. As the current varies rapidly, the coil vibrates back and forth, moving the cone with it. The cone pushes the air around it, producing sound waves. So the loudspeaker has converted electrical energy to kinetic energy and then to sound energy.



INQUIRY

7 Loudspeaker

You will need: loudspeaker, signal generator (e.g. radio), styrofoam beads

- 1 Connect a signal generator to a loudspeaker.
- 2 Put a handful of styrofoam beads into the cone of the speaker, and switch on the signal generator. What happens?
- 3 What happens when you slowly increase the volume of the signal?

Over to you

- 1 Name the energy conversions that occur in:
 - a an electric motor
 - a loudspeaker
 - an electric guitar.
- 2 List at least three devices that have an electric motor in them.
- 3
 - a What are the main parts of an electric motor? What does each part do?
 - b Why does the coil of an electric motor have so many turns of copper wire?
- 4 Why must magnets be kept away from tapes and computer disks?

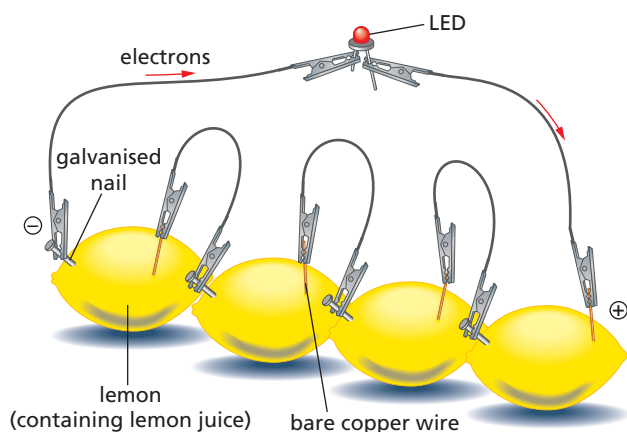
7.5 Generating electricity

INQUIRY

8 Lemon battery

You will need: 4 lemons, galvanised nails, bare copper wire, galvanometer or microammeter, light-emitting diode (LED), connecting wires (Both the galvanometer and the microammeter measure tiny electric currents. The LED is an electronic light bulb.)

- Put a galvanised nail and a piece of copper wire into a lemon.
- Use connecting wires to connect one terminal of the galvanometer (GAL-van-OM-it-er) to the nail and the other end to the copper wire. If you are using a microammeter the positive terminal must be connected to the copper wire.
 - Does the lemon produce an electric current?
- Disconnect the galvanometer and connect the 4 lemons in series as shown. Make sure the longer terminal of the LED is connected to the copper wire.
 - Does the LED glow?



- Investigate one or more of the following. What would happen if you:
 - increased the number of lemons?
 - squeezed the lemons by rolling them on the bench to start with?
 - changed the distance between the nail and the copper wire?
 - pushed the nail and the wire further into the lemon?
 - used different fruits or vegetables?
 - used different metals to stick into the lemon?

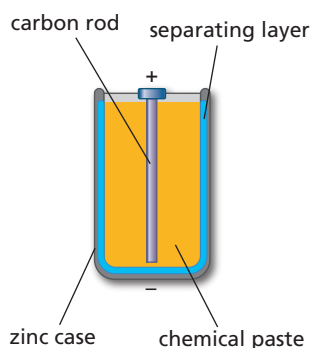
Write a brief report about what you discover.

Cells and batteries

When you put a galvanised nail and a piece of copper into a lemon, you made a simple **electric cell**. The zinc coating on the galvanised nail reacted with the acid in the lemon juice to produce electrons. These moved around the connecting wire to the copper wire. Here they took part in another chemical reaction. The copper wire is the positive *electrode* and the nail is the negative electrode.

A *battery* is made up of two or more cells connected in series. However, in everyday language the word battery is also used for a single cell.

The 1.5 V battery used in a torch is actually a single cell as shown below. It has a central rod made of carbon which forms the positive electrode, and a zinc case which forms the negative electrode. Between the two electrodes is a chemical paste. When you connect the battery in a circuit, a chemical reaction takes place between the paste and the zinc case, producing electrons. A separating layer stops the chemicals reacting when the cell is not being used. Such a cell produces a voltage of 1.5V.



A 1.5V torch cell is usually called a battery. The 9V battery on the right has been cut open to show the six individual 1.5 V cells.

Batteries are made by connecting several cells together. For example, a 9V battery consists of six 1.5 V cells connected in series as shown above. The tiny button cells used in watches and cameras are made in the same way as torch cells, but use different chemicals.

A cell or battery goes 'flat' and has to be thrown out once the chemicals in it are used up. However, with rechargeable cells it is possible to reverse these reactions by passing electricity through them in the opposite direction. Rechargeable cells are widely used in devices such as mobile phones, cordless drills and remote-controlled cars.

5 Which lasts longer?

Design a controlled experiment to test whether the claims made on TV advertisements for batteries are correct. Choose two different brands of batteries. Does brand A really last longer than brand B?

✱ Which variables will you need to control?

Write a report of your experiment using the usual headings. Other questions that you could investigate are:

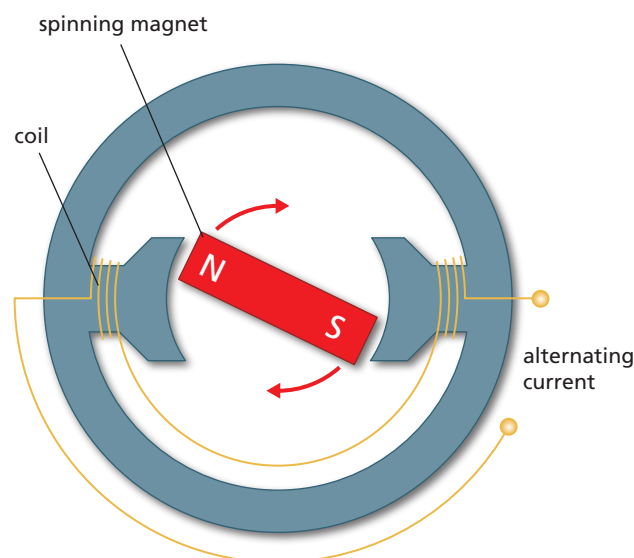
- What effect does the size of the cell have on how long it lasts?
- Alkaline cells last longer than normal cells, but are they better value for money? To compare cells you could divide their cost by the number of hours they last.
- Do two cells connected together last twice as long as one? Does it matter whether they are connected in series or in parallel?

How an electric generator works

An electromagnet uses electricity to produce magnetism. However, in 1831 Michael Faraday discovered that he could produce electricity by using a magnet. Moving a magnet through a coil produces an electric current in the coil. Moving the magnet in the opposite direction reverses the direction of the current that is generated. It doesn't matter whether you move the magnet or the coil, so long as one moves with respect to the other. You can produce a larger current if you increase:

- the strength of the magnet,
- the number of turns of wire in the coil, or
- the speed of relative movement between the coil and the magnet.

A device that converts kinetic energy into electrical energy is called an **electric generator**. It is the opposite of an electric motor. (See the diagram bottom right on page 157.) In a motor, you pass electricity into the coil to make it spin. In a generator, you spin the coil to produce an electric current. The generators in power stations produce electricity by spinning a magnet inside a huge coil, as shown. Because the magnetic field reverses with every half turn of the magnet, an alternating current (AC) is produced in the coil.



How a generator in a power station works

DC and AC

The current produced by a battery is called **direct current** or **DC**. The electrons move in one direction only—from negative to positive. However, the electricity we use in our homes is generated in power stations by spinning magnets inside huge coils of wire. This produces **alternating current** or **AC**, and the electrons move first in one direction and then in the opposite direction. The electrons change direction 50 times a second.

Both DC and AC can be used to run electrical appliances. When electricity first became available for use in homes in New York, there was much argument about which system was the best. Thomas Edison, the inventor of the light bulb, was promoting the use of DC. His business rival, George Westinghouse, claimed that the AC system was better.

At about this time the electric chair was invented by Harold Brown and it worked on AC. Both rival electricity companies opposed the electric chair because it showed that electricity can kill, and they were afraid that people would not use it. Edison thought that if he showed how dangerous AC was, people would use his DC system. So he allowed Brown to use his laboratories for public demonstrations using AC to electrocute cats. Thousands of people watched these demonstrations but it didn't stop them using AC in their homes. In the end, AC was found to be easier to transmit over large distances.

INQUIRY

9 Generating electricity

Part A

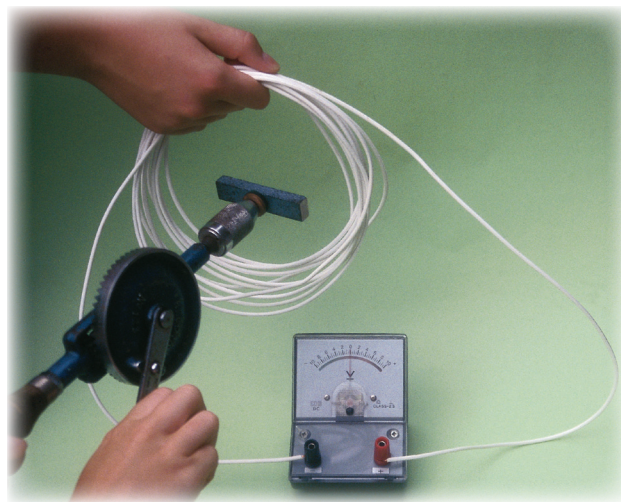
You will need: solenoid, bar magnet, connecting wires, galvanometer (measures tiny electric currents)

- 1 Connect the solenoid to the galvanometer.
- 2 Push the magnet into the coil quickly. What happens?
- 3 What happens when you:
 - a leave the magnet inside the solenoid?
 - b pull the magnet out of the solenoid quickly?
 - c push the south pole into the solenoid instead of the north pole?
 - d use two magnets instead of one?
 - e keep the magnet still and move the coil?
- 4 Write a generalisation to explain all your observations.

Part B

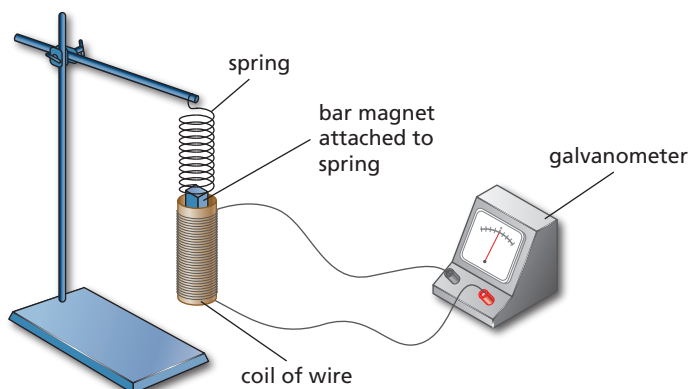
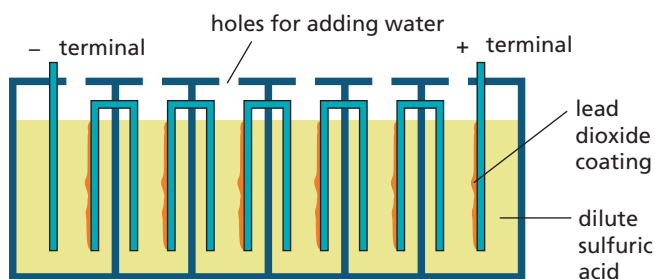
You will need: hand drill with a bar magnet glued to it
Set up the apparatus as shown on the right.

- Why does the needle of the galvanometer swing backwards and forwards as you use the drill to rotate the magnet?
- What do you call this type of electric current?



Over to you

- 1 What takes place inside an electric cell to cause a current to flow?
- 2 What happens to a cell when it goes 'flat'?
- 3 What is the difference between a cell and a battery?
- 4 How could you make a 6V battery from 1.5V cells?
- 5
 - a What is the difference between DC and AC?
 - b Where is DC used? Where is AC used?
- 6 Below is a cross-section of a car battery.
 - a How many cells are there in this battery?
 - b Are the cells connected in series or in parallel?
 - c If each cell can generate 2 V of electricity, what is the total voltage of the battery?
 - d What is the electrolyte in this battery?
- 7 What energy conversion occurs in an electric generator?
- 8 Explain the difference between an electric motor and an electric generator.
- 9 How could you convert the electric motor on page 157 into an electric generator?
- 10 Look at the set-up shown below.
 - a Predict what will happen when the magnet bounces up and down inside the coil of wire. Explain your prediction.
 - b Suggest ways of making the electric current larger.



7.6 Safety with electricity

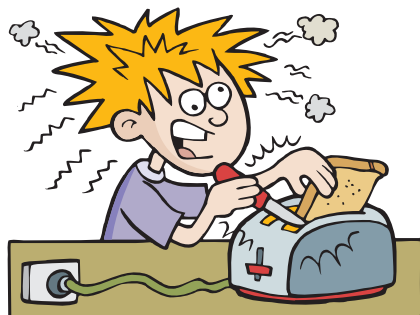
Short-circuits

The electricity we use in our homes is 240VAC. An electric current as small as 0.05 A passing through your body can cause electrocution.

An electric current always takes the path of least resistance. The heating element in a toaster has a high resistance. This is why it produces so much heat—to cook your toast. If you are foolish enough to stick a knife in a toaster while it is switched on, the electricity will find a pathway of less resistance through the knife then your body to the floor and the ground, where it leaks away. This electric current will burn a path through your body and may cause your heart to stop beating! The size of the current depends on the resistance of your body. If your hands or feet are wet, the resistance is less and the current will be greater. If your hands are dry and you have rubber-soled shoes on, your resistance will be greater and the current will be smaller.

Always stay clear of overhead power lines, especially if they have fallen. You could be electrocuted if you go near them.

An electric current that takes an easier but unintended path is called a **short-circuit**. Short-circuits can occur when the insulation on the cord of an appliance becomes frayed or brittle and bare wires come into contact with each other. This can cause sparking, which can cause a fire (see Inquiry 10).



15A. Doing this can allow too much current in the circuit, causing the wires to overheat and perhaps cause a fire.

Fuses are used in homes, in cars and in electronic appliances such as computers. There are many different types. Ask an adult to show you the fuse box in a car. Note how the fuses clip into place and how there are different fuses for different circuits.

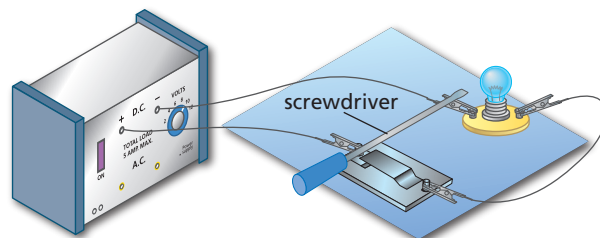
INQUIRY

10 Short-circuits and fuses

You will need: power pack, 3 connecting wires, 2.5 V bulb, switch, large screwdriver, piece of 8 A fuse wire, rubber stopper, 2 large pins, heatproof mat

Part A: Short-circuit

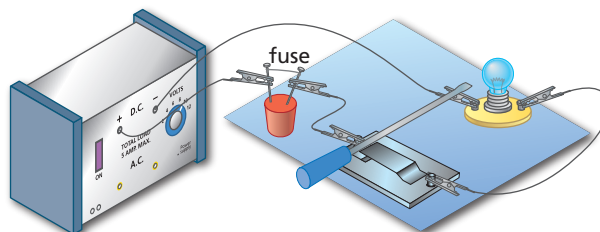
- 1 Set the power pack on 2 V DC and connect up the circuit shown.
- 2 Turn on the power and close the switch.
- 3 Touch a screwdriver across the alligator clips connected to the switch and bulb, as shown. Then *immediately take the screwdriver away*.



- What happened? How can you explain this?

Part B: Fuse

- 1 Make a fuse from a rubber stopper, two pins and a piece of 8 A fuse wire, as shown.

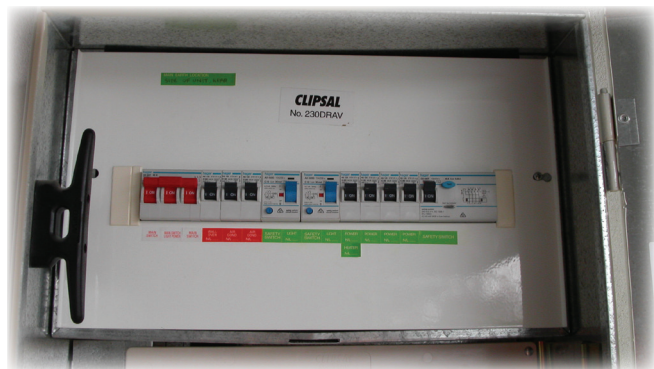


- 2 Connect your fuse into the circuit.
- 3 Touch the screwdriver across the circuit as before.
 - What happens to the fuse? (If nothing happens you may need to increase the voltage of the power pack.)
 - Explain how the fuse works as a safety switch.
- 4 What difference does it make if you use 15 A fuse wire instead of 8 A wire? Explain what happens.

Fuses

A **fuse** is a thin piece of metal that melts rapidly if the current passing through it reaches a certain limit. The melting of the metal breaks the circuit and thus acts like a switch and stops the current from flowing. If the wiring in a circuit can safely handle a current of up to 8 A, then an 8 A fuse is used. Fuses of 15 A and 30 A are used in circuits able to handle higher currents. Once a fuse has melted or 'blown' it must be replaced with a new one. Never put a 20 A or 30 A fuse in a circuit designed for a current limit of 8 A or

Most homes now have *circuit-breakers* instead of fuses. These are automatic switches that turn off when there is too much current in a circuit. They do the same job as a fuse, but are easier to reset once the fault has been fixed.



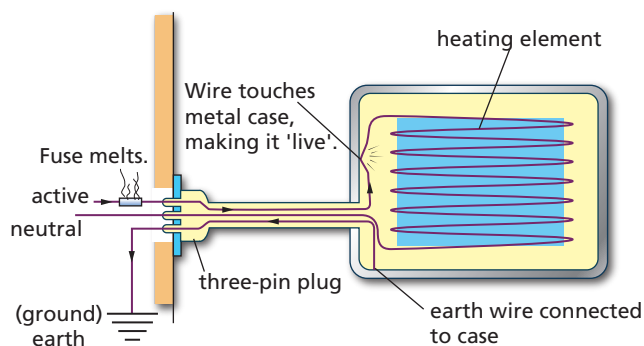
Circuit-breakers in a house meter box

Earthing

Electricity is supplied to your home at 240 V AC via two wires. The *live wire* carries electricity from the power station to your home. It is colour-coded brown for easy recognition. The blue neutral wire returns current to the electricity substation. However, when you plug in an appliance you will notice that there are usually three pins in the plug. The top two are connected to the live and neutral wires, and the longer bottom one is connected to the **earth** wire. This is another safety device. Here's how it works.

One end of the green and yellow earth wire is connected to the metal case of an appliance. The other end is connected to the earth pin of a three-pin plug. This contacts an earth wire in the socket, which is connected to a metal pipe or stake outside or under the house. (See if you can find it.)

Normally no current flows in the earth wire. This changes if the appliance develops a fault in which the active wire comes in contact with the case of the appliance (see diagram below). Without an earth



wire, the case becomes live and could electrocute you if you touched it. With the earth wire in place, current flows through it to the ground. As there is only a small resistance along the earth wire, the current is usually large enough to blow the fuse in the power circuit. This switches off the current and the appliance is no longer live.

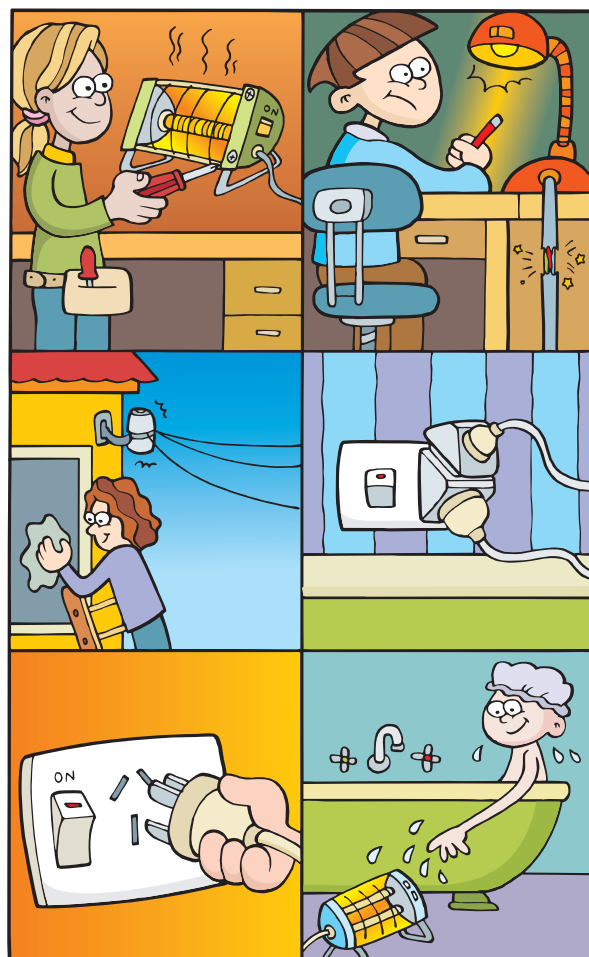
Many appliances such as portable radios and hair driers are made with no external metal parts. They are totally surrounded by two layers of plastic. This plastic insulation will protect you if a fault occurs. Such appliances are said to be double-insulated, and have the double insulation symbol  marked on them. They do not need an earth wire, and have a two-pin plug instead of the normal three-pin plug.

INQUIRY

11

What's unsafe?

Write a sentence about each situation, explaining why it is dangerous.



Paying for electricity

Different electrical appliances use different amounts of electrical energy. The *rate* at which an appliance uses energy is called its **power**, and this is measured in *watts* (W) or joules per second (J/s). For example, a 40W light bulb uses electricity at the rate of 40J/s, whereas a 100W bulb uses it at a much higher rate—100J/s. The higher the power rating or wattage of an appliance, the more electricity it uses and the more it adds to your electricity bill. The table below shows the power ratings of some common household appliances.

Appliance (using 240 V)	Power rating (W)
calculator	0.0003
clock	5
portable radio	10
light bulb	60
computer	100
television set	200
refrigerator	400–500
toaster	800
microwave oven	1300
air conditioner (medium size)	2000
hotplate (on stove)	2000
dishwasher	2500

Electrical energy is sold in *kilowatt-hours* (kWh). One kilowatt (kW) is 1000W, so 1 kWh is 1000W used for one hour. The price for electricity varies, depending on how it is used. To calculate the energy in kilowatt-hours used by an appliance, follow the steps below.

Example

How much does it cost to run a 2500W dishwasher for 45 minutes at 15 cents per kilowatt-hour?

- Change watts to kilowatts.
Power = $2500\text{W}/1000 = 2.5\text{ kW}$
- Change minutes to hours.
Time = $45\text{ minutes}/60 = 0.75\text{ hours}$
- Multiply kilowatts $\times$ hours $\times$ cost.
Cost = $2.5 \times 0.75 \times 15\text{ cents}$
= 22.5 cents

Over to you

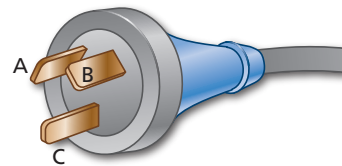
- What is the safest way to remove a piece of toast that has jammed in a toaster?
- What is a short-circuit? Why is it dangerous?

- How do fuses and circuit-breakers help protect you against short-circuits?

- Which is the earth pin on this three-pin plug?

- What is the purpose of the earth pin?

- Suggest why the earth pin is longer than the other pins.



- Which of the following two electrical appliances would use the most energy: a 2kW heater turned on for 15 minutes or a 10W clock radio left on for 24 hours? Show your calculations.

- A 100 W light bulb was left on for 5 hours.

- How much electricity did it use?
- If electricity costs 12 cents per kWh, what was the cost of running the bulb?

- Draw a diagram to show how a person touching a live wire can be electrocuted.

- What difference does it make if the person has wet hands or wet feet?

- What is the difference between a 10A fuse and a 20A fuse?

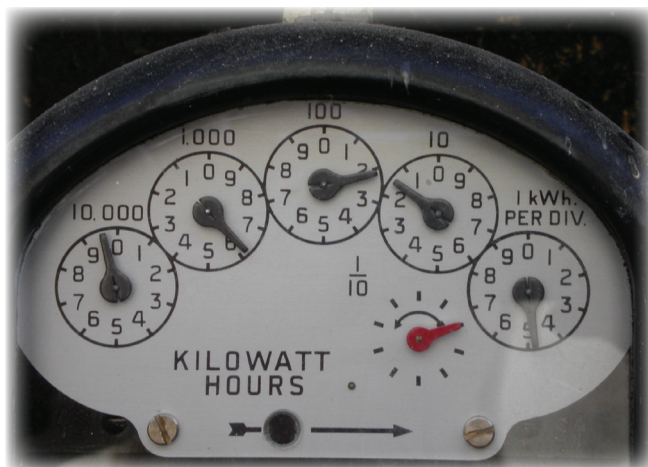
- If a 10A fuse has blown, it should be replaced by another 10A fuse. What problems could occur if it was replaced by:

- a 5A fuse?
- a 15A fuse?

- The power packs used in the laboratory have their own fuse. Why is this?

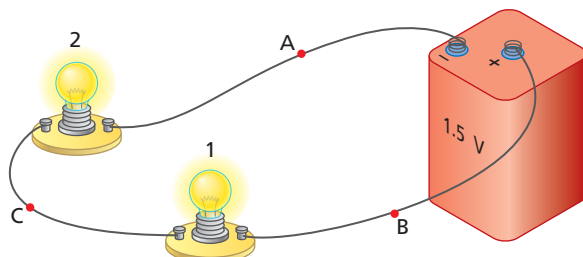
- Why can a bird perch safely on a power line and not be electrocuted? Why are bats electrocuted when they hang from two wires?

- What is the reading on this electricity meter? Start reading from the left dial and move across to the right, writing down the numbers. If the pointer lies between two numbers, write down the smaller one.



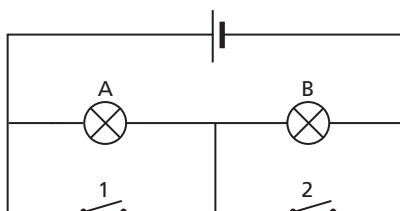
THINKING SKILLS ?

- 1 Look at the electrical circuit below. Between which two points could you connect a wire so that bulb 1 stays on but bulb 2 goes off?

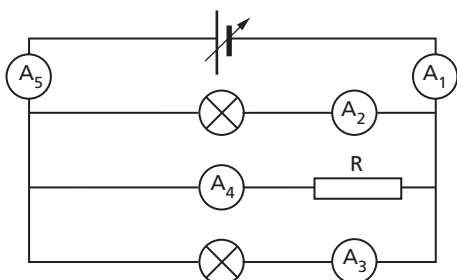


- 2 The two bulbs in this circuit glow dimly when both switches are open. Predict what will happen if:

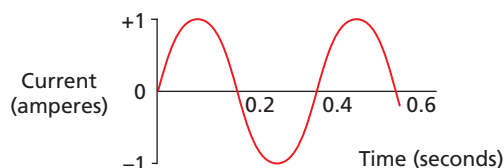
- a switch 1 is closed (two things)
b switch 2 is also closed.



- 3 The same current flows in an electric bar heater and in the cord connecting it to the power supply. Why don't the wires in the cord become red-hot like those in the heating element?
- 4 You have a battery, connecting wires and three bulbs, one of which is faulty. Draw a diagram of a circuit you could use to find out which bulb is faulty. It should include all three bulbs at the same time.
- 5 The two bulbs in the circuit below are identical, and R is a resistor. If the current reading on ammeter A_2 is 0.3A and that on A_4 is 0.2A, what current would you expect on ammeters A_1 , A_3 and A_5 ?



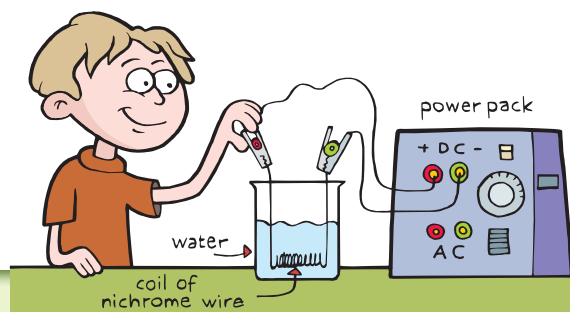
- 6 The graph below shows how the current produced in an electric generator varies with time.



- a Is this AC or DC?
b What is the maximum current generated?
c How long does it take for the coil of the generator to rotate once?
d A bulb is connected to the generator. Will the brightness of the bulb vary as the generator is turned? Explain.
- 7 Suggest three ways of making an electric generator produce a larger current.
- 8 Draw a circuit diagram for a parallel circuit that has two bulbs and a bell. There should be switches to turn each device on and off, and a switch that turns both bulbs off but doesn't affect the bell.
- 9 Design and sketch a circuit that uses an electromagnet to release a trapdoor when a person steps on a certain section of floor.
- 10 Make a model electric kettle as shown by coiling a piece of nichrome wire around a pencil. Investigate what would happen if you:
- changed the voltage used
 - changed the length of the coil
 - changed the diameter of the coil
 - used thicker or thinner wire or a different type of wire
 - changed the volume of water
 - measured the temperature above and below the coil.

This could be your chapter problem.

Remember to change only one variable at a time and to keep all the others the same.



Knowing and Understanding

Copy and complete these statements using the words on the right to make a summary of this chapter.

- 1 Electric current is a flow of _____. It is measured in amperes. It flows only if it has a continuous path or _____.
- 2 Materials with little resistance to the flow of electric current are called _____. Most _____ are good conductors of electricity. Materials with a lot of resistance to the flow of electric current are called _____.
- 3 In a _____ circuit, the same current flows through all parts of the circuit. In a _____ circuit, the current divides and passes through different branches of the circuit.
- 4 The electrical push in a circuit is called its _____. It is measured in _____.
- 5 If you increase the voltage in a circuit, the current _____. If you increase the resistance, the current _____.
- 6 In an electric cell, chemicals _____ to produce a flow of electrons. Two or more cells joined together make up a _____.
- 7 _____ current (DC) is a flow of electrons in one direction only. _____ current (AC) is a flow of electrons that continuously reverses direction.
- 8 An _____ uses electricity to produce magnetism, and an electric generator produces _____ by using a magnet.
- 9 A 1 kilowatt electrical appliance operating for one hour uses one _____ of electrical energy.

alternating
battery
circuit
conductors
decreases
direct
electricity
electromagnet
electrons
increases
insulators
kilowatt-hour
metals
parallel
react
series
voltage
volts

Self-management

What am I?

In groups, select a device from this chapter and write five clues describing it. An example is given below.

Write clues for five different devices, one device from each section of the chapter.

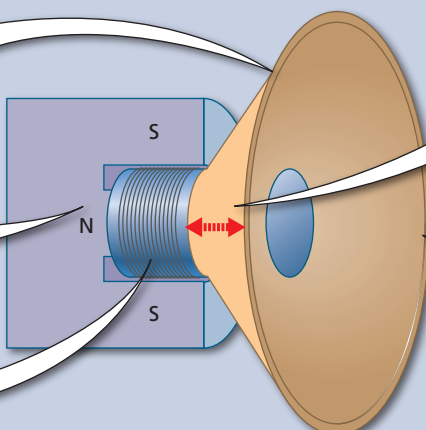
You can now have a competition between groups. Read out your first clue. If the other group correctly identifies the device they get 5 points. If they need two clues before they identify it, they get 4 points, and so on. The group with the most points wins.

What am I?

1 I am made up of a cardboard cone with a coil of wire around its base.

2 There's a cylindrical magnet inside my coil.

3 An electric current flows from a microphone into my coil.



4 As the current varies the magnet moves and vibrates my cone.

5 These vibrations produce sound waves.

I am a loudspeaker.

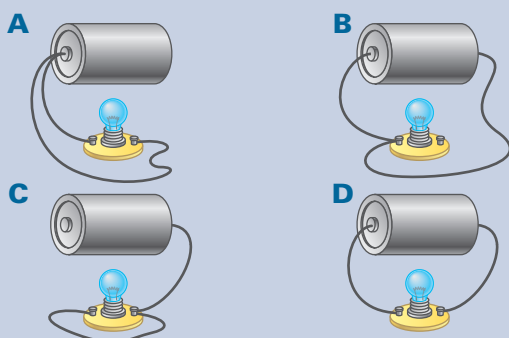
Checkpoint

Remember to look at
www.OneStopScience.com.au
 for extra resources

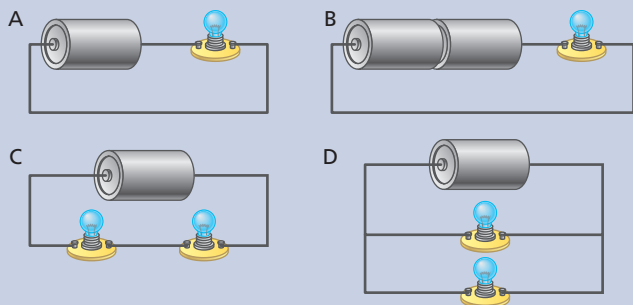
OneStopScience

- 1 A loudspeaker changes:
 - A electromagnetic waves into sound waves
 - B sound waves into electric current
 - C electric current into sound waves
 - D electric current into electromagnetic waves
- 2 In which three of the following situations would an electric current be generated?
 - A A magnet is pushed into a coil of wire.
 - B A magnet is left inside a coil.
 - C A magnet is taken out of a coil.
 - D A coil is moved towards a magnet.
 - E A coil sits beside a magnet.

- 3 Which one of these set-ups will make the bulb glow? For each one that doesn't glow, give a reason.

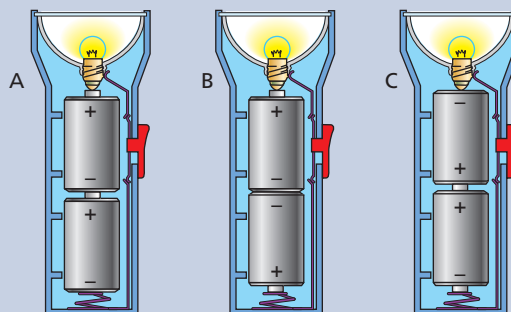


- 4 Look at the four circuits below.
 - a Which will have the brightest bulb(s)? Why?
 - b Which will have the dimmest bulb(s)? Why?
 - c In which circuit are the bulbs connected in parallel?

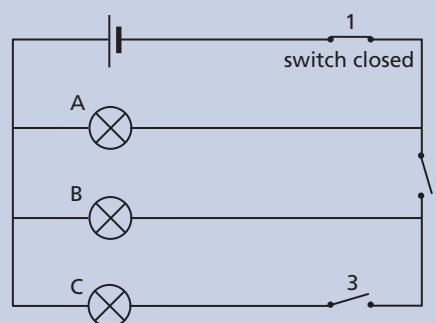


- 5 A circuit contains a 12 V battery and two light bulbs. The voltage drop across one of the bulbs is 8 V. Predict the voltage across the second bulb. Explain your answer.

- 6 Why are most electrical wires made of copper coated with plastic?
- 7 Ryan is trying to work out how to put two 1.5V batteries into his torch.



- a Which of these arrangements should work?
 - b Are the batteries connected in series or in parallel?
 - c What is the total voltage used by the torch?
- 8 In the circuit below, predict what will happen to each of the bulbs A, B and C when you do these three things one after the other:
 - a close switch 2
 - b then close switch 3
 - c then open switch 1.



- 9 An electric radiator has a small plate on the back that reads: 240V 1500W
 - a If W is the symbol for watts, what is the power rating in kilowatts?
 - b If the cost of electrical energy is 15 cents per kilowatt-hour, how much would it cost to run this radiator for 3 hours?
- 10 Explain why each of the following is unsafe:
 - a using a knife to clean out the dirt in a power point
 - b using an electric drill in a room with a wet floor
 - c putting a 20A fuse in a fuse box socket designed for a 15A fuse.