TOPIC 3 Electricity at work

3.1 Overview

Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you to learn the content and concepts covered in this topic.

3.1.1 Why learn this?

Imagine what life would be like without mobile phones, television, DVDs, CDs, video cameras, computers, video games or calculators. You do not have to understand how all of these technologies work to use and enjoy them, but it is important to understand some of the basic principles behind electrical devices.

LEARNING SEQUENCE

Electrical devices are in huge demand and commonplace in homes today.

Electricity — it's everywhere!

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Think

Work in a small group to compile answers to each of the following questions.

1. Make a list of all of the electrical devices used in and around the home.
2. Which devices are designed:
   (a) to reduce the amount of effort needed to perform tasks done at home?
   (b) for heating or cooling?
   (c) for lighting?
   (d) for entertainment?
3. Which devices contain motors?
4. What is the purpose of fuses and circuit breakers?
5. Why should electrical appliances be used with caution in bathrooms?
6. In terms of electricity, what is the difference between an 18 W and a 14 W light globe?

At home

7. Which electrical appliances have plugs with three pins while others have two?
8. Find an appliance with an energy rating sticker. What information is contained on the sticker?
9. Compact fluorescent and LED globes have replaced traditional incandescent lights. Explain why.
10. If one of the light globes in your home breaks, the others continue to work when switched on. What does that tell you about the way that your home lighting circuits are designed?

Our energy future

Electricity is provided to the home and school via transmission lines.

11. (a) How is most of the electricity generated in New South Wales? Does this use a renewable or non-renewable energy source?
    (b) Brainstorm some other ways that electricity can be generated.

3.2 Electric circuits

3.2.1 Simple circuits

When you switch on a light, a television, a computer or a CD player, you are completing a pathway along which electrical energy flows. The pathway is called an **electric circuit**. All electric circuits consist of three essential items:

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

3.2.2 What is electricity?

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

Most household appliances do not rely on batteries but rather receive electrical energy from a power station via a power outlet.

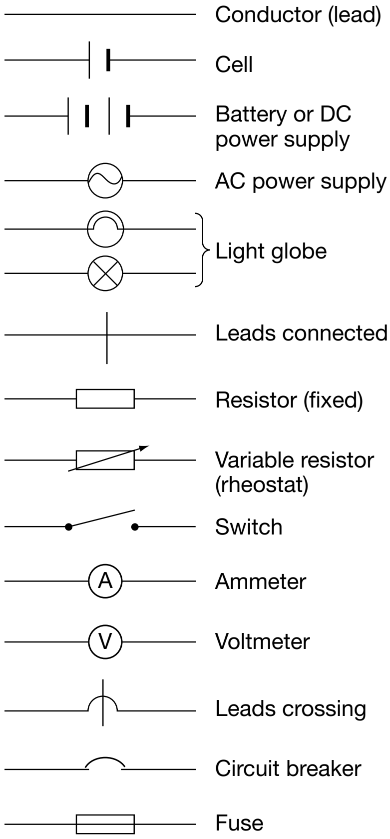
In electric circuits, electric charges travel around the circuit, gaining electrical energy from a power source and converting it to other useful forms in a load. To better understand the nature of the electricity in circuits it is important to grasp the concepts of electric current, voltage and resistance.

3.2.3 Current

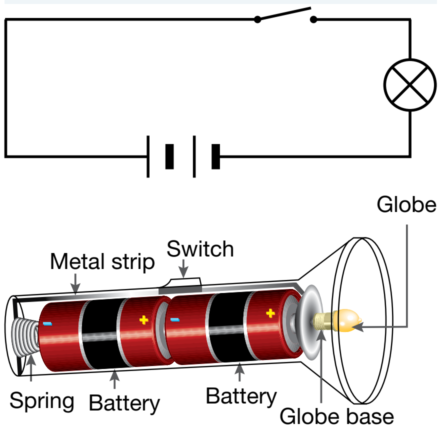
When a torch switch is clicked *on*, the light comes to life — what's happening? Pushing the button closes the switch in the torch circuit. This provides a complete (or closed) circuit through which electric charges, called electrons, can flow. This flow of charge is called an **electric current** (symbol, *I*). Electric current is measured in amperes (A) or amps for short, named after André Ampère (1775–1836), a French physicist and mathematician who is generally credited as one of the main discoverers of electromagnetism.

There are billions of electrons travelling around a circuit, each carrying an extremely small charge. If we were to quantify electric current in terms of individual electrons we would need to quote very large numbers indeed. Instead, scientists refer to the number of **coulombs** of charge flowing through a circuit. It's a little like referring to eggs in dozens rather than individually. A coulomb is equivalent to the charge of 6.2×10^{18} electrons. Consequently, the electric charge of a current of 1 ampere is equivalent to one coulomb of charge (or 6.2×10^{18} electrons) travelling around the circuit per second, so 2 amperes = 2 coulombs per second etc.

Symbols for common circuit components



Circuit diagram for a torch



3.2.4 Voltage

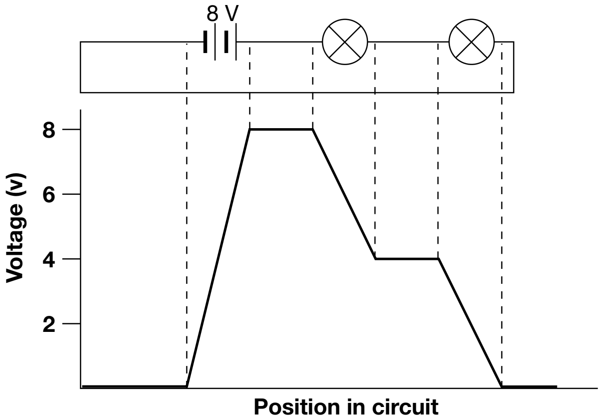
Voltage is a measure of the electrical energy carried by the charges in a circuit. Voltage (*V*) is measured in volts (also symbol; V) and named after Alessandro Volta (1745–1827), an Italian physicist renowned for the development of the first electric cell in 1800.

Voltage is sometimes referred to as potential difference because it measures the change in the potential, or stored electrical energy of the charges as they move from the start to the end of a circuit. For example, a 3-volt torch battery supplies the equivalent of 3 joules of energy per coulomb of charge in the circuit of the torch.

Electric charges gain electrical energy as they pass through the power supply in a circuit. They lose the same amount of electrical energy as they move through the rest of the circuit and this energy is transformed to other forms. This means that the voltage gain across the terminals of the power supply is equal to the total voltage drop across the rest of the circuit.

Components like light globes in an electrical circuit act as loads. It is in each of the loads that the electrical energy carried by the charges is transformed into other forms. In the example of a light globe, electrical energy is transformed into light and heat as the filament, a coiled tungsten wire, glows brightly when it gets hot. In a hair dryer there are two loads: a heater and a fan.

Voltage rises and falls in a simple circuit.



3.2.5 Resistance

Resistance (R) is a measure of how much a load restricts and reduces the flow of current. Resistance is measured in ohms (Ω), named after Georg Ohm (1789–1854), a German physicist who described the relationship between the voltage, current and resistance in an electrical circuit. In an efficient electric circuit, most of the electrical energy provided by the power supply is transformed in the loads. Little of the electrical energy is transformed in the conducting wires because they are made of metals like copper which have little resistance.

A summary of variables associated with electric circuits and their units of measurement

Variable		Unit	
Name	Symbol	Name	Symbol
Voltage	V	Volts	V
Current	I	Amperes	A
Resistance	R	Ohms	Ω

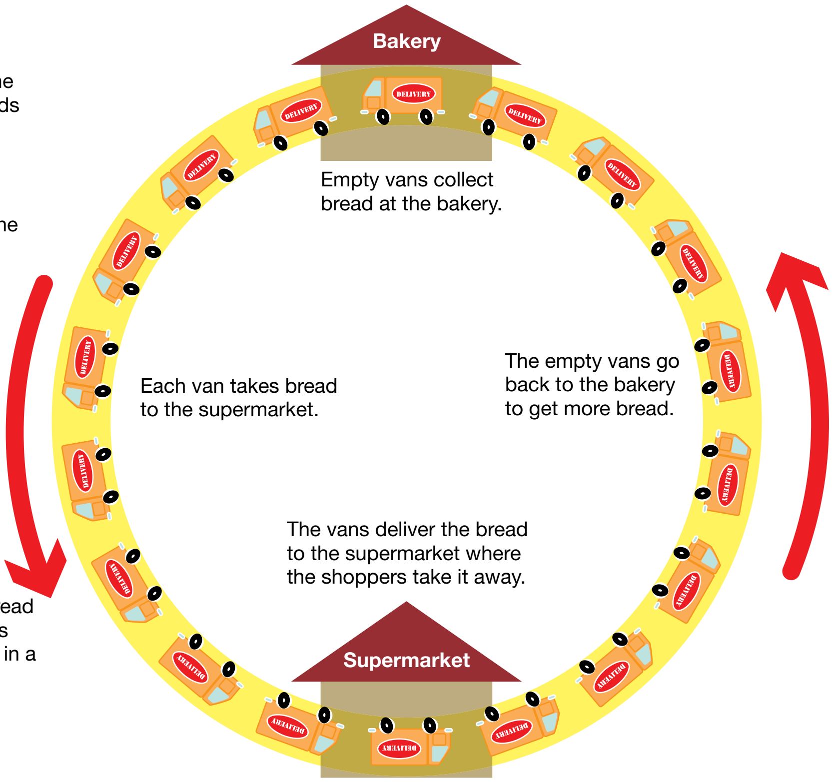
3.2.6 A useful analogy

To understand the concept of voltage, current and resistance in an electric circuit it is helpful to provide an analogy, or real-life comparison.

A bakery supplying bread to a supermarket is a good analogy for an electric circuit:

- The battery provides energy just like the bakery provides loaves of bread for delivery to supermarkets.
- The energy is carried around a circuit by electrical charges; similarly, the bread is carried around by delivery vans.
- The charges (electrons) are already there in the conducting wires of a circuit, just as the delivery vans are there waiting to deliver bread.
- The flow of charges is called an electric current and is like the line of moving delivery vans.
- The electrical energy carried by the charges is ‘given out’ in the bulb as heat and light and the charges return to the battery to collect more energy; similarly, the bread carried by the vans is sold to the supermarket and the vans return to the bakery to collect more bread.
- The resistance in the electric circuit due to the load slows the current in the same way that delivery to each supermarket slows down the movement of delivery vans.
- The more loads in an electric circuit, the more resistance and the less current, just as the more supermarkets that need to be visited by the vans, the slower the vans travel.

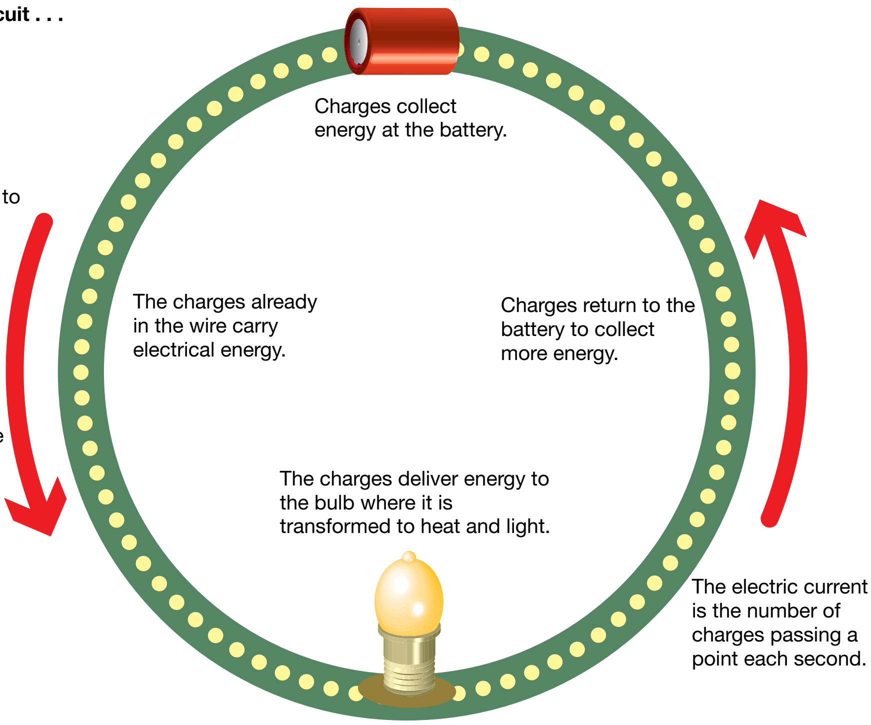
A bakery supplying bread to a supermarket can be an analogy for an electric circuit.



1. The bakery manager loads the bread onto the vans and sends them off.
2. As soon as the vans start to move, bread is delivered to the supermarket.
3. All the delivery vans move at the same speed.
4. If the manager speeds the vans up, more bread is delivered to the supermarket in a certain time.
5. If the manager loads more bread on to each van, more bread is delivered to the supermarket in a certain time.

Relating this to an electric circuit . . .

1. The battery provides energy and allows the charges to move.
2. As soon as the charges start to move, the bulb lights up.
3. All the charges move at the same speed.
4. If the charges speed up more energy is delivered to the bulb in a certain time.
5. If more energy is carried by each charge, more energy is delivered to the bulb in a certain time.



It is important to understand that the charges travelling through an electric circuit are present in the conducting wires already. A circuit's power source merely provides these charges with the energy to travel around the circuit. It's a little like the water in your water pipes. When you turn on a tap, you do not need to wait for the water to travel from the reservoir to the tap. Rather, the water is already in the pipes under pressure. Turning the tap on merely releases the water already in the system just like closing the switch in an electric circuit.

INVESTIGATION 3.1

A water analogy

AIM: To model an electric current

You will need:

long rubber hose
stopwatch

- Turn off the lights in the classroom then turn the light switch back on and time how long it takes for the electrical current to reach the lights.
- Attach the rubber hose to a tap and run it to a sink as far away as possible.
- Turn the tap on and time how long it takes for water to reach the sink. Record the time taken.
- Repeat this experiment, but this time start with the hose already full of water.

Discussion

1. Which is the better analogy for an electrical current, the current of water when the hose is full of water or when the hose is empty? Explain why.
2. In this analogy what do each of the following represent:
   (a) the water?
   (b) the hose?
   (c) the tap?
3. What aspect of an electrical circuit does this analogy not represent well?

3.2.7 Measuring current and voltage

A current of water in a river can be measured by determining the volume of water that passes a particular point every second. Similarly, the size of the electric current in a circuit can be measured by determining the amount of electric charge passing a particular point in an electrical circuit every second.

An **ammeter** is used to measure the size of electric current flowing in an electrical circuit. An ammeter measures electric current in amperes (A). Sensitive ammeters can measure currents as small as thousandths of an ampere, (milli-amperes mA), or even millionths of an ampere, (micro-amperes μA).

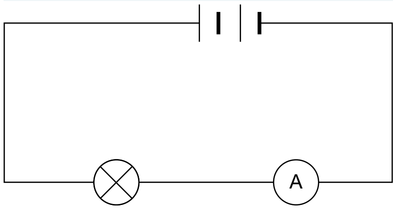
An ammeter is used to measure electric current.

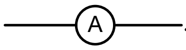
Using an ammeter

Many 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.
- Always read an ammeter from directly in front. The error obtained by not reading from directly in front is called a **parallax error**.
- If the ammeter has more than one red terminal:
- Use the positive terminal with the highest value first. If the measured current in your circuit is too small to be detected on this scale, change the connection to the positive terminal with a smaller value.

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



- Read the scale that matches the positive terminal used.
- An ammeter is represented by the symbol 

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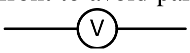
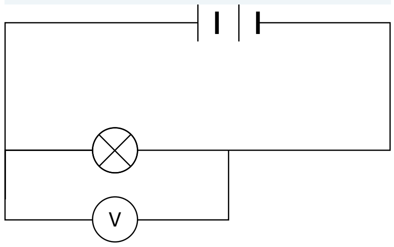
Using a voltmeter

A voltmeter is used to measure the voltage gain across the terminals of a power supply or the voltage drop across a load in an electric circuit. Voltage is 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 component 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 too small to be detected on this scale, change the connection to the positive terminal with a smaller value.
- Read the scale that matches the positive terminal used.
- Always read a voltmeter from directly in front to avoid parallax error.
- A voltmeter is represented by the symbol 

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



3.2.8 Understanding resistance

The negatively charged electrons moving in an electric circuit have to make their way around the atoms in the connecting leads and components 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 due to a crowded corridor limits the number of students who can pass through in a given time interval. Electrical resistance also determines how much energy is lost through transformation to heat, light etc. by the electric charges as they move through a circuit.

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 value of the resistance (R) of any part of an electric circuit can be calculated 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 0.2 A with a voltage drop of 3 volts therefore has a resistance of:

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

INVESTIGATION 3.2

Current and voltage in a circuit

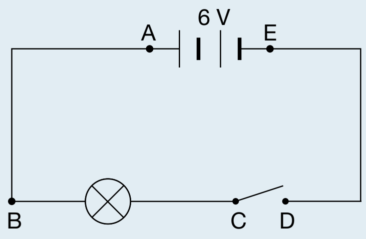
AIM: To investigate the electric current and voltage at various points in a circuit

You will need:

DC power supply (set to 6 volts)
12-volt light globe and holder
3 connecting leads with alligator clips or banana plugs

switch
ammeter
voltmeter

- Set up the circuit shown in the diagram at right. Make a copy of the table below in which to record your measurements.
- With the switch open, connect the ammeter in series at each of the points A, B, C, D and E to measure the electric current at these points. Record your measurements in the table.
- With the switch open, measure the voltage across each of the following components by connecting the voltmeter parallel to:
  (a) the power supply (across points A and E)
  (b) the light globe (across points B and C)
  (c) the switch (across points C and D)
  (d) one of the connecting wires (across points A and B).
- Close the switch.
- Repeat your measurements of electric current at each of the points A, B, C, D and E using the ammeter.
- Repeat your measurements of voltage across the power supply, the light globe, the switch and the connecting wire using the voltmeter.



Discussion

1. Compare the electric current when the switch is opened to when it is closed.
2. Were there any differences in the size of electric current at each of the five points when the switch was closed? Explain.
3. Across which parts of the circuit were there significant voltage drops? Explain.
4. How does the voltage across the terminals of the power supply compare with the voltage across the light globe when the switch is closed? Explain.
5. Where is most of the electrical energy provided by the power supply used?

Currents and voltages around a simple circuit

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

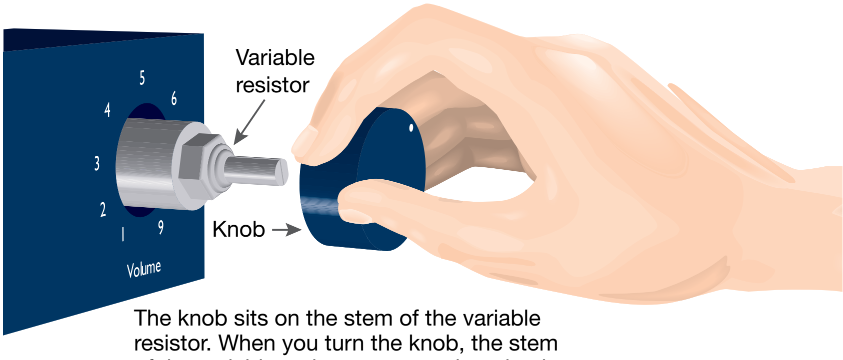
3.2.9 Controlling the flow

When you turn down the volume of a radio or television, you are changing the voltage and current available to the electric circuits inside. The volume switch acts as a **variable resistor**.

Resistors are used in electric circuits to control the voltage and current. They can have a fixed resistance or a variable resistance like those in volume controls. The photograph at right shows some different types of resistors. The two tall cylindrical resistors are a type of variable resistor used in volume dials.

A range of resistors

A variable resistor in a stereo system



The knob sits on the stem of the variable resistor. When you turn the knob, the stem of the variable resistor rotates, changing its resistance and controlling voltage and current.

INVESTIGATION 3.3

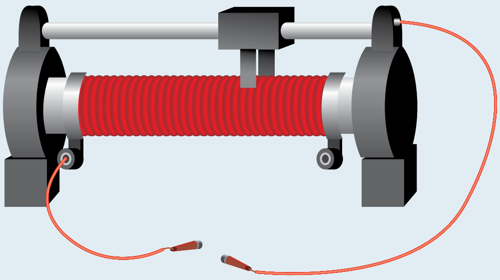
Variable resistance

AIM: To investigate the effect of a variable resistor in a circuit

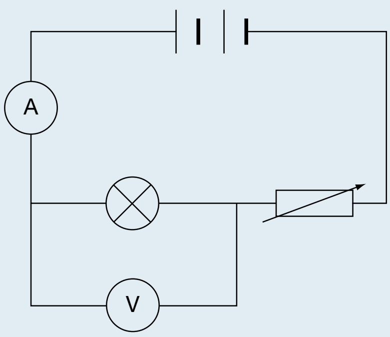
You will need:

DC power supply
ammeter
variable resistor (rheostat)
5 connecting leads with alligator clips or banana plugs
ruler
12-volt light globe
voltmeter

Connecting to a variable resistor



- Set up the circuit shown in the diagram below right. Turn the DC power source to 10 V. The variable resistor (see above right) 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.
- Measure the current through the circuit and the voltage across the light globe and record these values in a suitable table.
- Slide the variable resistor 3 cm from the starting point and repeat these measurements.
- Continue to take readings at 3 cm intervals until you reach the end of the variable resistor. Record your data in a suitable table.



Discussion

1. What evidence is there to suggest that at the start of the experiment the resistance of the variable resistor is at a minimum?
2. Explain what happens to the electric current flowing through the light globe as the resistance of the variable resistor increases.
3. Explain what happens to the voltage across the light globe as the resistance of the variable resistor increases.
4. Explain what happens to the brightness of the light globe as the resistance of the variable resistor increases.
5. What would you expect the sum of the voltage across the light globe and the voltage across the variable resistor to be? Explain.

3.2.10 Ohm's Law

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 relationship is known as **Ohm's Law**.

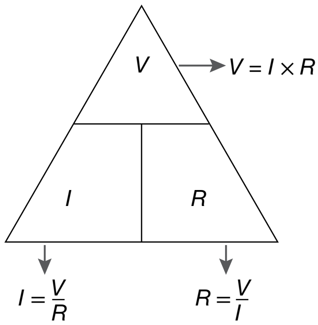
Materials that obey Ohm's Law are said to be ohmic. The fine filament in a light globe is not ohmic as it heats up. Metals and carbon are ohmic materials as long as the temperature remains fairly constant.

One way of working out whether a material is ohmic is to draw a graph of voltage drop versus electric current. Ohm's law is often defined by the equation:

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

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

Problems involving Ohm's Law can be calculated using this triangle. Place your finger over the variable that you wish to calculate.



INVESTIGATION 3.4

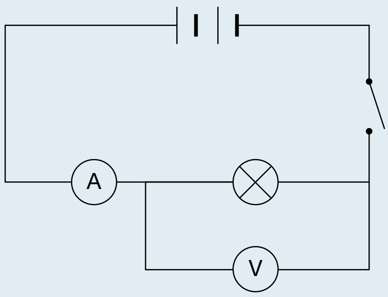
Calculating resistance

AIM: To calculate the resistance of a light globe using Ohm's Law

You will need:

DC power supply
12-volt light globe and holder
6 connecting leads with alligator clips or banana plugs
switch
ammeter
voltmeter

- Set up the circuit shown in the diagram at right and leave the switch open.
- Construct a table like the one given below to record your measurements.
- Set the power supply to 2 volts. 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 milli-amperes).
- Repeat the experiment with the power supply set to 4, 6, 8, 10 and 12 volts, each time quickly measuring and recording the electric current and voltage displayed on the meters.

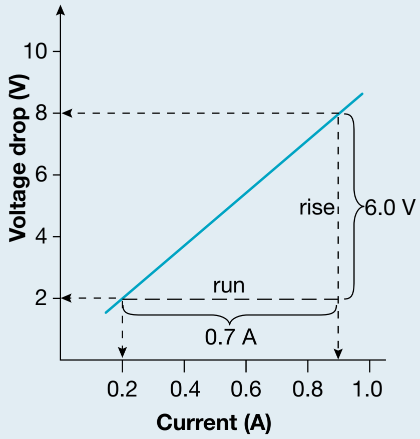


Power supply setting (V)	Electric current through the globe (A)	Voltage drop across the globe (V)
2		
4		
6		
8		
10		
12		

- Plot a graph of current (*x*-axis) against the voltage drop (*y*-axis) for the light globe. You might like to use a spreadsheet for this purpose. Draw a line of best fit (trend line) to display any pattern in your data.

Discussion

1. Is your line of best fit a straight line or a curve? Explain why.
2. Calculate the resistance of the light globe using Ohm's Law. One way of doing this is to calculate the resistance using V and I values several times and finding an average, but this treats each pair of values as equally valid even though some may be discrepant (also called outliers). A more accurate way to calculate the average resistance is to use the gradient of your graph (where the line of best fit is a straight line). An example is given at right.



$$\text{Resistance} = \text{gradient} = \frac{\text{rise}}{\text{run}}$$

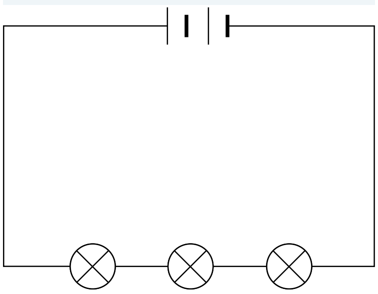
$$\text{Resistance} = \frac{V}{I} = \frac{6.0\ \text{V}}{0.7\ \text{A}} = 8.6\ \Omega$$

3.2.11 Series and parallel circuits

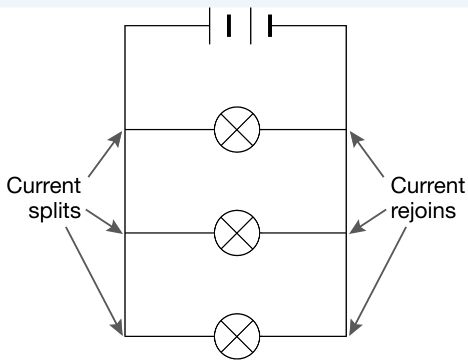
There are two ways that components can be connected in a circuit, series and parallel. In a series circuit the components are connected one after another in a row. As a result, the same current flows through each component. However, the voltage provided by the power supply is shared between each of the components.

In a parallel circuit the components are connected in separate branches. As a result, the current is divided between each of the components in the separate branches but each branch of a parallel circuit uses the full voltage provided by the power supply.

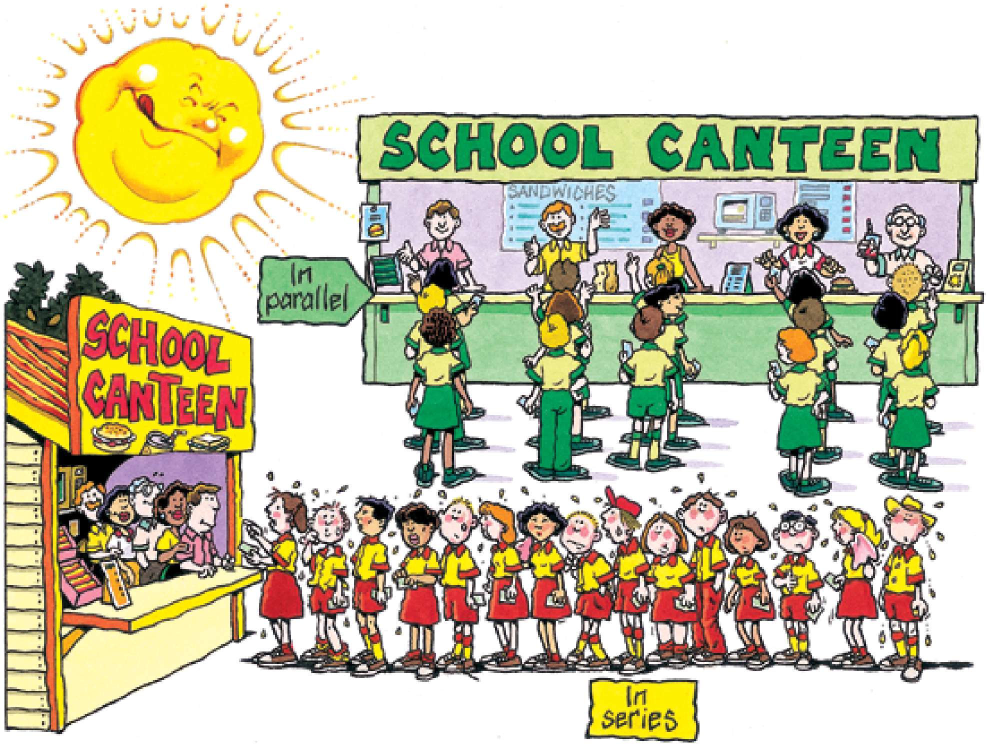
Three light globes connected to a power supply in series. The same current flows through each globe. Each globe, if identical uses one-third of the power supply's voltage.



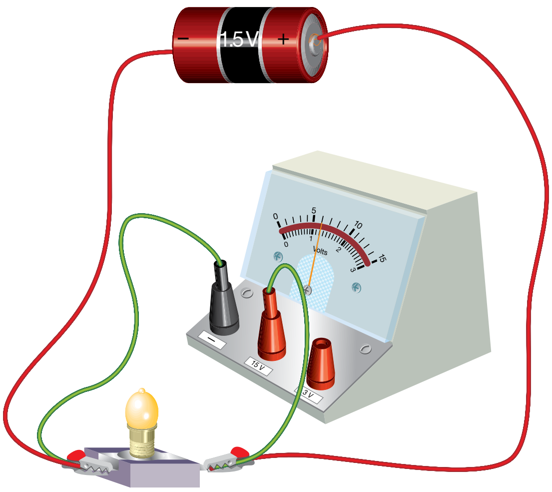
Three light globes connected to a power supply in parallel. Each globe uses the full voltage of the power supply. One-third of the current flows through each globe (if identical).



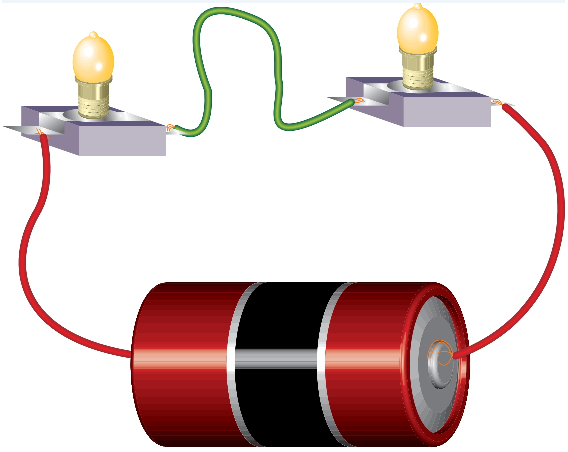
In a parallel queue of students, the congestion is reduced and they will be served more quickly. Similarly the total resistance in a circuit is reduced when the components are connected in parallel and this increases the total current.



How to measure voltage across one globe



Two globes connected in series



INVESTIGATION 3.5

Series circuits

AIM: To investigate the current and voltage in a series circuit

You will need:

DC power supply (set to 6 volts)
three identical 12-volt light globes and holders

5 connecting leads with alligator clips or banana plugs
ammeter
voltmeter

- Make a copy of the table below.
- Set up each of the circuits described in the table. Draw a diagram of the circuits in your workbook. Include the ammeters and voltmeter in your diagrams to show how the current flowing from the power supply and the voltage across one of the globes were measured.

Current and voltage in series circuits

Circuit description	Current (mA)	Voltage (V)
One light globe (globe X) connected to a 6-volt power supply		Globe X: ________ Power supply: ____
Two light globes (globes X and Y) connected in series with a 6-volt power supply		Globe X: ________ Globe Y: ________ Power supply: ____
Three light globes (globes X, Y and Z) connected in series with a 6-volt power supply		Globe X: ________ Globe Y: ________ Globe Z: ________ Power supply: ____

- Use the ammeter to measure the electric current flowing through each circuit. Place the ammeter in series with the light globes in each circuit so that the positive terminal is connected directly to the positive terminal of the power supply.

CAUTION: Check that the ammeter is connected properly. Check with your teacher if you are not sure.

- Use the voltmeter to measure the voltage drop across the power supply and each of the light globes in each circuit.
- Record all of your measurements in the table.
- While the third circuit is set up and switched on, unscrew one of the globes from its holder, if not too hot, and observe what happens.

Discussion

1. What happens to the electric current flowing through the circuit as more globes are added in series? Explain why this happens.
2. Why was it not necessary to separately measure the electric current flowing through each globe when two or three globes were connected in series?
3. What is the sum of the voltages across the globes in each of the three circuits?
4. How much voltage is 'lost' across each globe in the third circuit? Where has this electrical energy gone?
5. Make a general statement about voltage drops across light globes connected in series.
6. Make a general statement about electric current flowing through light globes connected in series.
7. Explain what happens to the other lights in series, if one of the lights breaks.
8. What happens to the brightness of the globes as more globes are added in series?

INVESTIGATION 3.6

Parallel circuits

AIM: To investigate the current and voltage in a parallel circuit

You will need:
DC power supply (set to 6 volts)
three identical 12-volt light globes and holders
5 connecting leads with alligator clips or banana plugs
ammeter
voltmeter

- Make a copy of the results table given below to record your measurements.

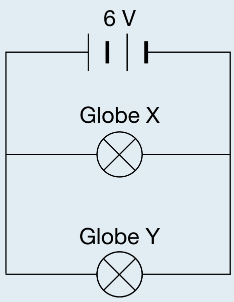
Current and voltage in circuits 1 and 2

Circuit	Current (mA)	Voltage (V)
Circuit 1	Globe X: ______________ Globe Y: ______________ Power supply: __________	Globe X: _________ Globe Y: _________ Power supply: _____
Circuit 2	Globe X: ______________ Globes Y and Z: ________ Power supply: __________	Globe X: _________ Globe Y: _________ Globe Z: _________ Power supply: _____

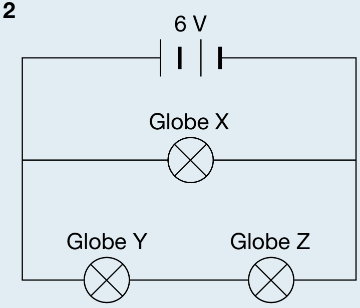
- Set up the circuits shown in the diagrams below. Observe whether adding the second globe in circuit 1 affects the brightness of the first globe (globe Y).
- Use the ammeter to measure the electric current flowing from the power supply and into each of the light globes in each circuit.

Parallel circuits

Circuit 1



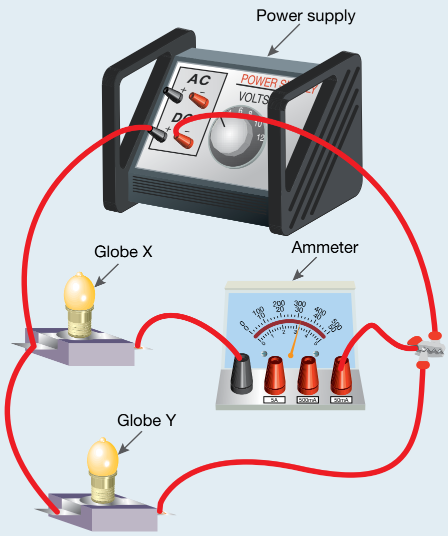
Circuit 2



CAUTION: Check that the ammeter is connected properly. Check with your teacher if you are not sure. Connecting the ammeter to measure the current in a parallel branch is tricky — see the diagram at right.

- Use the voltmeter to measure the voltage drop across the power supply and across each of the light globes in each circuit.
- While circuit 2 is set up and switched on, unscrew Globe X from its holder, if not too hot, and observe what happens.

Connecting an ammeter to measure the current in a parallel branch of a circuit containing globe X



Discussion

1. What is the sum of the currents flowing through globes X and Y in circuit 1?
2. What happens to the electric current flowing from the power supply when it meets a 'fork' in the pathway?
3. In circuit 2, how does the voltage drop across globe Y compare with the voltage drop across globe X? Explain why this is the case.
4. Make a general statement about electric current flowing through light globes connected in parallel.
5. Make a general statement about voltage drops across light globes connected in parallel.
6. Explain what happens to other lights connected in parallel if one of the lights break.
7. Does adding a second globe in parallel to the first affect the brightness of the first globe? Explain.

3.2 Exercise: Remember and think

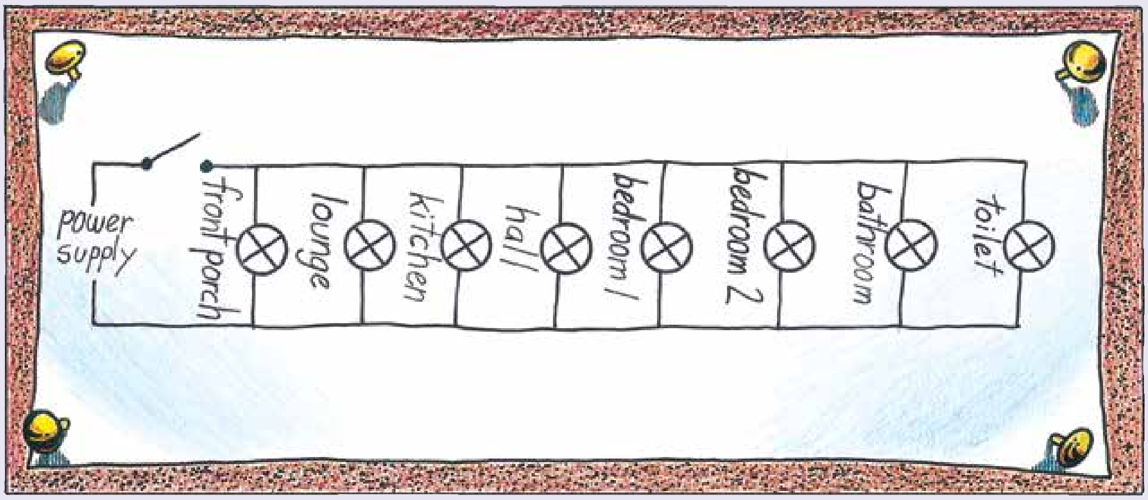
To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** the three essential features of all electric circuits.
2. **Identify** the energy transformation taking place in a torch.
3. **Explain** why connecting wires are usually made of copper.
4. Draw a circuit diagram showing:
   (a) a battery connected to two light globes connected in series
   (b) a battery connected to two light globes connected parallel.
5. **Explain** why voltage is also known as potential difference.
6. **Define** the term 'electric current'.
7. **Identify** the device used to measure:
   (a) electric current
   (b) voltage.
8. Use Ohm's Law to **outline** the relationship between the voltage supplied to an appliance and the electric current flowing through that appliance.

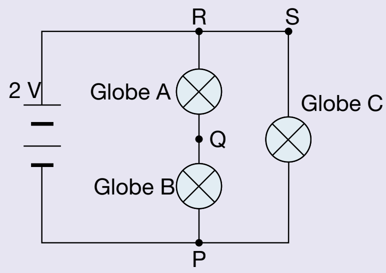
Think

9. A single light globe is connected to a power supply. Predict whether the brightness of this light globe will increase, decrease or remain the same when:
   (a) an identical light globe is connected in series with it
   (b) an identical light globe is connected parallel to it.
10. **Explain** two advantages of connecting the power outlets in a room of your home parallel to one another.
11. Redraw the circuit diagram from question 4(b), adding a switch that turns both light globes on or off at the same time.
12. An apprentice electrician has designed a lighting circuit diagram (shown below) for a new house. **Explain** what is wrong with this circuit design.

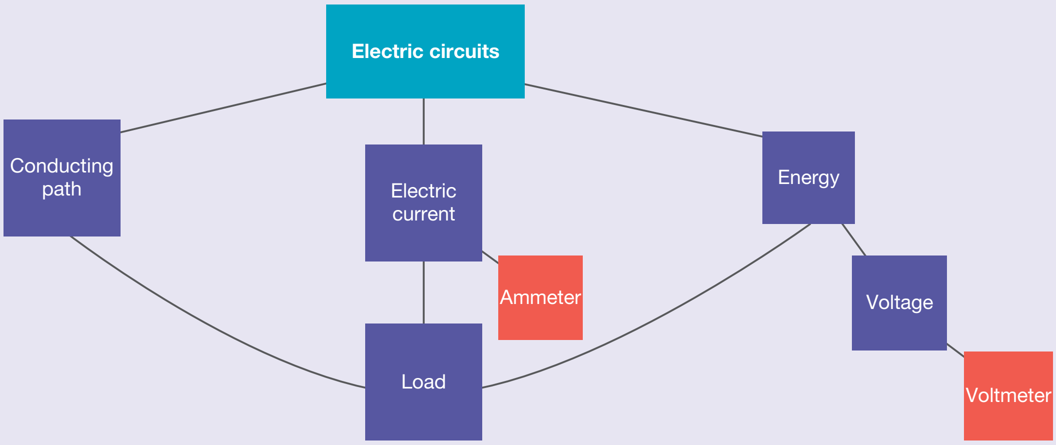


13. **Calculate** the voltage drop across a 100 Ω resistor when the electric current through it is 0.25 mA.
14. The electric current flowing through a light globe is 200 mA when the voltage across the globe is 1.5 V. When the voltage is increased to 3.0 V, the current is measured to be 360 mA.
   (a) **Calculate** the resistance of the light globe when the electric current is 200 mA.
   (b) **Explain** whether the light globe is ohmic.
15. When a light globe 'blows', the filament breaks. **Explain** what will happen if:
   (a) many light globes are connected in series and one blows
   (b) many light globes are connected in parallel and one blows.

16. In the circuit diagram at right, **predict** which of the light globes (A, B or C) will continue to glow if:
    (a) the filament in globe A breaks
    (b) the filament in globe B breaks
    (c) the filament in globe C breaks
    (d) a wire lead is connected between the points P and Q
    (e) a connecting lead is connected between the points P and R
    (f) a connecting lead is connected between the points P and S.

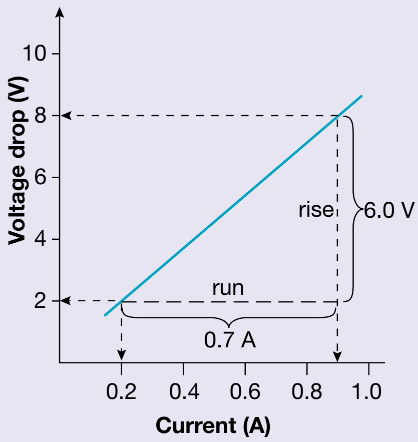


17. The incomplete concept map below represents some of the key ideas related to electric circuits. This concept map is just one way of representing ideas about matter and how they are linked. Copy and complete the concept map by writing suitable links between the ideas.



Using data

18. Answer these questions about the ohmic conductor described by the graph of voltage drop versus electric current at right.
    (a) **Predict** the voltage drop across the conductor when the electric current is 0.6 amperes.
    (b) **Predict** the electric current through the conductor when the voltage drop across it is 4 volts.
    (c) **Predict** the current through the conductor if it is supplied with 9 volts.



$$\text{Resistance} = \text{gradient} = \frac{\text{rise}}{\text{run}}$$

$$\text{Resistance} = \frac{V}{I} = \frac{6.0\ \text{V}}{0.7\ \text{A}} = 8.6\ \Omega$$

19. Read the measurement on the ammeter below accurately.

Investigate

20. Carry out an investigation to determine whether common loads like light globes and resistors are ohmic or non-ohmic. Present your data for each device as a line graph.
21. Research one of the following scientists and **outline** their contribution to our understanding of electricity:
    (a) André Ampere
    (b) Alessandro Volta
    (c) Georg Ohm.
    Present your research as a newspaper or journal article and emphasise the scientist's ground-breaking discoveries.
22. Use the **Hydraulic model of current** interactivity in the Resources tab to explore a DC circuit by adjusting the voltage and adding a combination of series and parallel resistors.
23. Use the **DC water analogy** weblink in the Resources tab to see a direct comparison between the flow of water and a DC circuit.

learnon RESOURCES — ONLINE ONLY

Explore more with this weblink: DC water analogy

Explore more with this weblink: Ohm's Law

Complete this digital doc: Worksheet 3.1: Simple circuits (doc-12747)

Complete this digital doc: Worksheet 3.2: Voltage and current (doc-12748)

Complete this digital doc: Worksheet 3.3: Ohm's Law (doc-12749)

Complete this digital doc: Worksheet 3.4: Series and parallel circuits (doc-12750)

3.3 Electricity at home

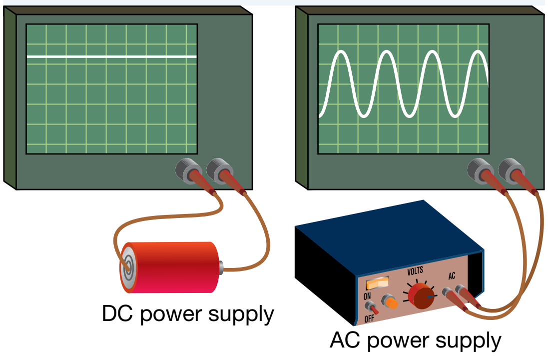
Science as a human endeavour

3.3.1 AC or DC

The electricity used to run many of the appliances in our homes is obtained by simply plugging a lead into a power point, also called a general power outlet (GPO) and switching it on. The electric current that flows from power points is not quite the same as the electric current that flows from a battery. Batteries provide a direct current (DC), meaning that a constant voltage is supplied causing the current to flow in one direction in a circuit. In a DC circuit, electrons carry electrical charge from the negative terminal to the positive terminal of the power source.

The current supplied to homes and available to appliances through power outlets is called alternating current (AC). As the name indicates, alternating current alternates or changes direction. In Australia, current alternates with a frequency of 50 Hz (50 times per second) and the voltage fluctuates from a positive to negative value with a voltage equivalent to 240 V.

The electrical voltage from a power supply can be displayed on a cathode ray oscilloscope (CRO). A DC power supply produces a constant voltage and a current that travels in one direction. An AC power supply produces a fluctuating voltage and a current that changes direction 50 times a second.



Alternating current, rather than direct current, is supplied by power stations because it is more efficient to distribute over large distances through the power grid.

A mobile phone charger

3.3.2 Appliance transformers

Many common electrical appliances are not designed to work on the 240 V AC electricity supplied to homes. These appliances contain devices called **transformers** that can increase or decrease the supplied voltage to the voltage required by the appliance. In addition, appliances that require DC electricity are supplied with an electrical device called a **rectifier** that converts AC to DC. Hence, the 240 V AC supplied to your home can supply a variety of appliances, each requiring a specific operating voltage. For example, mobile phone rechargers transform and rectify 240 V AC into the small DC current required to recharge the internal battery of the phone.

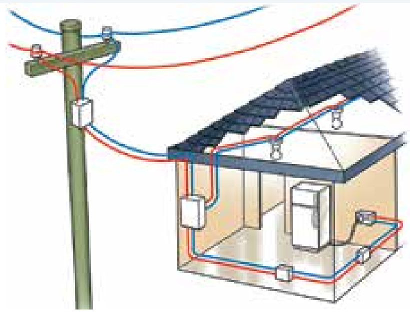
3.3.3 Electrical safety

The power cords that supply electrical appliances contain wires that have a double layer of insulation to prevent users from coming into contact with the wires. There is a plastic coating around each wire as well as a plastic cord around the two wires.

Electricity is provided to homes through wires covered with plastic insulation. The wire that carries AC electricity to your house is called the **active** (often called the **live**) wire. This voltage alternates, providing the equivalent of 240 V. A second wire, called the **neutral** wire, completes the electrical circuit from your home to the electrical power grid that supplies your home and neighbouring streets.

The electrical circuit supplying your home first passes through the electricity meter in the meter box to monitor your energy usage. From the meter box your home's main electric circuit splits into numerous parallel branches, each supplying different sections of your house. Some appliances such as hot water heaters and cooking stoves use particularly high electric currents and so may be on their own parallel branch. Often each room would be supplied with electricity by a separate parallel circuit, and within each room the lights may be on a separate branch to the power points. The advantage of this is that if a light blows in one room it won't affect the power points in that room or the lights in other rooms.

Active and neutral wires from transmission lines connect your home to the electricity grid.



3.3.4 Fuses, circuit breakers and safety switches

The separate circuits for each area of your home can be seen in the meter box. Each parallel circuit will contain a safety device called a **fuse** or a **circuit breaker**. Circuit breakers are installed in all new homes.

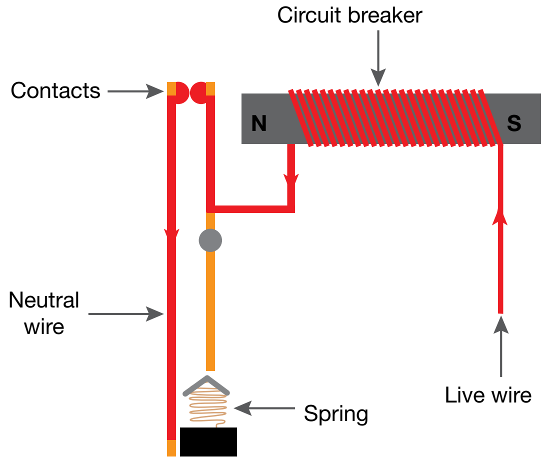
Circuit breakers within a meter box

Electrical faults can occur in places you can't see. For example, the wires that connect to the power points in your home are hidden behind walls. These wires will usually carry electricity without overheating. But if a **short circuit** occurs, the wires could overheat and cause a fire.

A short circuit occurs when an active wire comes into contact with a neutral wire without passing through a load. This may happen if the insulation around the wires frays and bare wires come in contact with one another. Without a load, the resistance in a short circuit is very small, resulting in an unusually high current that causes the conducting wires to heat up.

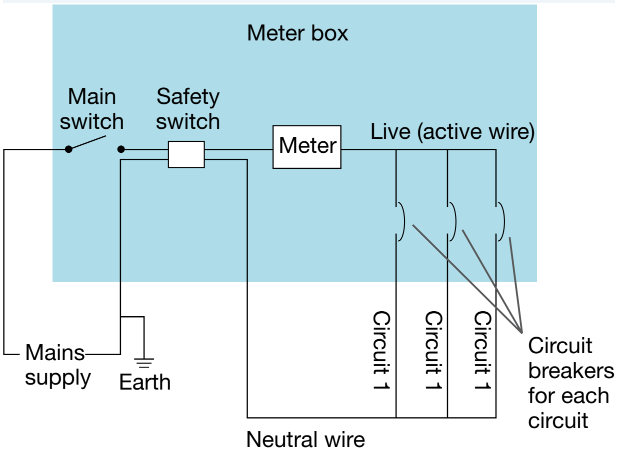
Fuses and circuit breakers prevent wiring from overheating due to short circuits or current surges from the mains supply. Fuses are made from a thin wire that heats up quickly when an unusually high current passes through it, causing the fuse wire to melt and break the circuit. Like a fuse, a circuit breaker acts as a switch that opens a circuit when the current in a circuit is too high. The current rating of a fuse or circuit breaker is selected to suit the current normally carried by each branch of a home circuit. The circuit breaker incorporated in a kitchen stove circuit for example would be triggered by a higher current than one connected to a room's lighting circuit.

Schematic diagram of a circuit breaker. If the live wire carries an unusually higher current, the electromagnet's strength is increased, causing the electrical contact to be withdrawn to open the circuit. The spring keeps the contact apart until the circuit breaker is reset.



Circuit breakers and fuses open circuits before they can overheat, but they do not stop people from getting an electric shock. An electric shock occurs when an electric current flows through the body instead of the electric circuit. The effects vary depending on the size of the current. At low levels, a tingling sensation or muscular pain will be felt. In more severe cases breathing difficulties, burns and ultimately heart failure can occur. Being in contact with water can increase the current flowing through you by making your body a better conductor of electricity. For this reason it is not safe to use electrical appliances in wet conditions; that is, near taps, with wet hands or in the rain.

Schematic diagram of a meter box circuit



To minimise the risk of injury due to electric shock, every new home built in Australia is required to have a device called a **safety switch** installed, also known as a residual current device or RCD. Located in the meter box, a safety switch interrupts the current from the mains supply when there is danger of electric shock. It does this by monitoring the current entering and leaving a building. If the two values are not equal, it may be that current is leaking somewhere in the circuit, possibly due to faulty appliances or damaged wiring. As soon as this current leakage is detected, the safety switch stops the current flow by opening the circuit and preventing any likelihood of injury.

A safety switch, also called a residual current device

INVESTIGATION 3.7

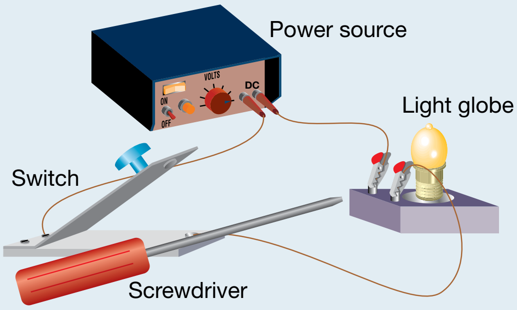
Modelling a fuse

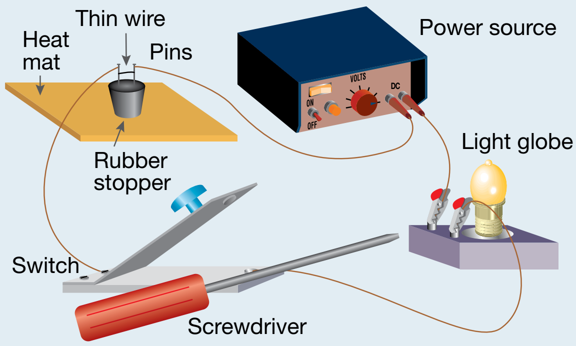
AIM: To demonstrate how an electric fuse works

You will need:

DC power source
4 wire leads with an alligator clip at one end
light globe and holder
switch
rubber stopper
heat mat
fine nichrome wire or strands of steel wool
screwdriver
2 metal pins

- Connect the circuit as shown on right. Set the voltage to 2 volts.
- Close the switch then carefully place a screwdriver across the alligator clips as shown in the diagram to bypass the light globe. Quickly observe any changes and remove the screwdriver again. Record your observations.
- Create a simple fuse and incorporate it into your circuit as shown below right.
- Place the screwdriver across the alligator clips as before to bypass the globe.
- Record any changes. If no changes are observed, increase the voltage and repeat the experiment.





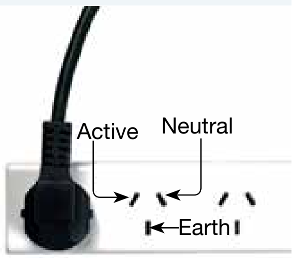
Discussion

1. What did you observe when a short circuit was first created using the screwdriver? Explain your results.
2. Explain how the fuse worked.
3. Outline the essential feature of a fuse wire.

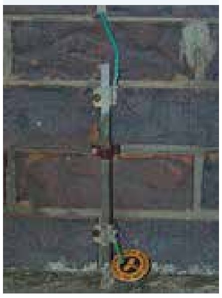
3.3.5 The 3-pin plug

Power points in Australia have sockets designed to fit either 2-pin or 3-pin appliance plugs. When an electrical appliance is plugged in and switched on, alternating current flows through the appliance between the top two pins of the socket. Metal appliances normally have a 3-pin plug. This third pin is connected to the metal casing of the appliance. If a live wire should come into contact with the casing, due to damage to the wiring, current flows directly out of the earth wire to a metal pipe in the ground outside the home.

A three pin plug and power outlet



The earth wire outside a home



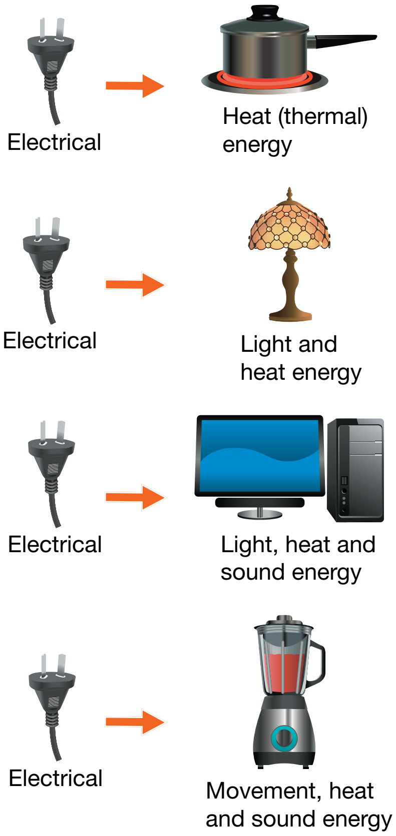
An earth wire prevents electric shock if you touch an electrical appliance with a short circuit.

This will prevent anyone coming in contact with the faulty metal appliance getting an electric shock. Appliances with 2 pin plugs means they are insulated instead of having an earth wire. This means they have a plastic external casing rather than a metal one and any external metal parts are carefully insulated from the internal wiring.

3.3.6 Electrical appliances — transforming electrical energy

Where would we be without electrical appliances? Our homes are full of them: in the kitchen you may have a toaster, blender, dishwasher, fridge, cooktop and oven. In the laundry you probably have a washing machine and clothes dryer. Not to mention the variety of personal communication and entertainment devices throughout the home. Each of these appliances transforms electric energy to other useful forms of energy.

Electrical appliances transform electrical energy to other useful forms.



3.3.7 Electric motors

What do a hair dryer, a DVD player, a food processor, a clothes dryer and an electric drill all have in common? These appliances all contain an **electric motor**. An electric motor is a device that converts electrical energy into kinetic energy.

An electric motor converts electrical energy into kinetic energy. This conversion can only take place because of the magnetic effects of an electric current.

3.3.8 How a DC electric motor works

The armature

When electric current flows through the **rotor coils** of the armature, a magnetic field is produced. The magnetic field produced by these coils interacts with the magnetic field of the **field magnets**. The repulsive and attractive forces acting on the rotor coils causes the armature to rotate.

The field magnets

The field magnets are permanent magnets located around the armature.

The brushes

These brushes are connected to the power supply and lightly touch the commutator as the armature turns. This allows current to travel through the rotor coils.

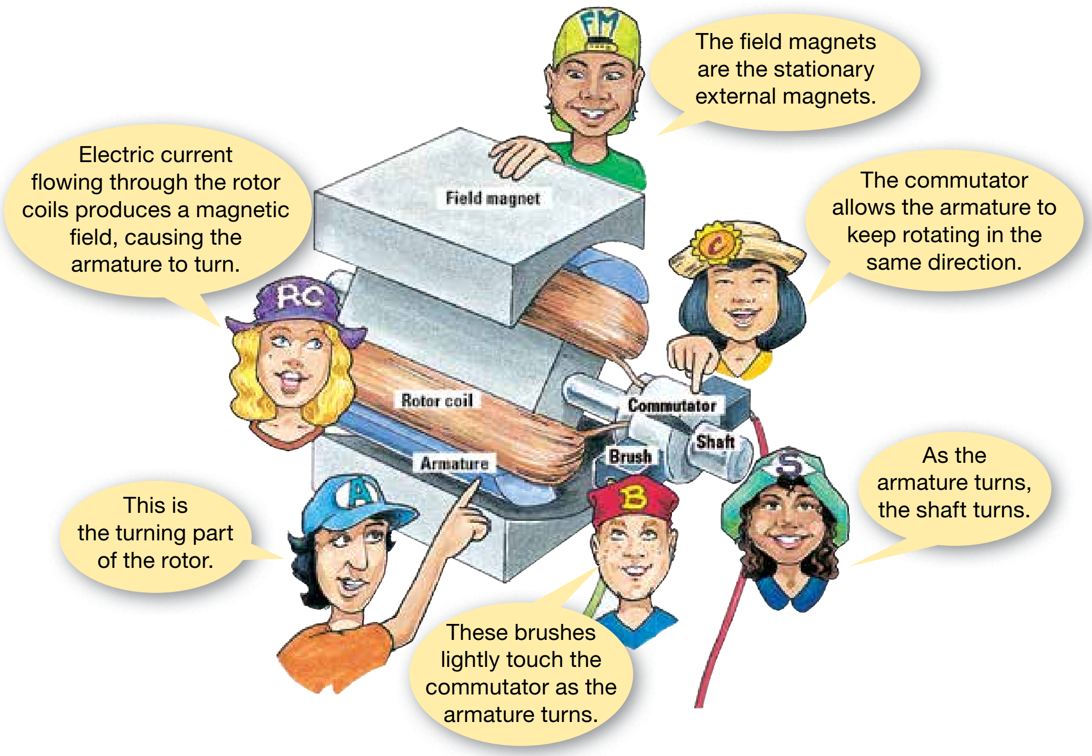
The shaft

This part of the motor is attached to the device the motor is turning, like a fan or gear wheel. As the armature turns, the shaft turns.

The commutator

As each rotor coil turns half a rotation to face the opposite field magnet, the force on it would change direction, turning it back the other way. The **commutator** consists of a split metal ring. As the armature turns, the commutator turns with it while the brushes remain still. When the armature has turned through 180 degrees, the opposite side of the commutator makes contact with the brush connected to the positive terminal of the power supply. This allows the armature to keep rotating in the same direction, rather than spinning first one way, then the other.

A simplified diagram of a DC electric motor



INVESTIGATION 3.8

A model motor

AIM: To construct an electric motor

You will need:

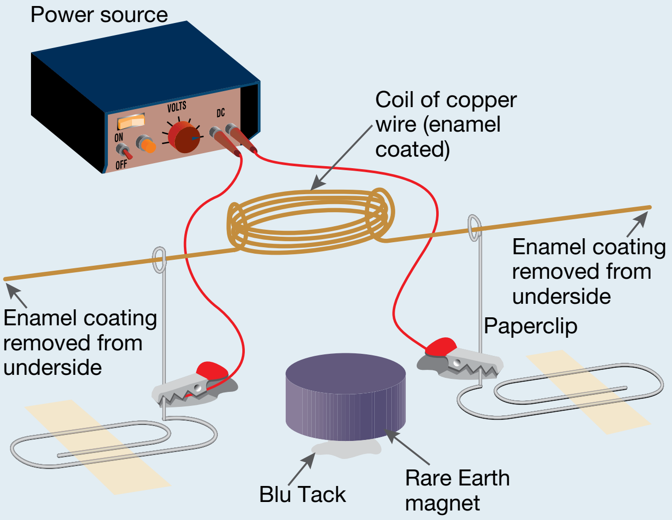
DC power source
2 large paperclips
sticky tape
Blu Tack
1 m of enamel-coated copper wire
a strong (rare Earth) magnet
large test tube
emery paper

- Wind the copper wire around a large test tube leaving a 3–4 cm length of straight wire at each end of the coil. Loop each end of the wire around each side of the coil to hold the coil together and extend the two ends of wire horizontally.
- Remove the enamel coating from the bottom side of each end of the wire using the emery paper.
- Bend the two paperclips as shown in the diagram and tape the base of each to the bench to create a stand to support the coil.

- Fix the rare Earth magnet to the bench using Blu Tack in a position directly below the coil.
- Connect wire leads to each paperclip stand, being careful to keep the alligator clips well away from the magnet to prevent them attracting.
- Connect the leads to a 6 V DC power source.
- Switch the power on. You may need to give the coil a gentle push to start it spinning.
- Record your observations.

Discussion

1. Outline the energy transformation taking place in this model motor.
2. Explain what causes the motion of the coil.
3. Identify the component of your model motor that acts as the:
   (a) rotor
   (b) brushes
   (c) field magnet
   (d) commutator.



3.3.9 Counting the cost

The power rating of an electrical appliance indicates how quickly electrical energy is used and converted to other forms of energy. The law of conservation of energy states that the energy input, in this case in the form of electrical energy, is equal to the energy output in an energy transformation. In electrical appliances, electrical energy is transformed to other forms. Some forms are useful, such as the light produced by an incandescent (filament) light globe, while other forms represent wasted energy such as the heat produced by these globes. Electrical power is measured in watts (W) and is equivalent to joules per second. A 75-W incandescent light globe uses 75 joules of energy per second and would be more costly to run than an 18-W compact fluorescent light which uses 18 joules/second.

Appliance	Typical power rating (W)
Fluorescent light	20
Notebook computer	20
Desktop computer	120
Television	200
Toaster	1000
Hair dryer	1500
Electric kettle	1700
Air conditioner (medium sized)	5000

The table at right provides the power rating of some common appliances.

The power rating can be used to determine the electrical energy used by an appliance as follows:

$$\text{Electrical energy use (joules)} = \text{electrical power (watts)} \times \text{time in use (seconds)}$$

For example, using a desktop computer for half an hour would use:

$$120\ \text{W} \times 30\ \text{min} \times 60\ \text{s/min}$$
$$= 120\ \text{J/s} \times 1800\ \text{s}$$
$$= 216\,000\ \text{joules}$$
$$= 216\ \text{kilojoules of energy}$$

An electricity meter located in your home's meter box monitors your energy usage in kilowatt-hours.

Electricity meters measure the number of kilowatt-hours of energy used in homes.

The joule is a very small unit of energy, so electricity suppliers charge us in units called kilowatt-hours (kWh). A kilowatt-hour is the energy used by a 1 kilowatt appliance for an hour. The power use of an appliance depends on the type of energy conversion it carries out. Low-power appliances include fluorescent lights and laptops and usually convert electrical energy to light and sound energy. High-power appliances such as electric kettles and toasters generally convert electrical energy to heat and cost more to run.

Electricity suppliers charge us for the amount of energy we consume in our homes.

Energy companies measure the amount of electrical energy used by a household in kilowatt-hours.

Every three months, the meter box is read so that the energy company knows how much electricity the customer has used.

Households are charged a fixed amount for every kilowatt-hour of electricity they use. This customer was charged 20.6 cents per kilowatt-hour.

Energy Used and Costs

METER ID –	THIS READING	=	LAST READING	×	USAGE SPLIT	×	RATE	=	COST
Single Energy Rate – Contract (12/01/17 – 11/04/17)									
	46851.0		45998.0		First 853.0 kWh		853.0*20.600c		$175.72
Electricity Service Availability Charge					91Days		48.000c/Day		$43.68
*based on 19.1781 kWh/billing day									
Total Electricity before GST 853.0 kWh $219.40									

INVESTIGATION 3.9

Comparing electrical appliances

AIM: To compare the power use and energy conversion in a range of electrical appliances and devices

You will need:

a range of electrical appliances and devices; e.g. radio, hair dryer, blender, laptop, fluorescent light, incandescent light, hot water kettle

- Examine each of the devices, preferably while they are operating. For each one record in a suitably designed table the:
  - type of energy input
  - useful energy output (there may be more than one)
  - wasted energy output (there may be more than one)
  - operating power in watts (this should be labelled on the device).

Discussion

1. Which appliance/device consumes:
   (a) the most power?
   (b) the least power?
2. Which device do you consider would be the:
   (a) most efficient, producing the least wasted energy?
   (b) least efficient, producing the most wasted energy?
3. Account for the higher operating power of some of the devices in terms of the type of energy transformation that takes place.

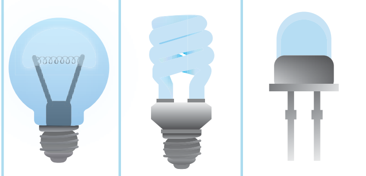
3.3.10 Energy efficient appliances

The light globes used for many years in Australian homes are called incandescent globes. In incandescent globes, electricity passes through a thin filament, generally made of tungsten metal, causing it to glow white hot. These are relatively inefficient devices for lighting as only 10% of the supplied electrical energy is converted to light; the rest is released as heat.

To encourage the use of more energy efficient lighting, the sale of incandescent light globes was phased out from 2010 and replaced by more energy efficient alternatives that produce at least 15 lumens per watt of electricity used. Lumens (lm) are a measure of light output. These energy efficient alternatives include compact fluorescent lamps (CFLs) and light emitting diodes (LEDs) which convert closer to 70% of electricity energy to light.

CFLs and LEDS represent a technological advancement in lighting. CFLs consist of a coiled glass tube filled with argon gas and a small amount of mercury vapour. An electric current passes through the gas-filled tube, causing the mercury atoms to emit ultraviolet light, which in turn excites a fluorescent phosphor coating on the inside of the tube, producing the visible light. A CFL's ballast regulates the current when the electricity starts flowing.

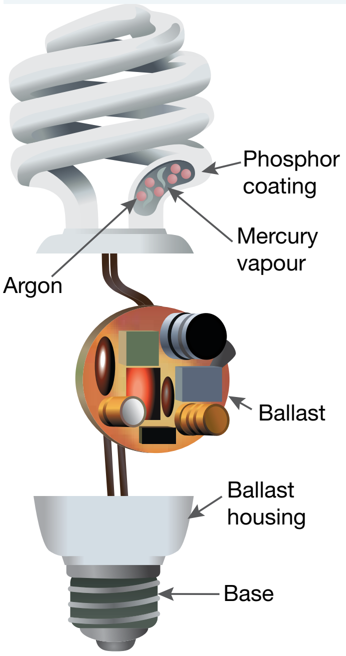
CFLs and LEDs are energy efficient alternatives for lighting.



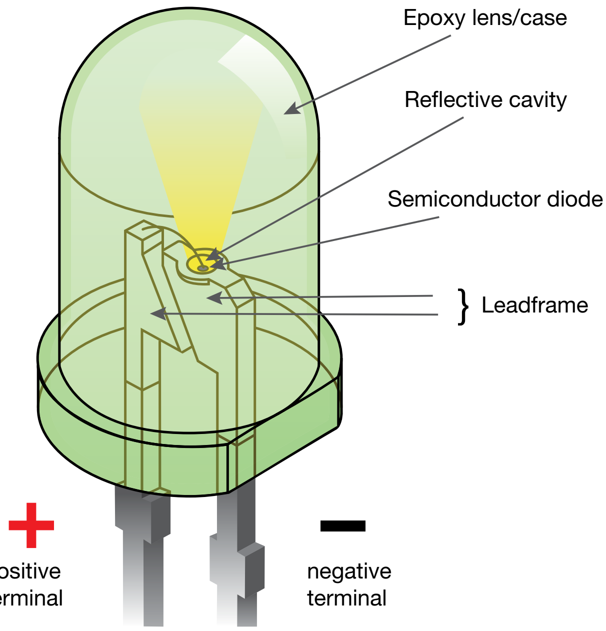
	Incandescent light bulbs	Compact fluorescent lamps (CFLs)	Light emitting diodes LEDs
Electrical power use equivalent to 60 W incandescent light bulb	60 watts	13–15 watts	6–8 watts
Electrical energy use per year based on 20 lights operating 8 hours per day	3506 kWh/yr	760 kWh/yr	350 kWh/yr
Approximate annual operating cost at 21 cents per kWh	$736	$160	$74

LEDs contain an electronic component called a semiconductor diode, similar to the miniature electrical components contained in an integrated circuit. When electricity flows through an LED, the electrical energy is converted to light energy very efficiently with minimal heat produced. One individual LED does not produce as much light as one CFL or one incandescent globe, so many small LEDs are often used together for lighting purposes.

The components of a CFL



The components of an LED



INVESTIGATION 3.10

Light globe efficiency

AIM: To compare the efficiency of an incandescent light with a CFL

You will need:

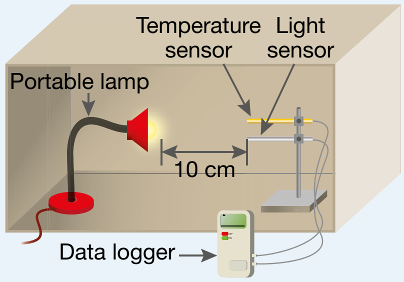
cardboard box
data logger
temperature sensor
light sensor (optional)
portable lamp
an incandescent light and CFL of equivalent light output as follows:

Incandescent light	CFL
40 watts	9–13 watts
60 watts	13–15 watts
75 watts	18–25 watts
100 watts	23–30 watts

- Insert the incandescent globe into the portable lamp.

CAUTION: Ensure that the lamp is not connected to the power outlet while light globes are inserted or removed.

- Connect the temperature sensor and light sensor (if available) to the data logger.
- Position two sensors 10 cm away from the lamp within the cardboard box and record the temperature and light intensity each minute over a 10-minute period.
- Repeat the experiment with a CFL.



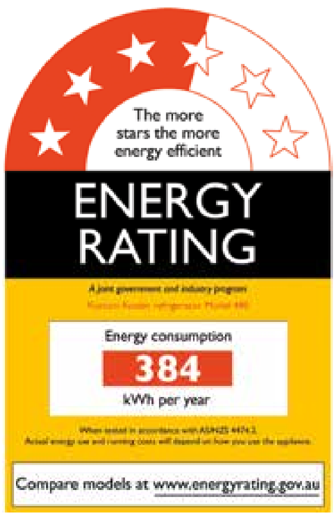
Discussion

1. Compare the temperature change due to the incandescent light and the CFL.
2. Compare the light intensity of the incandescent light and the CFL.
3. Which light globe is the most energy efficient? Explain in terms of the data collected.
4. Calculate the:
   (a) energy use for each globe in kWh if each was run for 8 hours
   (b) annual cost of running each lamp 8 hours per day assuming a tariff of 21c per KWh.

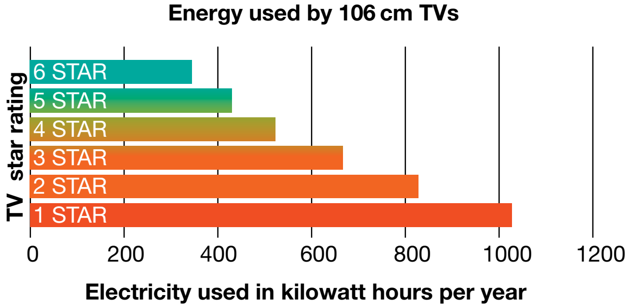
3.3.11 Rating energy efficiency

In Australia it is mandatory for electrical appliances such as refrigerators, washing machines, dishwashers, air conditioners and televisions to carry an energy rating label. The label provides each appliance with a star rating: the greater the number of stars, the higher the energy efficiency of the appliance, compared to others of a similar size or capacity. This rating is based on the appliance's estimated annual energy use (measured in kilowatt hours) calculated from its power consumption and information about the typical use of the appliance in the home.

The rating system enables consumers to compare the energy efficiency of appliances and provides incentive for manufacturers to improve the energy performance of their products through research and development.



The higher the energy efficiency rating of an appliance like a TV, the less electrical energy consumed per year.



INVESTIGATION 3.11

Investigating energy efficiency

AIM: To calculate the energy efficiency of an electrical appliance

You will need:

electric kettle
100 mL measuring cylinder
data logger and temperature probe
stopwatch

- Use the measuring cylinder to measure and pour 500 mL of water into the electric kettle.
- Place the tip of the temperature probe into the kettle and record the initial temperature of the water.
- Remove the temperature probe then switch on the kettle and heat the water for 60 seconds.
- Insert the temperature probe again to record the new water temperature.
- Calculate the temperature rise over the 60-second period and record your data.
- Refer to the label on the kettle to identify and record the power use of the kettle.

Discussion

1. Calculate the input of electrical energy to the kettle over the 60-second period:
   Electrical energy input (J) = Power (watts) × operating time (s)
2. Calculate the output of heat energy gained by the water in the kettle as follows:
   Heat energy output (J) = volume of water (mL) × 4.2 × temperature rise (°C)
3. Calculate the efficiency of the kettle as follows:

$$\text{Efficiency}(\%) = \frac{\text{Heat energy output}}{\text{Electrical energy input}} \times 100$$

4. Explain why the efficiency of the kettle is well below 100% in terms of transformation of electrical energy and the transfer of heat energy generated.

3.3 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Compare** AC and DC electricity.
2. **Explain** why devices like electronic games and computer printers have transformers attached to their power cords.

3. **Explain** why circuit breakers and fuses are an essential safety feature of home electrical circuits.
4. **Identify** the energy transformation taking place in:
   (a) an electric stove
   (b) a hair dryer.
5. **Explain** why incandescent lights have been phased out in preference for compact fluorescent lights and LEDs.

Think

6. What types of home appliances have the greater power use? **Explain** why.
7. **Explain** how a fuse or circuit breaker works.
8. What type of appliances require an earth wire and a three pin plug? Why?
9. **Identify** three devices that contain an electric motor.

Calculate

10. How much electrical energy (in joules) is transformed by each of the following appliances:
    (a) an 18 watt light globe in 6 hours?
    (b) a 2000 watt toaster used to toast a slice of bread for 2 minutes?
11. How much would it cost to operate each of the following appliances if the cost of electrical energy is 21 cents per kilowatt-hour? (Remember, 1 kW = 1000 W.)
    (a) A 5000 watt air conditioner for 30 minutes
    (b) A 1500 watt electric blanket for 8 hours
12. Assuming that the cost of electrical energy is 21 cents per kilowatt-hour, use the data in the table below to **calculate** how much it costs to:
    (a) use a medium sized air conditioner to cool a room for four hours
    (b) watch television for two hours every day for a week.

Appliance	Typical power rating (W)
Fluorescent light	20
Notebook computer	20
Desktop computer	120
Television	200
Toaster	1000
Hair dryer	1500
Electric kettle	1700
Air conditioner (medium sized)	5000

3.4 Meeting our future electricity needs

Science as a human endeavour

3.4.1 The electronics age

Over the past decade there has been huge growth in the use of electronic devices like computers (both laptops and desktops), MP3 players, DVD technology, mobile phones and personal organisers.

Electronics is one of the fastest growing industries in Australia and world wide. This is partly because we are becoming more dependent on computers and electronic communication involving the internet and mobile phones.

3.4.2 Integrated circuits

Electronic devices rely on complex electrical circuits that are almost too small to see. In these devices **integrated circuits** that contain thousands of miniature electronic components are etched onto **chips**; thin pieces of the semiconductor silicon.

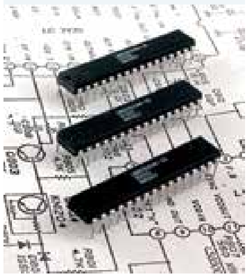
A desktop computer's integrated circuit

Modern communication devices rely on integrated circuits.

The first silicon chip was developed in 1958 and, by 1965, most chips could hold about 30 electronic components. In 1975, a similar sized chip could hold about 30 000 components, allowing the production of desktop computers with increasingly sophisticated processing capabilities. New methods of producing chips with smaller and more complex circuits has meant that chips may now contain millions of electronic components.

The manufacture of silicon chips

Silicon chips make up only a very small part of the circuit boards and memory cards in electronic devices. The chips are usually no larger than the fingernail on your little finger. They are very delicate and can be damaged by vibrations, moisture, heat, magnets and light. The silicon chips are glued to a plastic case and linked to metal pins by thin copper or aluminium wiring.



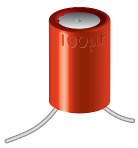
A close-up of silicon chips

A silicon chip that is able to store information, process it and control other electric circuits is called a **microprocessor**. Since their development in 1971, microprocessors have been used in calculators and computers. As microprocessors became less expensive and smaller, they began to be used in household appliances like microwave ovens, televisions and washing machines. The inclusion of microprocessors in these appliances makes them 'programmable' and able to perform tasks with little human effort. Microprocessors are used in automated equipment in many industries including manufacturing, mineral processing and the car industry. They are also used in cars, phones, cameras, watches and many other devices that need to store and process information.

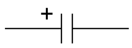
3.4.3 Electronic building blocks

Apart from resistors, the most common electronic components in circuits are capacitors, diodes and transistors.

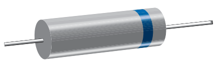
Capacitors store electric charge for a short time before allowing it to flow to other parts of a circuit. The amount of charge that can be stored per volt across a capacitor is called its capacitance. Capacitance is measured in units of farad (F) or microfarad (μF).



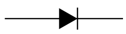
Capacitor



Symbol

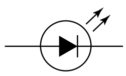


Silicon diode



Symbol

Light-emitting diode (LED)

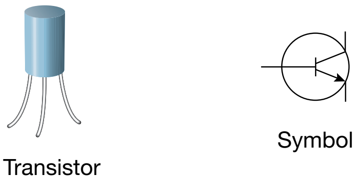


Symbol

Diodes allow electric current to travel through them in only one direction. They look like small resistors but have a single band at one end. This end of the diode is the negative end and should be connected closer to the negative terminal of the power supply.

LEDs are often used as indicator lights in electrical appliances. An arrangement of seven LEDs can be used in devices like watches, clocks, calculators and digital meters to display any number between 0 and 9. The display circuit is designed so that the LEDs light up in different combinations.

Liquid crystals displays (LCD) are often used instead of LEDs for the same purpose. Small voltages cause the molecules in liquid crystals to rearrange themselves, changing the colour of the crystals.



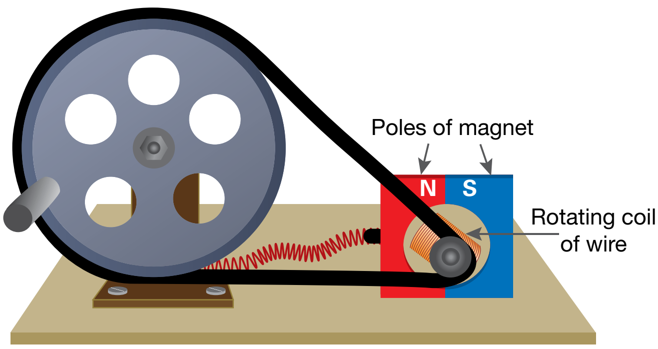
Transistors act like switches, changing the size or direction of electric current as a result of very small changes in the voltage across them. This makes them ideal for use in devices that amplify sound. However, they have many other uses and most electronic devices contain chips that hold many microscopic transistors.

3.4.4 Generating electricity

The electricity used to charge your mobile phone and laptop and to power other electrical appliances common in society today is the result of an energy transformation that takes place in power stations, often thousands of kilometres from the consumer. In a power station fossil fuels such as coal are burnt, and the chemical energy released is used to boil water that generates steam, which at high pressure has sufficient kinetic energy to turn the blades of huge turbines. The turbines then spin industrial generators, creating AC electricity. Cold water is pumped through a condenser to convert the steam returning from the turbine back to water. This water, which is still hot, is pumped into a cooling tower where some steam escapes into the atmosphere.

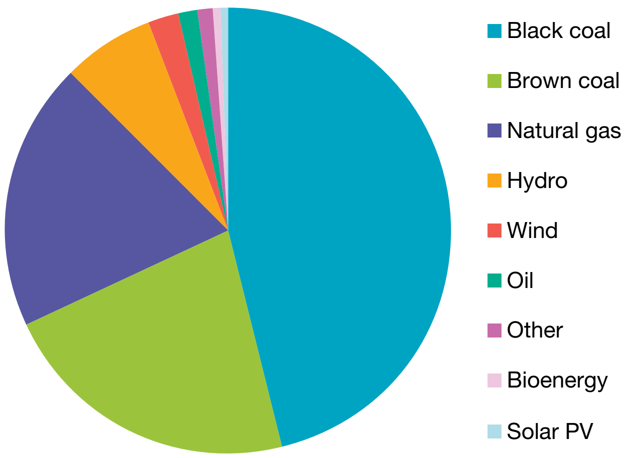
Generators work on the principle that a coil of wire moving in a magnetic field creates a current of electricity. This can be demonstrated with a simple hand generator.

A model generator demonstrates that motion between a coil of wire and a magnetic field creates a current in the coil.

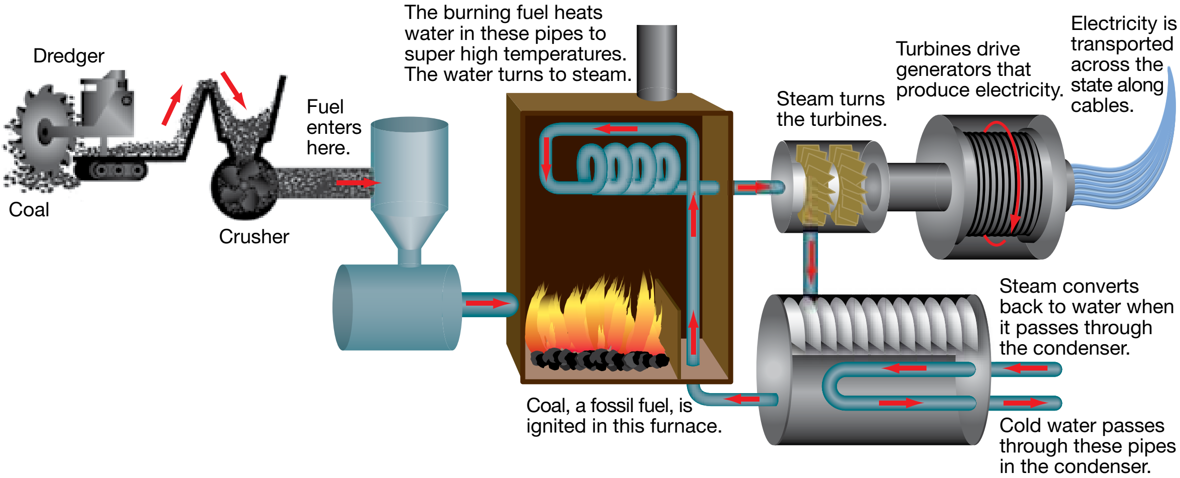


Coal fired power plants account for over 75% of Australia's electricity production and natural gas a further 15%. These fossil fuels are examples of non-renewable energy resources. Australia relies so heavily on coal in particular because coal is a relatively cheap energy source in Australia and coal reserves are relatively abundant along the eastern seaboard, where the majority of electricity is generated and consumed.

Energy sources used in electricity generation in Australia. Fossil fuels like coal, gas and oil account for over 90%.



The chemical energy contained in fossil fuels like coal is used to generate electricity in power stations.



INVESTIGATION 3.12

Electricity generation

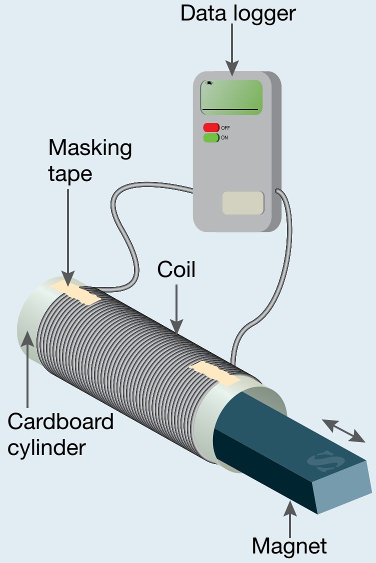
AIM: To investigate the principles of electricity generation

You will need:

solenoid or coil of laminated wire wound around a cardboard cylinder
micro-ammeter
2 wire leads
2 bar magnets
rubber band
handheld generator
data logger and voltage sensor

Part A: Current produced by a solenoid

- Connect the solenoid to the micro-ammeter.
- Move the north pole of the bar magnet quickly into an end of the solenoid and record the current produced — both its magnitude and whether it is positive or negative.
- Remove the bar magnet quickly and record the current again.
- Carry out each of the following investigations and record your observations for each of the following:
  (a) the effect of moving the magnet in and out more rapidly
  (b) whether holding the bar magnet stationary in the solenoid generates a current
  (c) the effect of increasing the strength of the magnet — this can be done by attaching the north poles of two bar magnets together using a rubber band.



Part B: Voltage produced by a hand generator

- Connect the voltage sensor to the data logger and connect the leads of the voltage sensor to the terminals of the hand generator.
- Record the voltage produced as the handle of the generator is turned. You may be able to generate AC or DC or both. Monitor the effect of spinning the generator faster and slower.

Discussion

1. What magnitude of current is generated by moving the bar magnet in and out of the solenoid? Don't forget to include scientific units.

2. Is the direction of the current affected by the direction of the moving magnet? Are you generating AC or DC electricity? Explain.
3. Is motion required for a current to be generated? Refer to your observations.
4. Do the speed of the magnet and the strength of the magnet affect the size of the current? Discuss.
5. Did your generator create AC or DC electricity? How do you know?
6. What energy transformation is taking place in the hand generator? What takes the place of your hand in the turbine of a coal power station?
7. How does the speed of the generator affect the voltage produced? Are there parallels with the activity examining the current in a solenoid?

3.4.5 Non-renewables versus renewables

Our dependence on coal and gas to generate electricity brings with it certain responsibilities — for government, industry, power companies and individuals. The first step is to be aware of the problems caused by using fossil fuels and the alternative methods of generating electricity.

One of the products of the combustion of fossil fuels in power stations is carbon dioxide. Increased levels of carbon dioxide in the atmosphere is contributing to global warming which could have significant consequences for the climate and the biosphere in the years ahead. In addition, some of the chemicals in the coal burnt in power stations produce gases like sulfur dioxide and various nitrogen oxides, causing **air pollution**. These gases may also dissolve in water vapour in the atmosphere, creating acid rain. Acid rain speeds up the weathering of rocks, eats into building materials, and threatens plants and other living things that depend on the plants.

However, there is another form of pollution that is not so obvious. During electricity generation heat energy is transferred to the surroundings, increasing the temperature of the air and waterways. This increase in the temperature of the environment is known as **thermal pollution**. Thermal pollution of lakes is a serious problem as the increased temperature (even one or two degrees Celsius) decreases the amount of oxygen dissolved in the water, threatening organisms that live in the water and within the ecosystem.

3.4.6 Looking for alternatives

The demand for electrical energy is increasing, both in Australia and worldwide and so the supply of **fossil fuels** like coal, natural gas and oil used in power stations is diminishing.

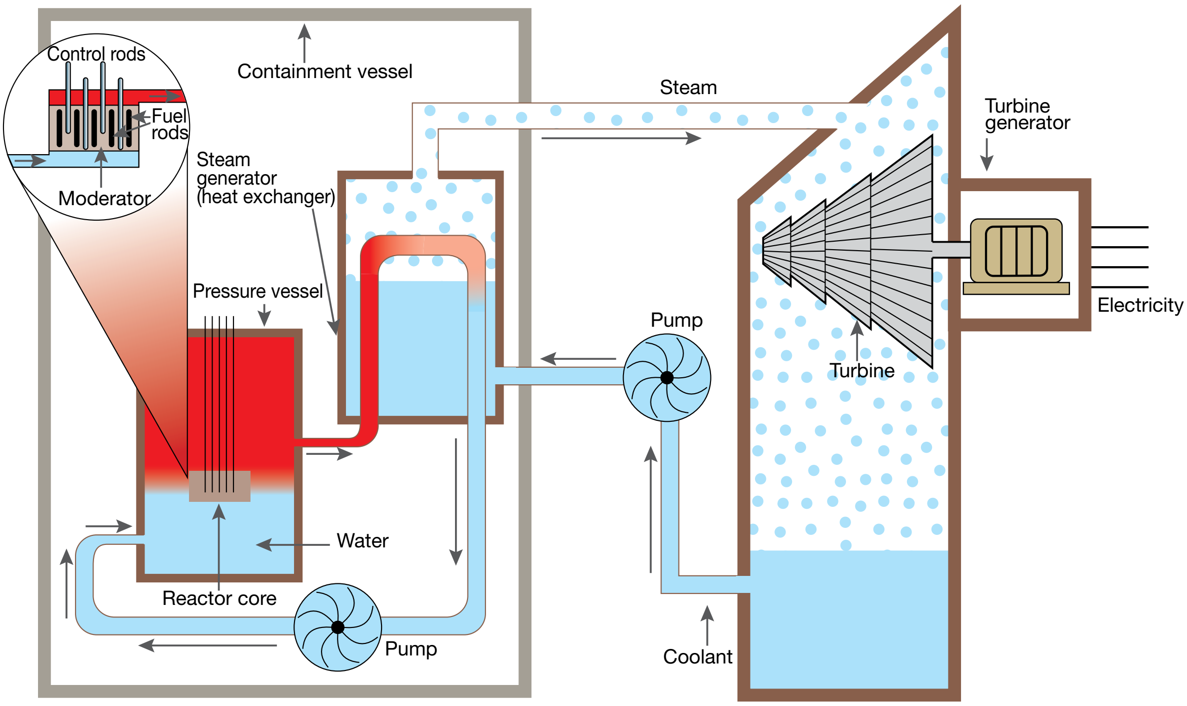
	Known reserves based on current rates of production and use (years)	
Fossil fuel	**Australasia**	**Global**
Coal	53	112
Oil	14	54
Natural gas	35	64

The air, water and thermal pollution caused by burning fossil fuels to generate electricity is not acceptable to many people. So even though the cost of electricity production using fossil fuels is low by comparison with newer non-renewable technologies, many governments throughout the world are supporting research and the development of alternative methods for electricity generation.

3.4.7 Nuclear energy

Nuclear power stations use energy released from the nuclear fission of radioisotopes like uranium to drive turbines that generate electricity in the same way that fossil fuel power plants operate. Like fossil fuels, uranium is a non-renewable resource, but because nuclear power plants do not rely on the combustion of fossil fuels to generate electricity, greenhouse gases are not emitted. The critics of nuclear power object to this alternative because the nuclear waste produced must be stored for many years and because of the risk of nuclear accidents.

In a nuclear power plant fuel rods, generally of uranium oxide, are placed within the reactor core. The rods are bombarded with neutrons to initiate a fission reaction that liberates huge quantities of heat energy and further neutrons. A moderator within the core, usually water or graphite, slows the neutrons released from fission so that they cause more fission. Control rods, made of neutron-absorbing material such as boron, are inserted or withdrawn from the core to control the rate of reaction. A liquid or gas is circulated through the core to transfer the heat produced to the steam generator from which high pressure steam is used to drive a turbine and generate electricity.

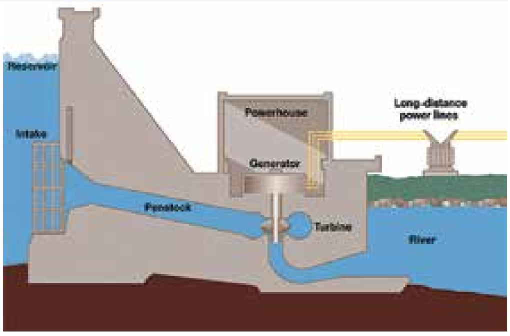


While Australia is yet to utilise this technology for generating electricity, there are 439 nuclear reactors operating in 30 countries that account for around 17 per cent of world electricity production. Nuclear power accounts for a large proportion of the electricity supply in many parts of Europe, Japan and the USA.

3.4.8 Hydro-electricity

A small proportion of Australia's electricity is generated by hydro-electric power plants, a renewable source of energy. As water stored in a dam at high elevation falls through pipes, it gains kinetic energy. This kinetic energy is used to turn turbines that generate electricity. This does not involve combustion of a fossil fuel and so does not generate greenhouse gases. A disadvantage of hydro-electricity is that it involves damming river systems and thus alters ecosystems.

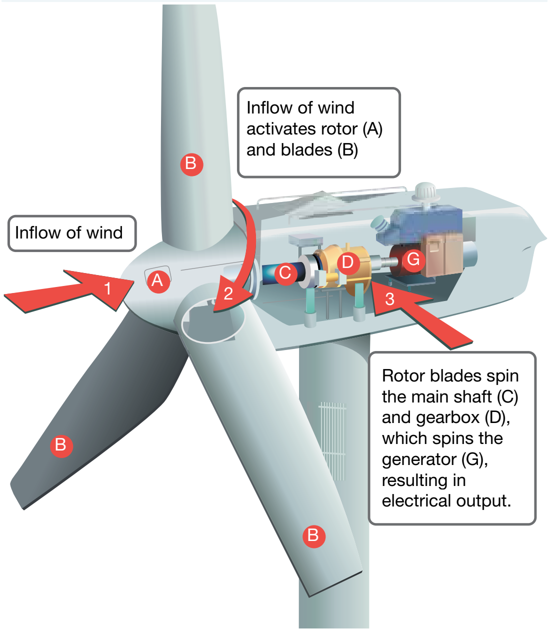
Turbines in a hydro-electric power plant are driven by the kinetic energy of water.



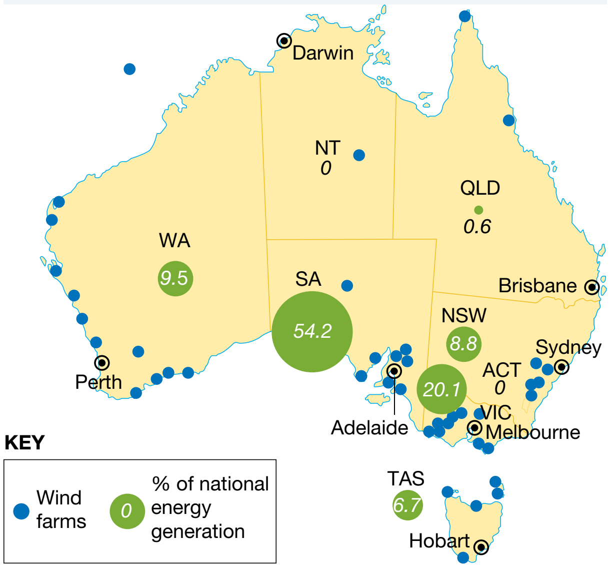
3.4.9 Wind energy

Wind ‘farms’ dotted with wind turbines can be found in many countries throughout the world, including Australia. One of Australia’s largest wind farms is located near Ararat in Victoria and consists of 35 towers generating 53 000 kilowatts of electricity. In comparison, one of New South Wales’ smallest coal-fired power stations at Redbank produces 150 000 kilowatts of electricity while the largest, Baywater in the Hunter Valley, generates almost 20 times more. In 2011, 57 wind farms in Australia provided 1188 wind turbines generating sufficient electricity to power 900 000 homes or 2.7% of our nation’s electricity needs.

How a wind turbine works



Wind farms with percentage of national energy generation



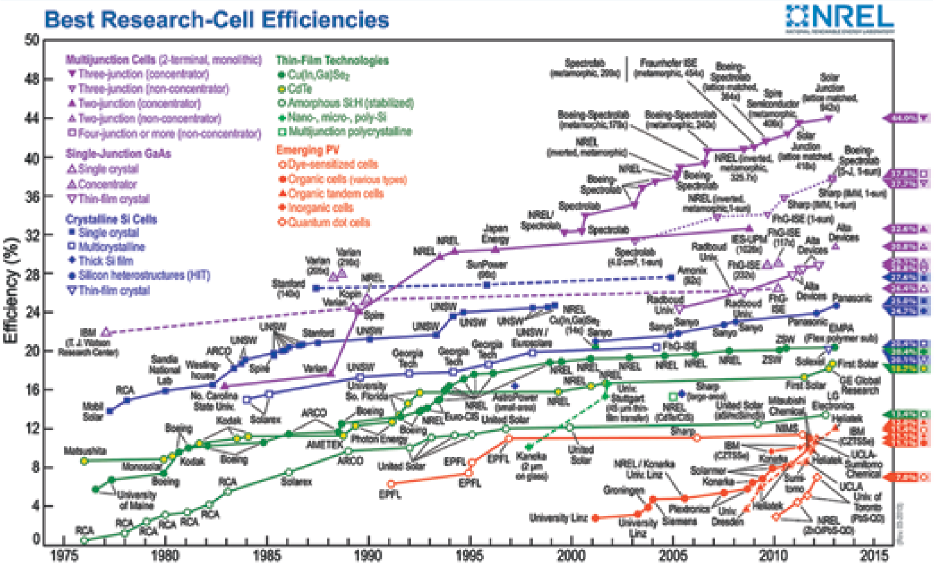
3.4.10 Solar energy

Electricity can be generated by solar energy in two different ways. **Photovoltaic cells**, often called solar cells, like those on the house illustrated below right, consist of silicon wafers, with impurities of other elements added like boron and phosphorus. When sunlight falls on the cells, electrons are emitted from the wafers creating an electric current. The most advanced solar cells convert over 40% of incident solar radiation to electrical energy. Scientists and engineers worldwide are endeavouring to develop more efficient photovoltaic cells.

Another solar technology, solar thermal power stations, uses arrays of curved mirrors to reflect sunlight onto tubes filled with oil. The hot oil is used to heat water to form steam which drives turbines just like those in coal-fired power stations.

Six to eight solar roof panels generate approximately 2300 KWh of electricity per year.

Competition between research institutions worldwide has led to new breakthroughs in photovoltaic technology and has resulted in greatly increased efficiency in the more advanced solar cells.



3.4.11 Biomass

Biomass is an energy source that involves burning waste vegetation or burning methane, the biogas produced by the breakdown of organic matter to drive small generators. In Australia biomass accounts for 15% of the electricity generated from renewable sources. In Queensland and northern New South Wales the waste vegetation from sugar production is used in commercial power generation. Small amounts of energy are also produced by burning wood waste at some timber mills.

Methane-powered generators at rubbish tips such as Woodlawn near Goulburn have taken in over 2.2 million tonnes of waste from the Sydney metropolitan area and Goulburn surrounds, producing up to 3000 KWh of green electricity.

Woodlawn waste complex and its biogas generator. Woodlawn is a worked out copper, lead and zinc mine and as a landfill site has capacity for 70 years of Sydney's waste.

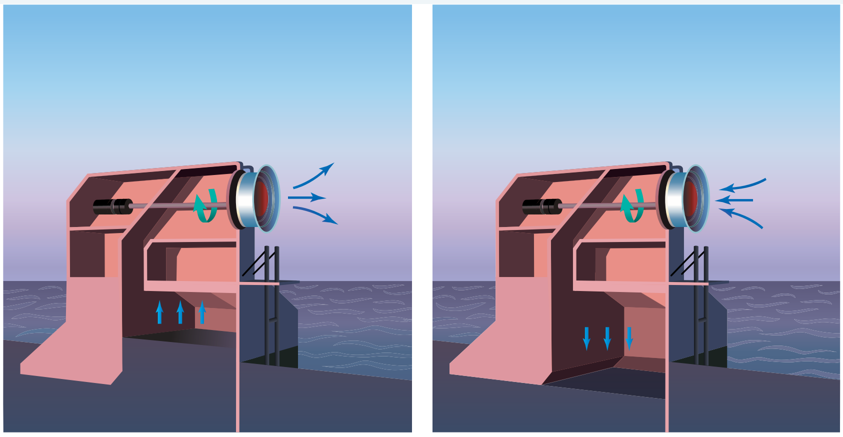
3.4.12 Ocean energy

Electricity can be generated using a range of ocean energy sources including tides, waves, marine currents, thermal layering and salt gradients. Only two of these sources are being investigated for development in Australia — tides and waves.

Tidal power stations harness energy from the rise and fall of tides and are currently being used in France, Russia and China. Turbines with reversible blades are placed at the entrance to a bay in areas with extremely high and low tides. Water moving in and out of the bay turns the turbines to generate electricity. A tidal range of at least 5 m is considered necessary for large-scale installations. Several areas were identified as suitable in the Kimberley region on the northwest coast of Western Australia.

Wave energy systems do not make use of waves as such, but rather the swell that occurs in deeper water or can be captured by coastal installations. Wave energy, for example, is being used to generate electricity in Norway. The waves flow into a narrow channel on the coast, where they are funnelled towards turbines. CSIRO studies show that waves off Tasmania's west coast have three times as much energy as those in Norway. One wave energy technology is being trialled off the coast of South Australia.

Electricity generation using wave energy is being developed in Port Macdonnell off the coast of South Australia. In this system, as waves rise (in the diagram on the left) and fall (in the diagram on the right) within a water column, it acts like a piston, driving a column of air ahead of it and through the turbine. The plant is expected to generate 1000 kilowatts of electrical power.



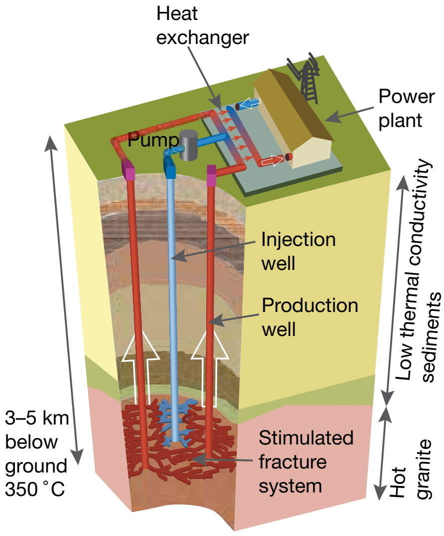
3.4.13 Geothermal energy

Heat energy trapped within the Earth's crust can be used to turn water into steam and drive turbines in Z power stations. Volcanically active regions of New Zealand have been tapped as a source of geothermal energy for electricity generation since the late 1950s and currently provide 7% of New Zealand's total electricity generation.

Hot fractured rock (HFR), normally granite, can be found at temperatures of over 250 °C at depths of 3 to 5 km. This represents an enormous energy resource that can be used to generate high-pressure steam to drive turbines in electricity generation. Preliminary work by Geoscience Australia suggests a potential HFR resource equivalent to 20 000 years of Australia's energy use at 2005 levels.

To develop this resource, boreholes need to be drilled into the HFR to allow the injection of water, which passes through fractures in the rock and returns to the surface as steam. Success primarily depends on the ability to drill deep into hot hard rock. Current drilling technology limits geothermal extraction to 5 km — at this depth sufficiently high temperatures to make the process

Geothermal energy from hot rocks involves circulating water via boreholes. The water returns to the surface super-heated then passes through a heat exchanger. Steam produced by the heat exchanger is used to generate electricity in a conventional steam turbine.



economically feasible occur only in ‘hot spots’ of above average temperature. Future development of drilling and extraction technologies is expected to expand the available geothermal resources.

INVESTIGATION 3.13

Solar cells

AIM: To investigate the performance of a solar cell under different lighting conditions

You will need:

a solar cell
a milli-ammeter or milli-voltmeter
wire leads

- Investigate the performance of the solar cell under different light conditions. You may like to try artificial lighting in the classroom, a dim area within the room, bright sunlight and outdoor shade.
- Record the current or voltage produced.

Discussion

1. Under which conditions was the greatest current/voltage produced?
2. Under which conditions was the least current/voltage produced?
3. Bright artificial light creates a similar current and voltage as bright sunlight. Do you agree? Explain why.

3.4 Exercise: Remember and think

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

Remember

1. **Identify** three household devices that utilise computer chips and integrated circuits and **outline** the use of each.
2. **Identify** an element incorporated in computer chips and **identify** a metal often used in the wiring of those chips.
3. Copy and complete the table below.

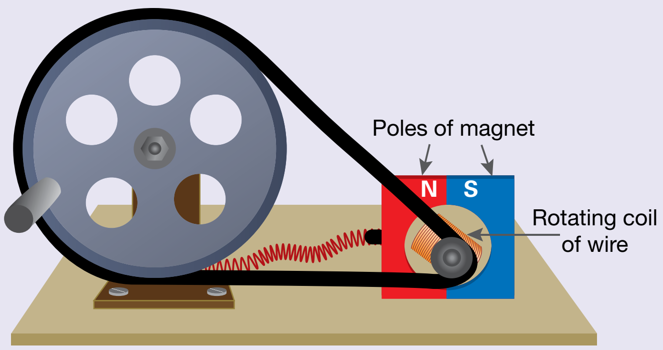
Electronic components

Component	Circuit symbol	Function
Capacitor		
Diode		
Transistor		

4. **Identify** the role of each of the following in a nuclear reactor:
   (a) moderator
   (b) control rods.

Think

5. **Identify** the role of the components of the generator labelled at right.
6. Use a table to list each of the following energy sources as renewable or non-renewable:
   (a) nuclear
   (b) hydro
   (c) coal



(d) wind
(e) biomass
(f) solar
(g) geothermal
(h) ocean energy
(i) natural gas

Think

7. How does photovoltaic (solar) energy technology differ to other forms of energy sources in the generation of electricity?

Analyse

8. Refer to the figure Wind farms with percentage of national energy generation. Which state in Australia satisfies the most of its electricity needs using wind power and which uses the least? **Explain** why this might be the case.
9. (a) Use the data contained in the table below to plot a line graph of the amount of energy produced using renewable energy sources in Australia from 2004–05 to 2009–10. A terawatt hour (TWh) is 10^{12} watt hours
   (b) Which renewable energy source has increased in use the most over the five year period?

Australian electricity generation by fuel

	2004–05 TWh	2005–06 TWh	2006–07 TWh	2007–08 TWh	2008–09 TWh
Thermal					
Black coal	130.0	131.0	138.7	141.7	143.2
Brown coal	61.1	61.6	57.2	55.7	56.9
Oil	1.9	2.4	2.1	2.7	2.6
Gas	32.3	30.8	32.0	37.7	39.1
Total thermal	225.3	225.8	230.1	237.8	241.8
Renewables					
Hydro	15.3	15.7	14.3	11.9	12.3
Wind	0.9	1.7	2.6	3.1	3.8
Solar	0.1	0.1	0.1	0.2	0.3
Biomass	1.1	1.1	1.1	1.2	1.5
Biogas	0.8	0.9	0.9	1.0	1.3
Total renewables	18.1	19.5	19.0	17.4	19.2

Source: ABARES.

10. The table on the next page shows energy consumption by various industries in Australia over time.
    A petajoule (PJ) is equivalent to 10^{15} Joules.
    Which industry has increased its electricity use the most as a percentage over the time period? **Account for** this increase.

Energy consumption in Australia by industry

	1974–75 PJ	1979–80 PJ	1989–90 PJ	1999–00 PJ	2008–09 PJ
Agriculture	39	47	55	72	95
Mining	65	81	160	273	429
Manufacturing	928	965	1067	1192	1257
Electricity generation	540	743	1066	1427	1744

Investigate

11. **Investigate** the generation of electricity by hydro-electric power stations in Australia. Include information on their location, history and the process of electricity generation. Present your research as an educational tourist brochure.
12. Coal seam gas is a controversial source of energy and its mining and use are currently being explored in Australia. What is coal seam gas and why do many sectors of society oppose it?
13. Survey your friends and family to develop a list of at least 20 strategies to cut your electricity use and so reduce your power bills. Use the **Reducing power usage** weblink in the Resources tab to compare your list with the list online.

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Explore more with this weblink: Reducing power usage

3.5 Project: Go-Go Gadget online shop

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3.5.1 Go-Go Gadget online shop

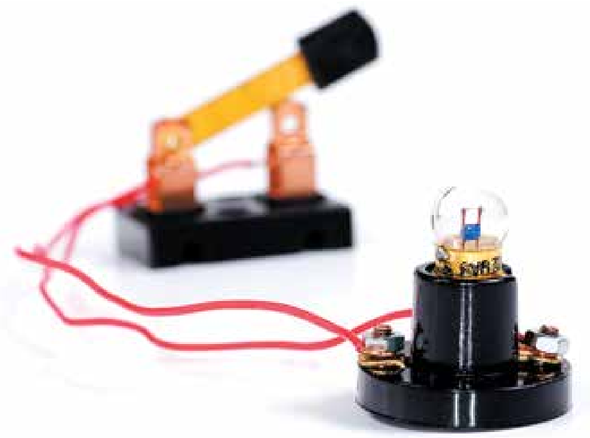
Scenario

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.

3.6 Review

3.6.1 Electric circuits

- design, **construct** and draw circuits containing a number of components **3.2**
- **define** the terms 'current', 'voltage' and 'resistance' **3.2**
- **identify** the symbols for current, voltage and resistance and their units of measurement **3.2**
- **describe** voltage, resistance and current using analogies **3.2**

- **outline** how current and voltage can be measured in circuits 3.2
- **describe** the relationship between voltage, resistance and current 3.2
- solve problems using Ohm's Law 3.2
- **compare** the characteristics and applications of series and parallel circuits 3.2

3.6.2 Electricity at home

- **compare** AC and DC electricity 3.3
- apply the law of conservation of energy to energy transfers and transformations in electrical appliances 3.3
- **describe** the features of electrical circuits in the home, including safety features 3.3
- **outline** how electrical energy use is monitored and charged 3.3
- **investigate** the energy efficiency of domestic appliances 3.3
- **discuss** how the values and needs of contemporary society have led to a focus of scientific research on the efficient use of electricity 3.3

3.6.3 Meeting our future electricity needs

- **relate** developments in electronics to the growth in the use of electronic devices 3.4
- **describe** how generators create electricity and relate this to the commercial production of electricity in power stations 3.4
- **identify** examples of renewable and non-renewable energy sources 3.4
- **account for** the research and development of technologies using non-renewable energy sources 3.4
- **describe** scientific and technological developments in the generation of electricity using renewable energy 3.4

Individual pathways

ACTIVITY 3.1	ACTIVITY 3.2	ACTIVITY 3.3
Investigating electricity doc-10639	Analysing electricity doc-10640	Investigating electricity further doc-10641

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FOCUS ACTIVITY

Option 1

Conduct a survey of the electrical appliances on display in a department store. Focus on a range of models within a category of appliance such as refrigerators or washing machines. Collect data on each model including the capacity, e.g. fridge volume, as well as the energy rating, estimated annual energy use, cost and any special features. Construct a poster or multimedia presentation to critique the models surveyed. Include a calculation of the estimated running costs, appropriate graphs to display your data and photos of each of the models.

Option 2

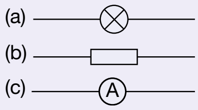
Join with other members of your class for an energy summit. As a contributor you will research a method for generating electricity using any renewable or non-renewable energy source and promote it as the best way of meeting Australia's future electricity needs. For the method of generation selected, examine how the technology works as well as the advantages and disadvantages of this technology. Present your information in the summit and be prepared to critique other methods of electricity generation and to defend your mode of generation. Be sure to have lots of facts and figures at your fingertips to present objective arguments and to counter the proposals of others.

Access more details about focus activities for this topic in the Resources tab (doc-10638).

3.6 Review 1: Looking back

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au. *Note:* Question numbers may vary slightly.

1. **Define** each of the following terms:
   (a) electric current
   (b) load in a current
   (c) components in series
   (d) components parallel
   (e) conductor.
2. Draw a circuit diagram to show how a voltmeter and ammeter are used to measure the voltage drop and the current flowing through a single light globe connected to a 6-volt DC power supply. Label the positive and negative terminals of the power supply and each side of the meter with + and – symbols.
3. Complete the table at right by **identifying** the missing quantity, unit or abbreviation.
4. **Identify** each of the following circuit components:

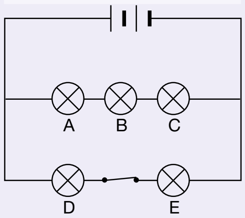


Electrical quantities and their units

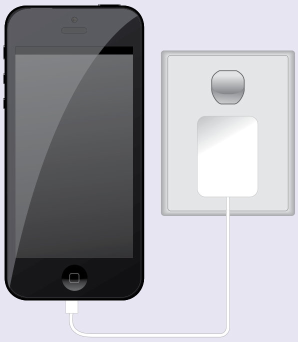
Quantity	Unit name	Unit abbreviation
Voltage	volt	
Electric current		A
	ohm	
Electrical power		W
Electrical energy		J
		kWh

Questions 5–11 refer to the circuit diagram at right. The light globes, labelled A–E, are identical to each other.

Circuit diagram for questions 5–11



5. **Identify** the light globe(s) connected:
   (a) in series with globe A
   (b) parallel with globe A.
6. The electric current flowing through globe B is 200 mA and the electric current flowing through globe D is 300 mA. **Predict** the electric current flowing:
   (a) through globe A
   (b) from the power supply
   (c) through globe E.
7. If the voltage drop for globe C was measured to be 4 volts, **predict** the voltage across:
   (a) globe A
   (b) the terminals of the power supply
   (c) globe E.
8. If the filament in globe B was to break, **predict** which of the light globes would remain glowing.
9. If the switch in the circuit was opened, **predict** which light globe(s) would stop glowing.
10. **Outline** how you could make all of the light globes stop glowing without opening the switch or turning off the power supply.
11. The voltage across globe C is measured to be 4 volts and the current flowing through it is 200 mA.
   (a) **Identify** the electric current flowing through globe C in amps.
   (b) **Calculate** the resistance of globe C while this current is flowing.
12. Design and draw a circuit diagram for a studio apartment containing an AC power source, a fuse, three parallel lights with two master switches that can operate all three lights simultaneously from different locations in the apartment.
13. Power points in Australia provide 240 V AC electricity. **Explain** what this means.
14. One of the arguments against the use of coal-fired power stations for generating electricity is the air pollution they cause. However, hydro-electric power stations can also damage the environment. **Explain** how.
15. **Identify** the method(s) of generating electricity that:
   (a) could be described as renewable energy sources
   (b) involve the use of energy from the sun
   (c) create thermal pollution.



16. The mobile phone charger shown in the figure at right contains a transformer and a rectifier.
    Outline the purpose of the:
    (a) transformer
    (b) rectifier.
17. **Explain** how each of the following electrical safety devices protects us from injury:
    (a) earth wire
    (b) circuit breaker
    (c) safety switch.
18. **Calculate** how much electrical energy, in kilowatt hours, is transformed by a 70-watt electric blanket over a period of eight hours.
19. **Calculate** how much it would cost to heat a frozen pie in a 650-watt microwave oven if it takes two minutes to heat the pie and the cost of electrical energy is 14 cents per kilowatt-hour.
20. **Describe** the principle by which generators create an electric current.
21. **Explain** why the development of electronics with integrated circuit technology has revolutionised society.
22. **Describe** the process by which a nuclear reactor generates electricity.
23. Draw a table to **summarise** each type of renewable energy source for electricity generation in Australia. In the first column, **identify** each energy source and in the second outline what each involves.

Test yourself

1. A useful analogy for an electric circuit is a bakery supplying bread to a supermarket. What do each of the following in the analogy equate to in an electric circuit? **(1 mark)**

	The bakery	The delivery van	Speed of the delivery vans	The loaves of bread	Supermarkets requiring delivery
A	Electrical energy	Battery	Current	Resistance	Charges
B	Battery	Charges	Current	Electrical energy	Resistance
C	Electrical energy	Current	Charges	Resistance	Battery
D	Charges	Current	Resistance	Electrical energy	Resistance

2. The correct units of measurement for voltage, charge, current and resistance are
   (a) amperes, coulombs, volts and ohms.
   (b) volts, coulombs, amperes and ohms.
   (c) joules, coulombs, amperes and ohms.
   (d) joules, amperes, coulombs and degrees Celsius. **(1 mark)**
3. A 6.0 V DC power source supplies two light globes connected parallel. If the resistance of the circuit is 12 Ω, the voltage and current for each light globe is
   (a) 3.0 V and 0.5 A.
   (b) 6.0 V and 0.5 A.
   (c) 3.0 V and 0.25 A.
   (d) 6.0 V and 0.25 A. **(1 mark)**
4. A 1000 W toaster takes 2 minutes to toast a slice of bread. The energy used over that time is
   (a) 120 000 J.
   (b) 2000 J.
   (c) 1000 J.
   (d) 33 J. **(1 mark)**
5. A circuit is supplied with 12 V DC. Two identical globes are connected parallel. If the current through one of the globes is 0.3 A, **calculate**:
   (a) the total current **(1 mark)**
   (b) the total resistance in the circuit. **(1 mark)**

6. Create a flow chart that shows all of the energy transformations and transfers that take place in the generation and transmission of electricity from the time that brown coal begins to burn until the time that you use a hair dryer to dry your hair. Remember that during each energy transformation or transfer, some of the energy is 'lost' to the environment as heat. **(4 marks)**

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Complete this digital doc: Worksheet 3.5: Electricity at work puzzles (doc-12751)

Complete this digital doc: Worksheet 3.6: Electricity at work summary (doc-12752)