

Electricity at work

4

Electricity and magnetism could be described as 'close relatives'. Many of the devices that you use every day contain electric motors or speakers. Such devices depend on the magnetic effects of electricity. The generation of electric power for homes and industry also relies on the close connection between electricity and magnetism.

Think about these

What is the connection between electricity and magnetism?

How does an electric doorbell work?

What is inside a loudspeaker?

How does an electric motor work?

How is the electric power that you 'plug into' every day supplied?

What is a brownout?

How can the wind be used to generate electricity?

Key outcomes

Describe the effect of electronic and electrical components in the operation of electromagnetic devices.

Describe the operation of a communication system and explain associated energy transfer processes.



YourQuest

Electricity — it's everywhere!

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 by members of the household?
 - (b) for heating or cooling?
 - (c) for lighting?
 - (d) for entertainment?
3. Which devices need to be connected to a power point while they are in normal operation?

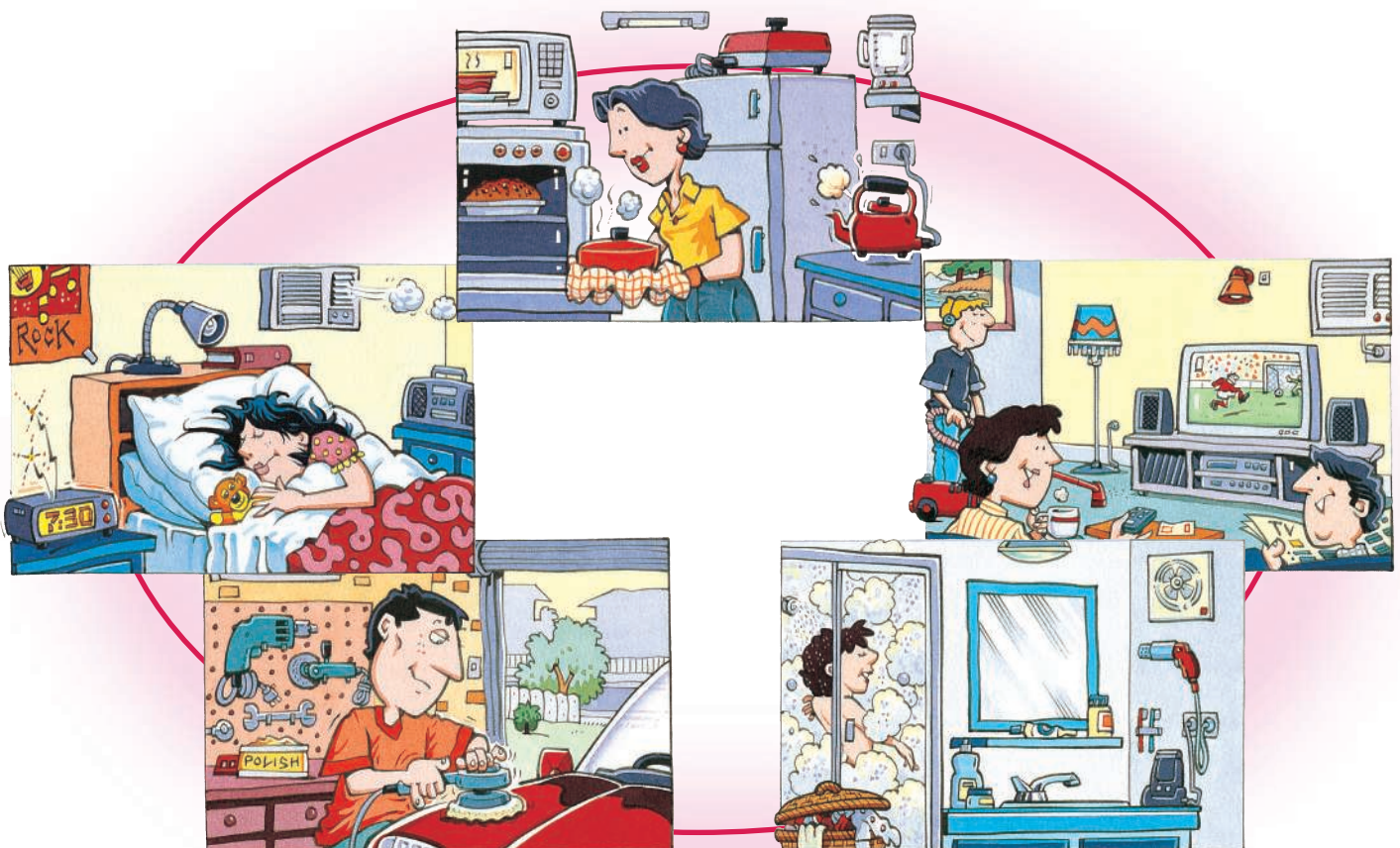
4. Which devices are powered by rechargeable or non-rechargeable batteries?
5. Which devices contain motors?
6. Which devices would you expect to contain permanent magnets or electromagnets?

What's the connection?

THINK

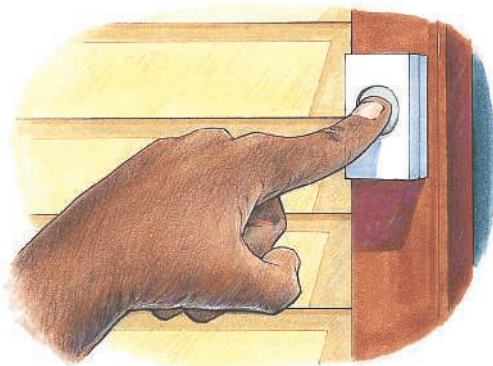
You probably already know quite a lot about electricity and magnetism. Use what you already know to answer the following questions.

7. What is a magnetic field and how can you know when it is present?
8. What is an electric field and how can you demonstrate its existence?
9. Describe at least one example of evidence that there is a connection between electricity and magnetism.



Ring that bell

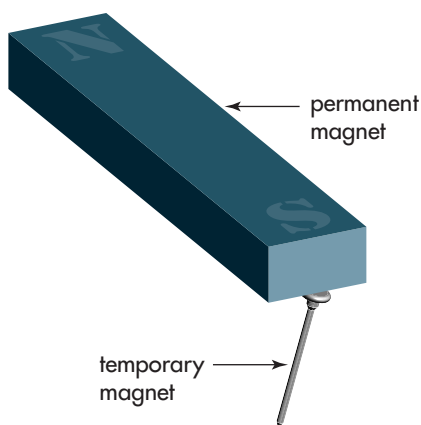
Your visitor pushes a doorbell button outside your door and an electric current flows if the doorbell is connected to the button by wires. The magnetic effects of electricity are used to make a doorbell ring.



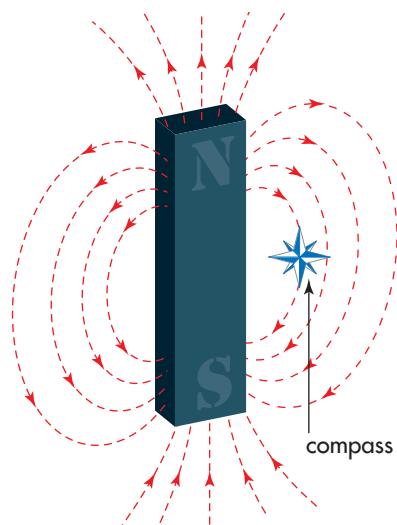
A magnetic attraction

Magnets attract iron and alloys containing iron. They also attract alloys containing nickel and cobalt, which, like iron, have magnetic properties. All magnets, no matter what their shape, have a **north pole** and a **south pole**. Like poles of magnets repel while unlike poles attract. **Permanent magnets** retain their magnetism at all times, while **temporary magnets** (like the nail suspended from the permanent magnet in the diagram below) lose their magnetism when removed from other magnets.

The region in which a magnetic force exists is called a **magnetic field**. A 'map' of a magnetic field around a bar magnet is shown below. It shows the direction of the magnetic force around the magnet. The direction of the magnetic force is defined as flowing away from the north pole and towards the south pole. A compass needle is a small magnet that lines itself up with the magnetic field. It always points in the direction of the magnetic force.



The nail is a temporary magnet while it is in contact with the permanent magnet.

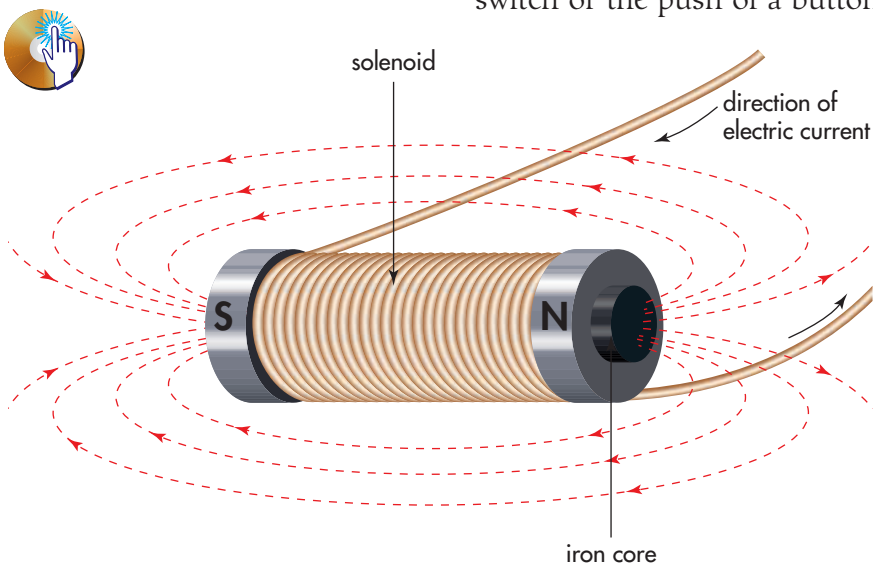


The magnetic field around a bar magnet. The closeness of the lines gives an indication of the relative strength of the magnetic force, which is strongest near the ends of the magnet.

Switched on magnets

An **electromagnet** is a temporary magnet consisting of a coil of wire and an iron core. The coil of wire is called a **solenoid**. When electric current flows in the coil, a magnetic field is produced in and around the solenoid. Without the iron core, a magnetic field would still be created. However, it would not be as strong. The iron core increases the strength of the magnetic field while the current is flowing. The diagram below shows that, just like a bar magnet, one end of a solenoid is a north pole and the other end is a south pole.

A big advantage of electromagnets over other magnets is that the magnetic field can be turned on or off at the flick of a switch or the push of a button.



The magnetic field of a solenoid. An iron core inside the solenoid increases the strength of the magnetic field.

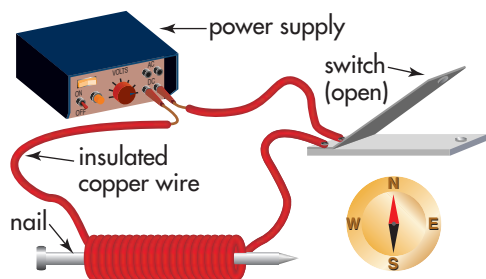
experiment

> A LOOK AT THE FIELD

You will need:

insulated copper wire switch
power supply compass
large iron nail

- Set up the circuit shown below. Wind 20 turns of wire around the nail. There will be a lot of wire left over but don't cut it.

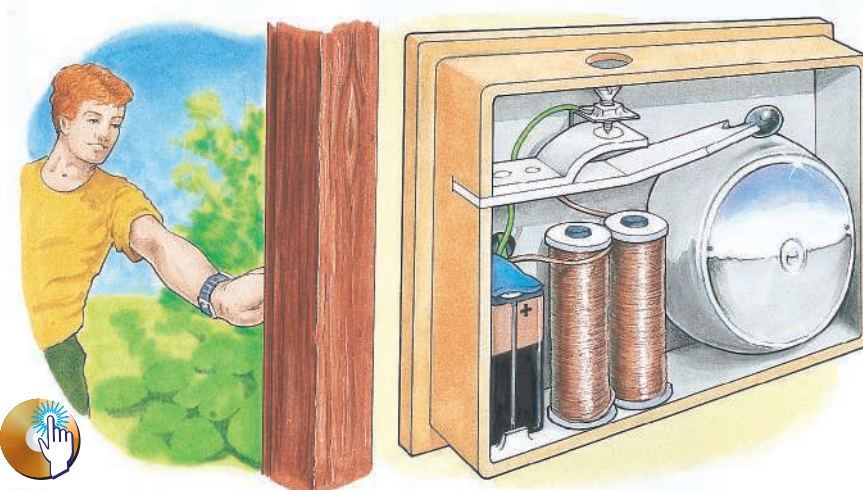


Circuit for an electromagnet

- Set the power supply to two volts.
- Use the compass to find north and line the nail up so that the sharp end points to the east.
- Place the compass at the sharp end of the nail as shown in the diagram and close the switch just long enough to observe any change in direction of the compass needle.
- State whether the sharp end of the nail is the north or south pole of the electromagnet. (Remember that the end of the compass that originally pointed north now points in the direction of the magnetic field.)
- Place the compass at the blunt end of the nail, close the switch briefly and observe the change in direction of the compass needle.
- Place the compass beside the nail, close the switch briefly and observe the change in direction of the compass needle.
- Draw a diagram of the magnetic field in and around your home-made electromagnet. Label the north and south poles.
- Reverse the connections to the terminals of the power supply so that the electric current travels in the opposite direction.
- Repeat your tests with the compass to find which end of the electromagnet is the north pole and which end is the south pole.
- What happens to the electromagnet when the direction of the electric current is reversed?

A look inside

When the button is pressed on the doorbell in the diagram on the right, an electric current flows through the electromagnets. The metal arm is attracted to the electromagnet, causing the hammer to strike the gong. The arm is also attached to a pair of contacts through which the current flows. When the arm moves, the contacts open and the current stops flowing to the electromagnets. The electromagnets lose their magnetism and the arm and hammer spring back to their original positions. The circuit is no longer complete. As the arm and hammer move back, the contacts come together and the current begins to flow again. The arm and hammer are attracted to the electromagnets and the gong is struck again. This process continues again and again — as long as the button is pressed.



A simple electric bell. This is a single gong bell. Bells that ring with a 'ding dong' sound use an electromagnet to hammer different metal bars one after the other.

activities

REMEMBER

- How is a temporary magnet different from a permanent magnet?
- What is a magnetic field?
- Explain the difference between an electromagnet and a solenoid.
- What advantage do electromagnets have over other types of magnet?

THINK

- Electromagnets are used to pick up scrap metal in junkyards. List other uses of electromagnets.
- Why does a compass needle line itself up with the magnetic field?

CREATE

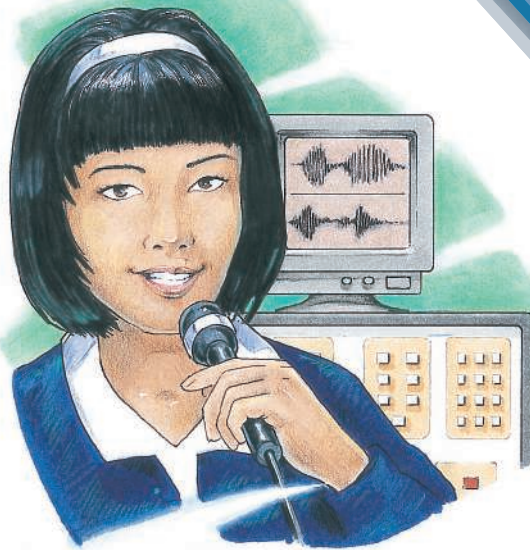
- Construct a device that uses an electromagnet.

Sounds cool

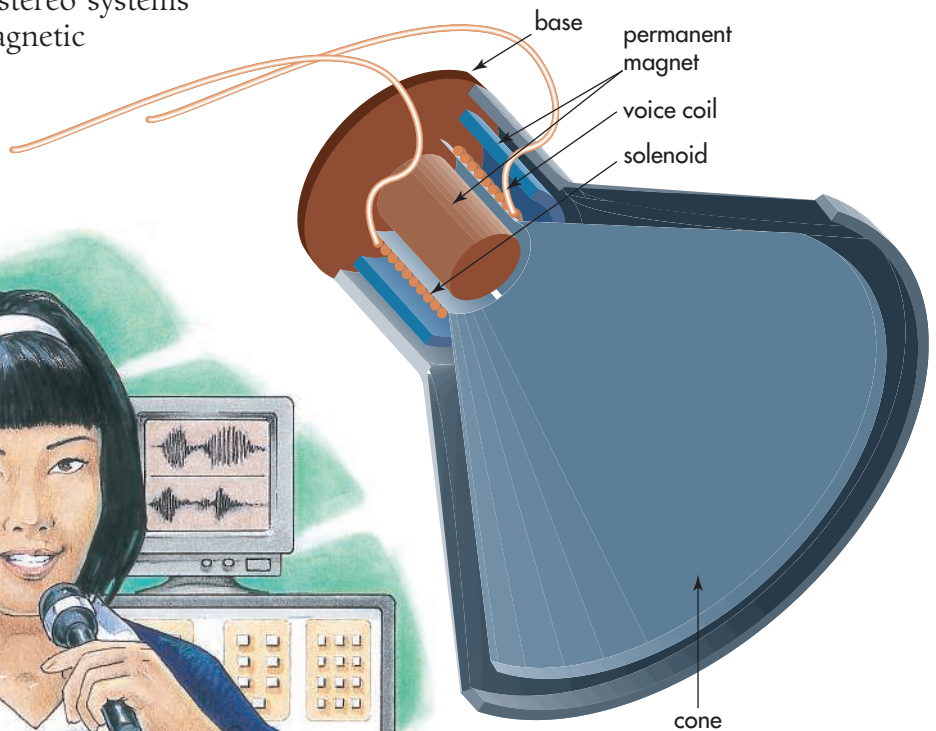
The speakers in television sets, most stereo systems and telephone earpieces use the magnetic field produced by an electric current to convert electrical energy into the sound energy that you hear.

Picking up vibrations

When you speak, sing or play a musical instrument, you cause the air around you to vibrate. A microphone or electronic 'pick-up' like those on an electric guitar converts the kinetic energy of vibrating air into electrical energy. In the illustration on the right, a cathode-ray oscilloscope displays the electric signal produced by a student singing into a microphone. The electric current changes direction rapidly — the higher the pitch of the note, the more rapidly the electric current changes direction.



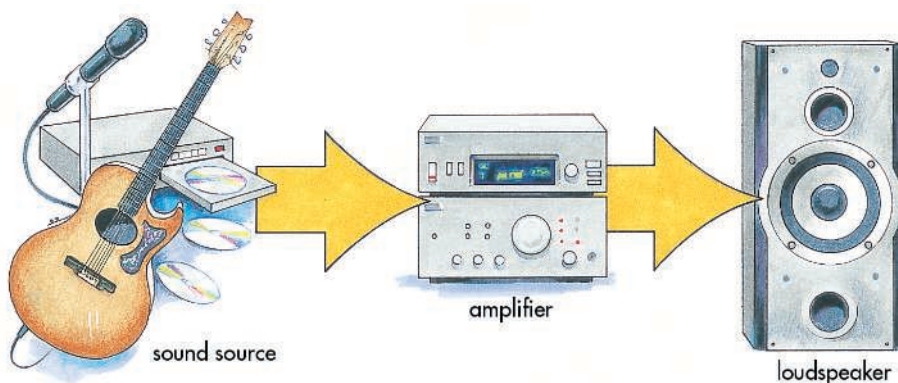
A microphone converts the kinetic energy of vibrating air into electrical energy.



Inside a moving coil speaker

Producing sound through a loudspeaker

CD players, MP3 players, radios and television sets also produce changing electric currents. These changing currents are so small that they need to be amplified before being sent to a loudspeaker.



The process of producing or reproducing sound through a loudspeaker

Inside a speaker

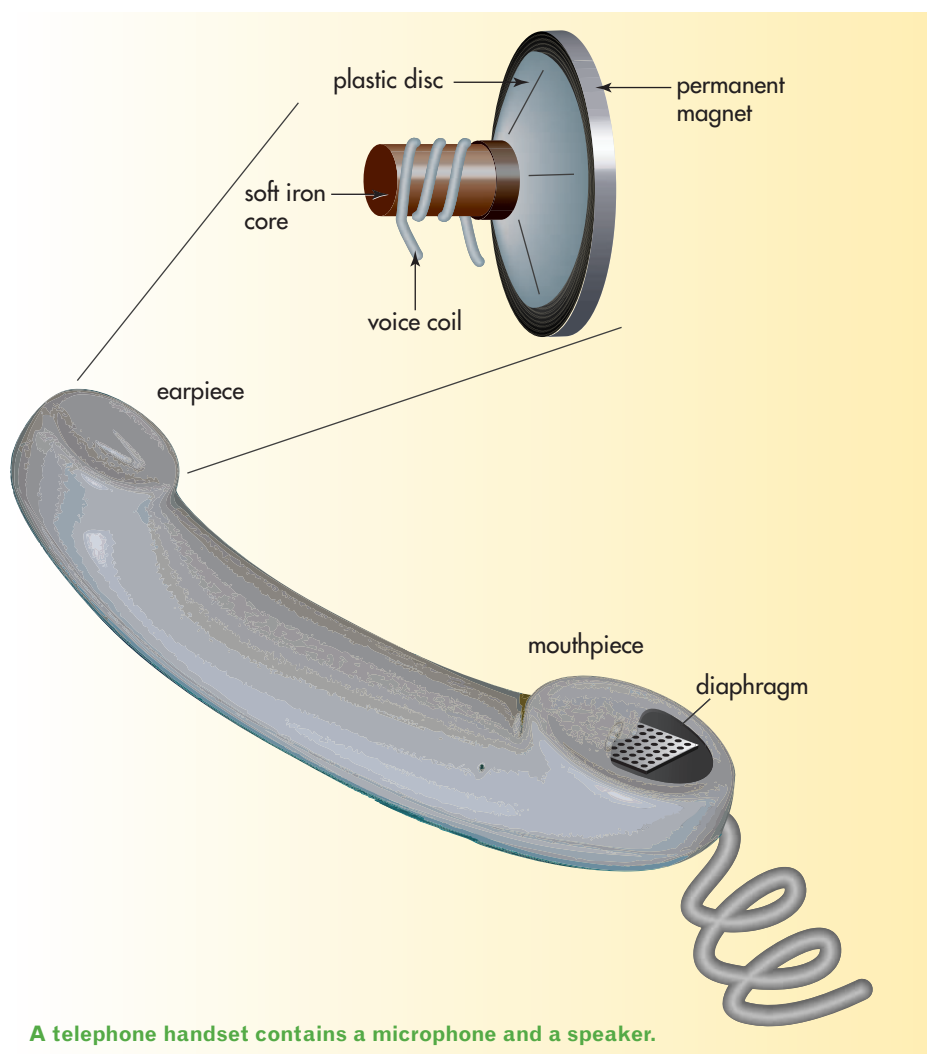
Inside a speaker, the electric current flows through the copper wire coil that is tightly wound around the base of the **cone**. The coil, known as the **voice coil**, and the base of the cone sit inside a cylindrical permanent magnet. Like any solenoid with electric current flowing through it, the coil produces its own magnetic field. However, in a speaker the electric current is rapidly changing direction. The coil moves backwards and forwards as it is alternately repelled and attracted to the base of the cylindrical magnet. The cone of the speaker, also known as the **diaphragm**, vibrates as the coil moves, causing the air nearby to vibrate, producing sound.

Phone talk

Your telephone handset has two parts: an earpiece and a mouthpiece. When you have a conversation on a telephone, a microphone in the mouthpiece converts sound into electrical energy so that a signal can be sent to the other telephone. A speaker in the earpiece converts the electrical energy received from the other telephone into sound energy.

The mouthpiece of a telephone handset contains a small metal plate (the diaphragm), which vibrates when you speak. A crystal beneath the diaphragm gets pushed out of shape when the diaphragm vibrates. The electric current flowing from the microphone changes with the shape of the crystal. In older telephones, carbon grains beneath the metal plate vibrated. As the grains moved closer together or further apart, the electric current passing through them changed.

The earpiece of a telephone handset contains a speaker. It consists of a permanent magnet, a voice coil wound around a soft iron core and a plastic disc (the diaphragm). The plastic disc is pulled backwards and forwards by the iron core in the voice coil as the electric current in the coil changes. In older telephones, a thin iron plate was used instead of a plastic disc. The iron plate was vibrated by the combined pull of the permanent magnet and the changing magnetic field produced by the voice coil.



A telephone handset contains a microphone and a speaker.

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When you sing a middle C through a microphone, the surrounding air particles vibrate 256 times a second (frequency = 256 Hertz). It sounds different to the middle C notes made by musical instruments because each instrument produces a slightly different waveform, which changes the quality of the note.

activities

REMEMBER

- 1 What is a permanent magnet's role in a speaker?
- 2 Why is the voice coil in a speaker attached to the cone?
- 3 The mouthpiece and earpiece of a telephone handset each contain a diaphragm that vibrates. How are the mouthpiece and earpiece different from each other?

THINK

- 4 Draw a flow diagram to show the electromagnetic and other changes that take place in the telephones that two people are using during a conversation.
- 5 List all the energy transformations in sound devices such as microphones and speakers.

INVESTIGATE

- 6 Find out what measures are taken to ensure high-quality sound reproduction in expensive stereo speakers.
- 7 Research and report on piezoelectric crystals. What are they? How do they work? What are they used for?

Motoring along

What do a hair dryer, a DVD player, a food processor, a clothes dryer and an electric drill all have in common? The obvious answer is that they all use electrical energy. Another thing that these appliances have in common is an **electric motor**. An electric motor is a device that converts electrical energy into kinetic energy. An electric motor turns because it contains coils of wire that produce a magnetic field when electric current flows through them.



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

The electric current supplied by a cell or battery is called **direct current** (DC). It flows in one direction only. The electric current provided to your home by power stations is called **alternating current** (AC). It changes direction about 100 times every second.

How a DC electric motor works

The armature

This is the turning part of the motor on which coils of wire are wound. The coils are called rotor coils because they cause the **armature** to rotate.

The rotor coils

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

The field magnets

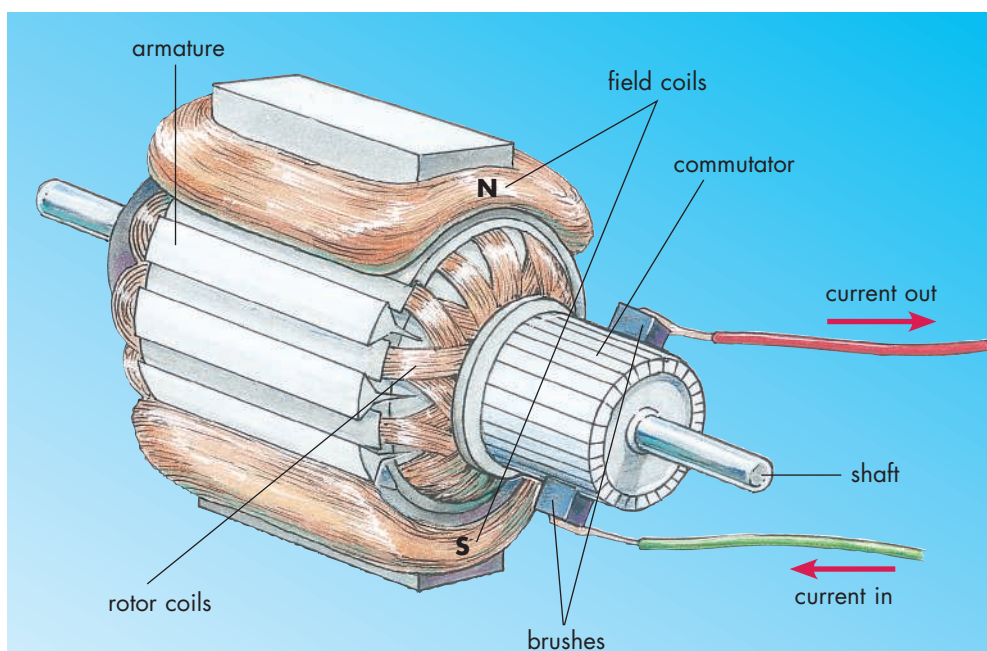
The field magnets are permanent magnets that do not move. In larger commercial motors they are replaced with a separate coil (called a field coil) which provides a stationary electromagnet.

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.



A commercial DC motor

The commutator

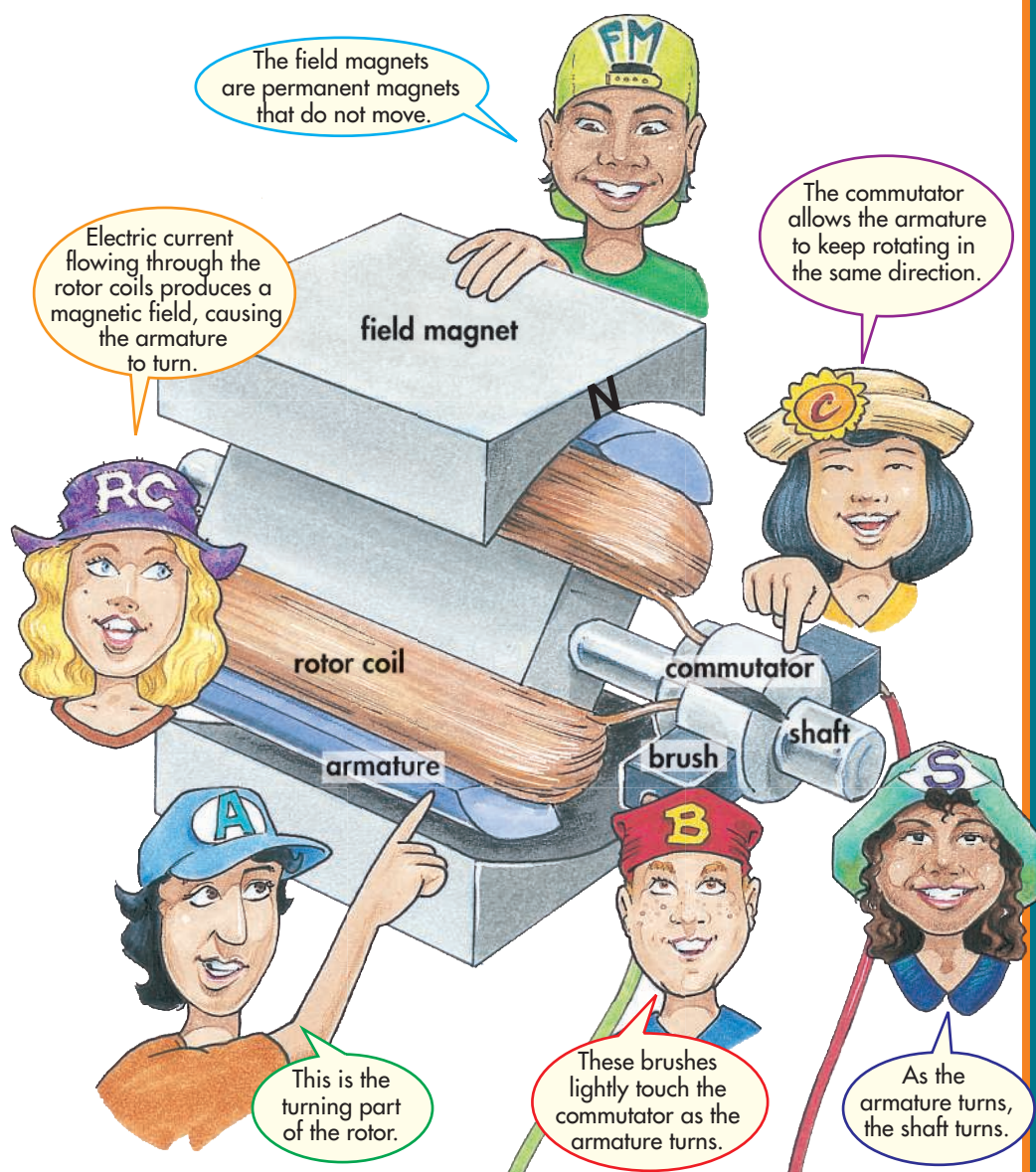
As each rotor coil turns through 180 degrees to face the opposite field magnet, the force on it would change direction, turning it back the other way. The **commutator** consists of a split metal ring. As the armature turns, the commutator turns with it while the brushes remain still. When the armature 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. The direction of the current in each rotor coil reverses. This allows the armature to keep rotating in the same direction, rather than spinning first one way, then the other.

Tinkering with an electric motor

You will need:

electric motor kit and/or DC electric motor

- Use an electric motor kit to build an electric motor. Follow the instructions that come with the kit very carefully.
- 1. Draw a diagram of the electric motor that you have built and label as many of the parts shown in the diagram below as you can.
- If an electric motor is available, examine it closely.
- 2. Draw a diagram of the DC electric motor and label as many of the parts shown in the diagram below as you can.



A simplified diagram of a DC electric motor

activities

REMEMBER

- 1 Into what form of energy do motors convert electrical energy? How does this differ from the energy transformations in microphones and speakers?
- 2 Explain the difference between AC and DC.
- 3 Construct a table to group all the parts of an electric motor into 'moving' and 'non-moving' parts.

THINK

- 4 List as many appliances or toys as you can that contain electric motors.
- 5 Why doesn't an AC motor need a commutator?

IMAGINE

- 6 Imagine you were advertising in the employment pages of a newspaper for the parts of a DC electric motor. Write a job description for each part.

INVESTIGATE

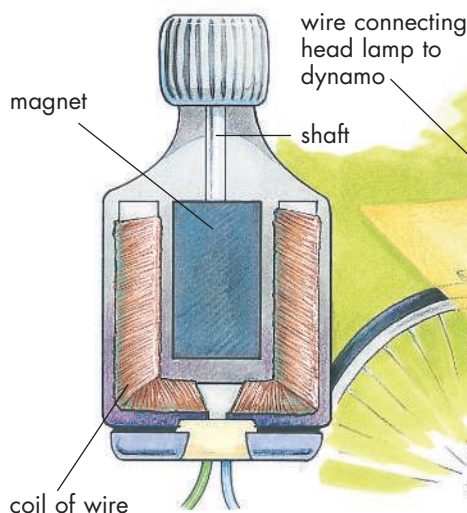
- 7 The needles of moving coil ammeters and galvanometers are connected to a coil of copper wire that lies between the poles of a magnet. Take a close look at one of these instruments and write an account of what makes the needle move when a current passes through the coil.

What a dynamo!

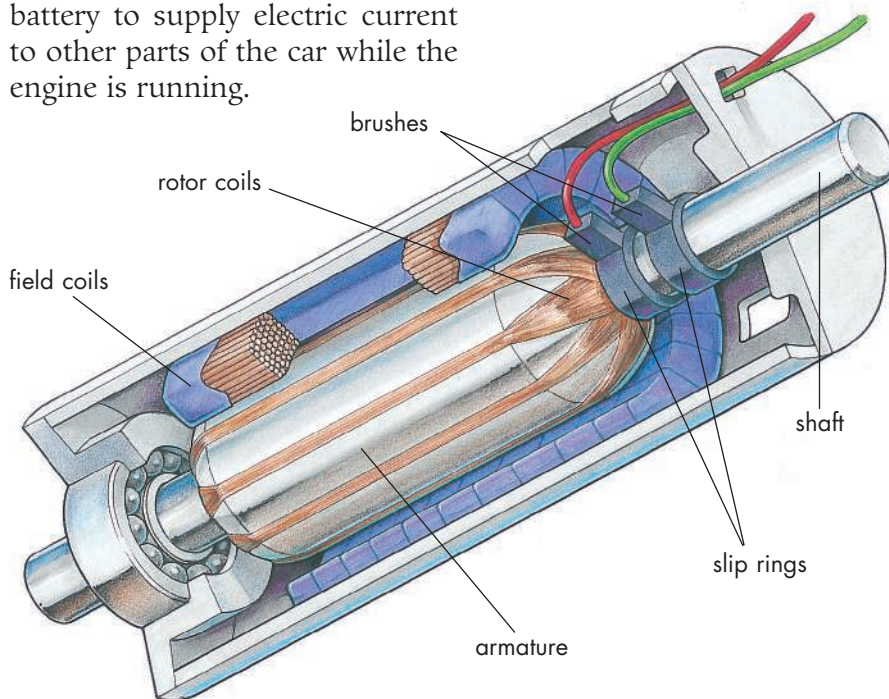
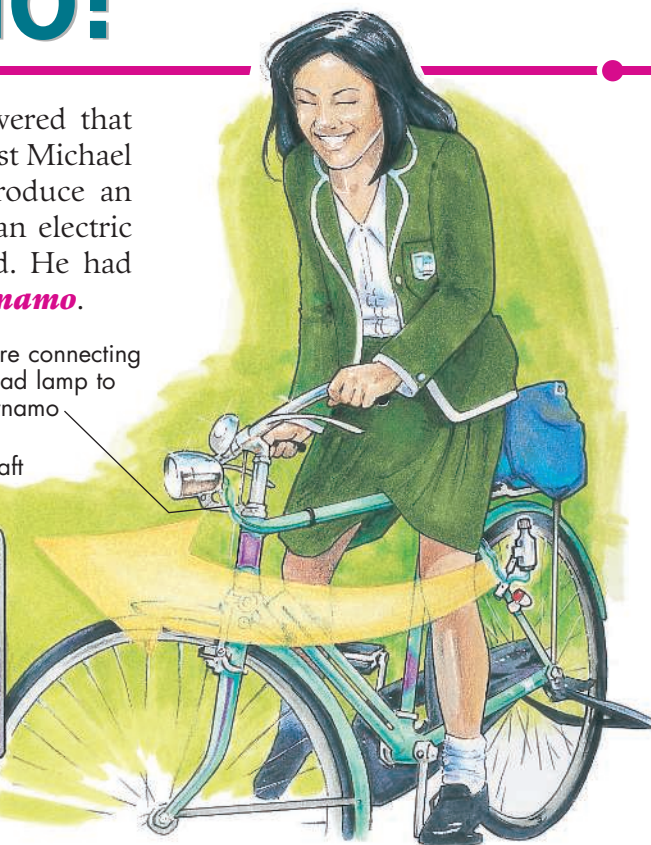
Several years after Danish scientist Hans Ørsted discovered that electric currents produced magnetic fields, British scientist Michael Faraday suggested that perhaps a magnetic field might produce an electric current. In 1831, Faraday succeeded in generating an electric current by moving a coil of wire through a magnetic field. He had made the very first **electric generator**, also known as a **dynamo**.

It's all relative

Current flows in a generator as long as there is relative movement between the magnetic field and the coil. It does not matter if it is the coil that moves while the magnet remains still, or the magnet that moves while the coil remains still. In a bicycle generator, a magnet spins while the coil of wire remains still. In the generator of a motor car, many coils spin around inside a stationary electromagnet. The coils are turned by the car's engine. The electromagnet is connected to the car battery. The car's generator is used instead of the battery to supply electric current to other parts of the car while the engine is running.



A bicycle dynamo generates electricity to keep a headlamp glowing. As the wheel turns, a magnet spins inside a stationary coil of wire. The relative movement between the magnetic field and the coil results in an electric current in the coil which powers the headlamp. Bicycle dynamos have been largely replaced by batteries as an energy source for bicycle lamps.



This car generator looks very much like an electric motor. However, instead of converting electrical energy to kinetic energy, it converts kinetic energy into electrical energy. Each slip ring is connected to one end of each coil of wire. Like the bicycle dynamo shown above, it generates an alternating current (AC).

Increasing the current

The size of the electric current produced by a generator can be made larger by increasing:

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

AC or DC?

The current flowing from an AC generator changes direction after every half turn. In a DC generator, the slip rings are replaced with a commutator like the one on page 96. The electric current generated then flows in the same direction while the armature is turning.

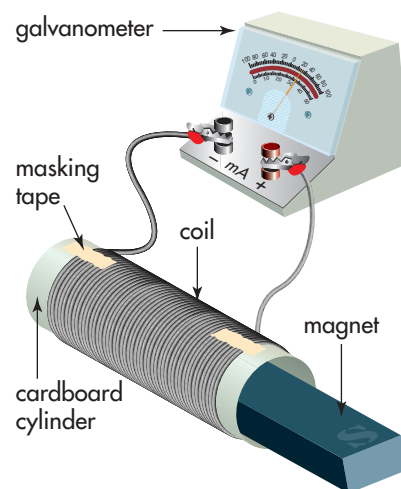
> ELECTRICAL ENERGY FROM KINETIC ENERGY

You will need:

bar magnet
length of insulated copper wire
cardboard tube
masking tape
galvanometer

- Make a solenoid by winding the insulated copper wire evenly around the cardboard tube. Tape the wire down so that it cannot unwind itself. Connect the free ends of the wire to the galvanometer.
 - Place the magnet inside the solenoid so that the end you are holding is just inside the cardboard tube.
1. A galvanometer is used to detect and measure small electric currents. What is the reading on the galvanometer while the magnet is inside the solenoid?
 - Watch the needle on the galvanometer while you rapidly pull the magnet out of the solenoid.
 2. Describe what happens to the needle of the galvanometer while the magnet is being pulled out.
 - Watch the galvanometer needle while you rapidly push the magnet back into the solenoid.
 3. Describe what happens to the needle of the galvanometer while the magnet is being pushed in.
 4. Predict which way the needle of the galvanometer will move if the magnet is reversed and pulled out of the solenoid and then pushed into the solenoid.
 - Test your predictions about the movement of the galvanometer needle with the magnet reversed.
 5. Were your predictions correct?
 6. Does a stationary magnetic field inside a solenoid produce an electric current in the solenoid?
 7. Does a moving magnetic field inside a solenoid produce an electric current in the solenoid?
 - Find out how the size of the electric current changes if the magnet is moved faster or slower, if the solenoid is pulled away from the magnet or if a larger magnet is used.

8. How is the current affected if the magnet is moved into or out of the solenoid faster?
9. Does pulling the solenoid away from the magnet have the same effect as pulling the magnet away from the solenoid?



activities

REMEMBER

- 1 How did Michael Faraday generate an electric current?
- 2 How is the electric current produced by an AC generator different from the electric current produced by a DC generator?
- 3 What changes can be made to a dynamo to increase the size of the electric current generated?

THINK

- 4 Examine the diagram of the car generator on the opposite page.
 - (a) How is the AC generator similar to an electric motor?
 - (b) Describe the differences between an AC generator and a DC motor.

(c) The electric generator is sometimes described as the reverse of an electric motor. Explain why this is so.

- 5 The speakers used in some fast food 'drive thru's' also act as microphones. They contain a permanent magnet, a voice coil and a diaphragm just as normal speakers do. (See pages 94 and 95.) Explain how it might be possible to use the speaker to change sound energy into electrical energy.

CREATE

- 6 Use readily available materials to make your own model generator. Use a sensitive galvanometer to check that it works. Remember that your main objective is simply to create a model that allows relative

movement between a coil of wire and a magnet.

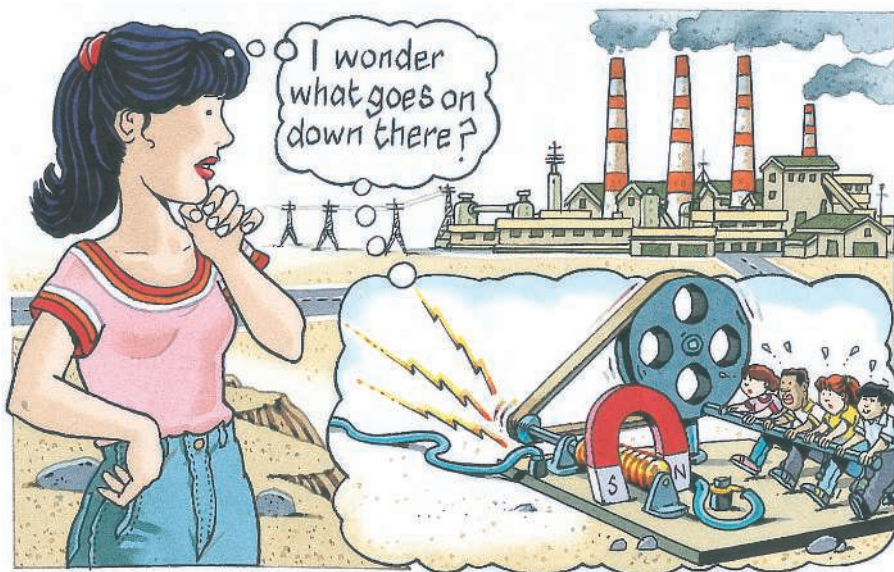
INVESTIGATE

- 7 Investigate the operation of a hand-operated generator.
 - (a) Use a stopwatch, a voltmeter and two connecting leads to investigate how the number of turns of the handle per minute affects the voltage output.
 - (b) Draw a diagram of a hand-operated generator and label the magnet, the coil, the slip rings (or commutator), the shaft and the brushes.
 - (c) Explain in your own words how a hand-operated generator produces an electric current.

Power to the people

The electricity used in your home is usually generated at a place quite distant from where you live. Most of Victoria's electricity is generated by coal-fired power stations in the Latrobe Valley. Less than 10 per cent of Victoria's electricity is generated by hydro-electric power stations.

The method used to generate electricity for use by millions of people is not very different from that used by a single hand-operated generator or bicycle dynamo. It involves relative movement between coils of wire and a magnetic field. Of course, as you can see in the cartoon on the right, the scale is very much larger.



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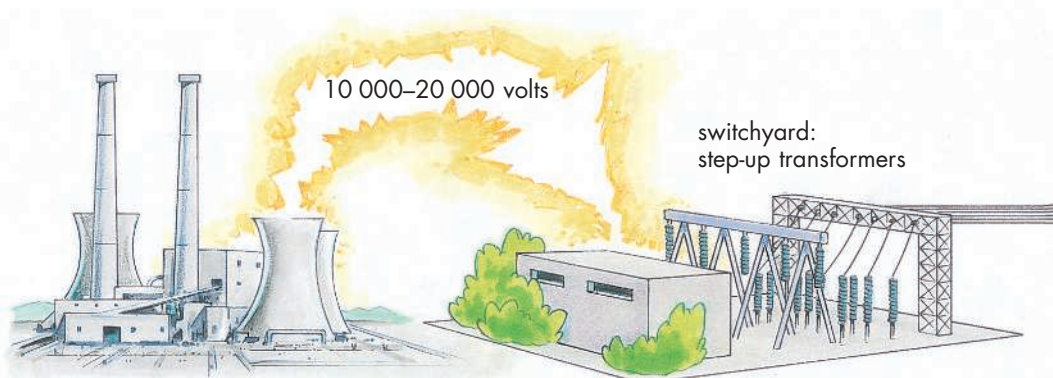
A brownout is a reduction of voltage that occurs when the demand for electricity is greater than the amount that can be supplied. During a brownout you might notice the lights dimming and television and computer monitors fading.



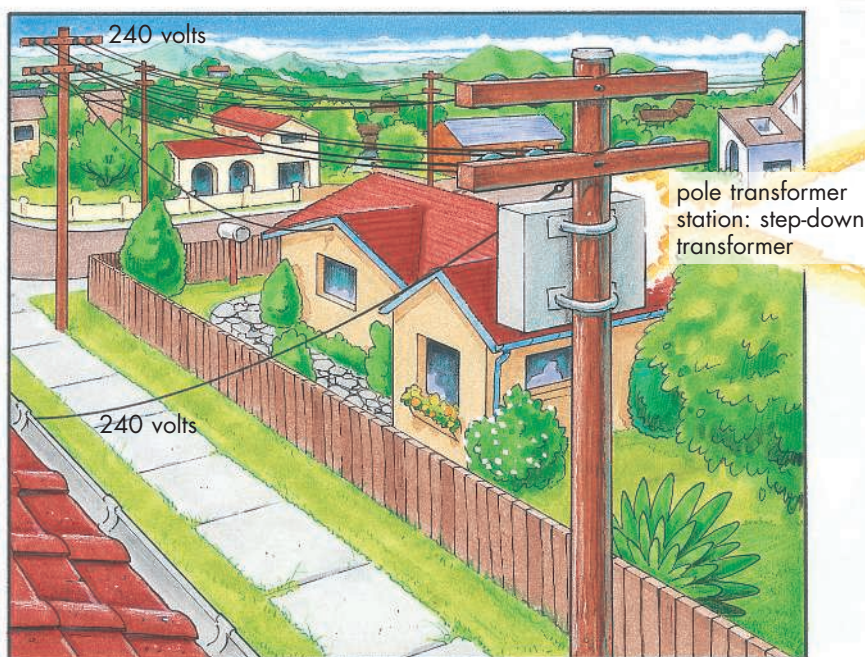
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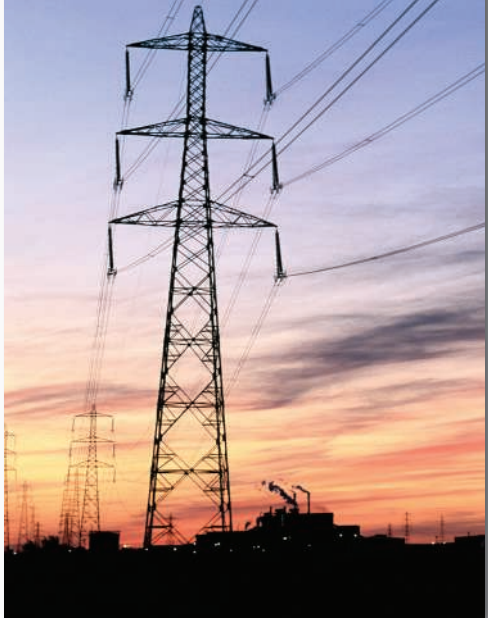
A 500 MW generator produces energy at the rate of 500 000 000 joules every second. MW is an abbreviation for megawatts (one megawatt equals one million watts). The turbines in Australian power stations turn 3000 times every minute — that's 50 times each second.

The transmission of electricity to your home



coal-fired power station

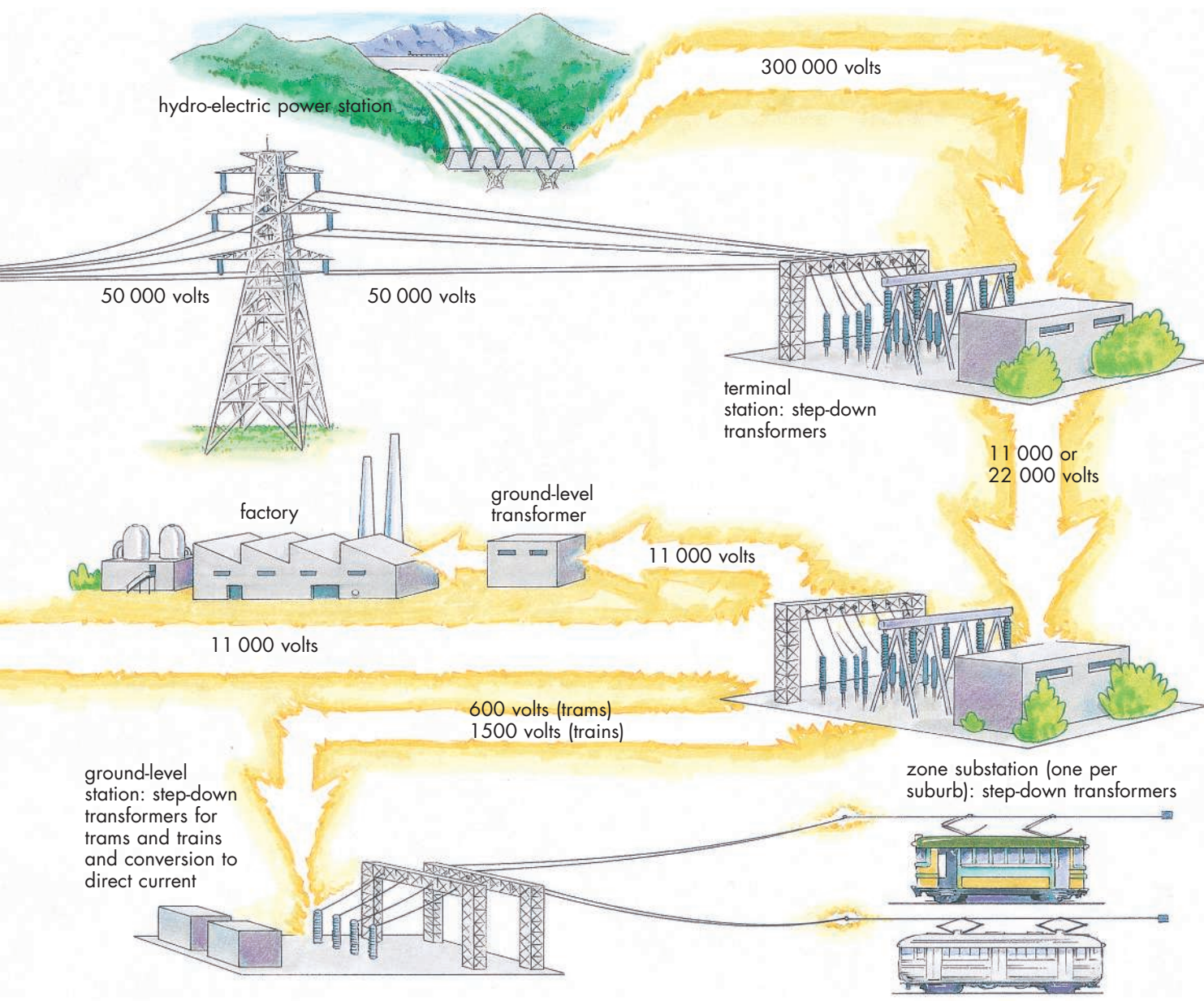




Carrying power to the people



Loy Yang power station in the Latrobe Valley. Victorian coal-fired power stations are built close to open-cut coalmines. Coal is burned to boil water. The resulting high pressure steam is used to drive huge turbines like the ones in the photograph on page 102.



The generator

In coal-fired and nuclear power stations, the fan-like **turbines** are turned as high pressure steam pushes on the blades. Coils at the other end of the generator (the end closest to you in the photograph below) rotate rapidly inside huge electromagnets. The motion of the coils in the magnetic field produces a large electric current. In hydro-electric power stations, falling water is used to turn the turbines.



A 500 MW superheated steam turbine generator during construction

The transformers

The electric current produced by generators in power stations is very large. If such large electric currents flowed through wires to distant cities, the wires would get very hot. A lot of energy would be wasted heating the air around the wires. One of the advantages of generating AC electricity rather than DC electricity is that **transformers** can be used to increase or decrease the voltage of the electricity.

A **step-up** transformer increases the voltage of the electricity. It decreases the size of the electric current. A **step-down** transformer decreases the voltage of the electricity. It increases the size of the electric current.

Step-up transformers are used to increase the output voltage of power stations so that the electric current flowing through the transmission wires is smaller. This decreases the amount of energy lost in the wires.

Step-down transformers are used in substations and on some power poles to decrease the voltage to the amount required for homes, offices and factories. The electric current flowing to homes, offices and factories is greater than the electric current flowing in the high voltage transmission wires.

The transformers attached to the plugs of some electric devices like computer printers and electronic games are step-down transformers, reducing the voltage from 240 volts to 9 volts or 12 volts.

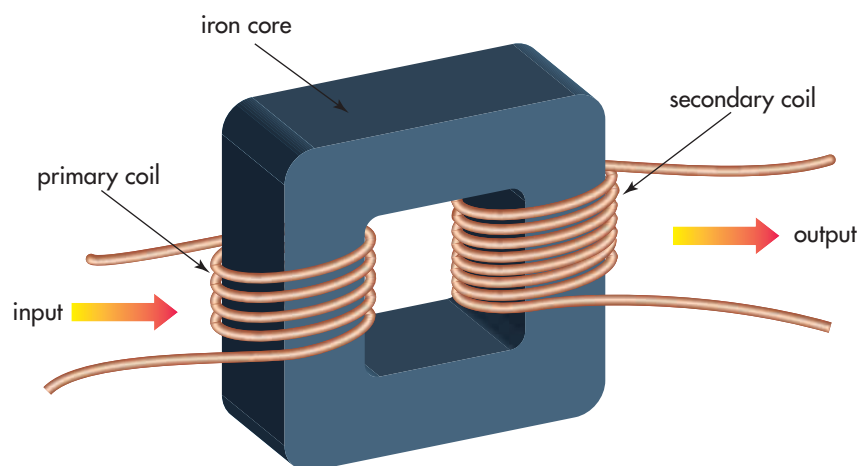
How transformers work

A transformer consists of an iron core and two coils of wire. The input coil is called the **primary coil**. The output coil is called the **secondary coil**. A changing electric current in the primary coil produces a changing magnetic field inside the secondary coil. This produces an electric current in the secondary coil.

In a step-up transformer, the secondary coil has more turns than the primary coil and the secondary (output) voltage is greater than the primary (input) voltage. That means that each electric charge flowing out of the transformer has more energy than each electric charge flowing in. However, there is no extra energy created because less electric charge flows out of the transformer each second than flows in. That is, the secondary current is less than the primary current.

If the current flowing through the primary coil is direct current, the transformer will not work because there will be no changing magnetic field inside the secondary coil to produce an electric current.

In a step-down transformer, the secondary coil has fewer turns than the primary coil and the secondary (output) voltage is less than the primary (input) voltage.



A simple step-up transformer

REMEMBER

- How is the generation of electricity in a power station similar to the generation of electricity by a hand-operated generator?
- What is the role of the turbines in a power station?
- What drives the turbines in:
 - a coal-fired power station?
 - a nuclear power station?
 - a hydro-electric power station?
- Use two diagrams to illustrate the differences between a step-up transformer and a step-down transformer.
- Why is it necessary to increase the voltage output from power stations before the electricity is transmitted over long distances?
- Explain why a transformer would not work if the electric current in the primary coil was DC rather than AC.

ANALYSE AND EVALUATE

The table below shows the Victorian demand for electricity on two typical winter days.

Demand for electricity in Victoria on two typical winter days

Time	Day 1 power demand (megawatts)	Day 2 power demand (megawatts)
midnight	3800	3500
2.00 am	3200	3100
4.00 am	2900	2800
6.00 am	3000	2900
8.00 am	4300	3000
10.00 am	4500	3200
noon	4300	3200
2.00 pm	4200	3100
4.00 pm	4150	3000
6.00 pm	4600	3500
8.00 pm	4000	3350
10.00 pm	3700	3350
midnight	3800	3500

Domestic (household) use of electricity accounts for only about one quarter of the electrical energy used in Victoria. Another 15 per cent is lost as heat during its generation and transmission. Most of the remainder is used by industry and commerce.

- Use the data in the table to plot graphs for the two days on the same set of axes. Plot the power in megawatts on the vertical axis and the time on the horizontal axis.
- At what time or times is the demand greatest on:
 - day 1?
 - day 2?
- At what time is the demand at its lowest on:
 - day 1?
 - day 2?
- Between which times is the difference in demand on each of the two days:
 - the most?
 - the least?

Suggest one or more reasons for your answers.

- One of the two days shown in the table is a weekday. The other day shown occurs on a weekend.
 - Use the table and additional information provided to decide which of the two days is a weekday.
 - Explain how you made your decision.
- Explain the reason for the 'peak' demand on day 1.
- Why does the demand decline more slowly between 6.00 pm and 10.00 pm on day 2 than on day 1?
- Explain how the demand might be different on a typical warm weekday in spring.

THINK

- Why are Victoria's power stations in the Latrobe Valley, over 150 km from the biggest population centre of Victoria?
- From which forms of energy is electrical energy converted in:
 - a coal-fired power station?
 - a hydro-electric power station?
- During which times of the year would brownouts most likely occur?
- The air pollution caused by coal-fired power stations is obvious — it can be seen and sometimes smelt. However, hydro-electric power stations can also damage the environment. Explain how.

INVESTIGATE

- Research and report on the generation of electricity by hydro-electric power stations in Australia. Find out about their location and their history.

Civics and citizenship: A new generation

Whether you are at home, at school, at a football match, at a concert or just going shopping, it is almost certain that you will use electrical energy generated by power stations.

Most power stations in Australia rely on coal to drive the turbines used to generate electricity. Our dependence on coal 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 coal and alternative methods of generating electricity.

Energy is not created

Electrical energy is not created — in fact energy can never be created or destroyed. That is the **Law of Conservation of Energy**. Energy can, however, be converted, or **transformed**, from one form into another. It can also be **transferred** from one object to another. In the coal-fired power stations of the Latrobe Valley, chemical energy is transformed into thermal energy by burning brown coal. The thermal energy is used to boil water, changing it into steam. The kinetic energy of the water molecules that make up the steam is transferred to the turbines. The kinetic energy of the turbines is then transformed into electrical energy.

Pollution — it's not just chemicals

During the burning of brown coal in power stations, some of the chemicals in the coal pour from chimneys into the air, causing air pollution. When it rains, some of these unwanted chemicals in the air dissolve in the falling raindrops. The falling rain becomes acidic and is known as acid rain. Acid rain speeds up the weathering of rocks, eats into building materials, and threatens plants and the other living things that depend on them.

However, there is another form of pollution that is not so obvious. Whenever energy is transformed to another form or transferred to another object, some energy is 'lost'. It doesn't disappear — it is transferred to the surroundings, increasing the temperature of nearby objects, 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 the organisms that belong to the same food web.

Looking for alternatives

The demand for electrical energy is increasing, both in Australia and worldwide. Yet the supply of the **fossil fuels** (like coal, natural gas and oil) used to heat water to drive turbines in power stations is diminishing.

The air, water and thermal pollution caused by burning fossil fuels to generate electricity is not acceptable to many people. For these reasons, many governments throughout the world are supporting alternative methods of producing electricity.

Hydro-electricity

About 15 per cent of Australia's electricity is generated by hydro-electric power plants. As water stored in a high dam falls through pipes, it gains kinetic energy. This kinetic energy is used to turn turbines that generate electricity. One advantage of hydro-electricity is that it can be shut on or off very quickly.

Ocean thermal energy

The difference in the temperature between the warm water at the surface of the oceans and the colder water below has been used in experimental power plants in Hawaii. Liquid ammonia flows through tubes from the cold water region up to the warm water region where it becomes a gas and drives a turbine. It then returns to the cold water region where it condenses into a liquid again. Another small experimental ocean thermal energy plant is being planned in Taiwan.

Nuclear energy

Nuclear power stations use energy released during the nuclear fission of uranium or plutonium to boil water to produce the steam that drives turbine generators. The process is explained on pages 42–3.

Most of the world's nuclear power stations can be found in the United States, Europe, Japan and Canada.

Wind energy

Wind 'farms' dotted with wind turbines can be found in 13 countries throughout the world, including Australia. The largest Australian wind farm is at Chalcum Hills, near Ararat in Victoria. Its 35 towers generate a total of 53 megawatts of electricity. That's less than 3 per cent of the output of the Victoria's Loy Yang power station.

Biomass

Decaying **biomass** (plant and animal tissue) produces wastes including methane gas, methanol and oils. Methane can be burnt to boil water and produce steam to drive small turbine generators. In the future, many farms could supply surrounding areas with electricity generated with biomass. Some small biomass electricity generators already exist in rubbish tips.

Wave energy

The energy of ocean waves has been 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. Scientists are investigating the possibility of using wave energy in Bass Strait.

Tidal energy

The energy of the rising and falling tides is used in six power stations worldwide. Three of them are in China. Turbines with reversible blades are placed at the entrance to a bay in areas with extremely high and low tides. Water moving into and out of the bay turns the turbines to generate electricity.

Several areas have been shown to be suitable for tidal energy in the Kimberley region on the north-west coast of Western Australia.

Geothermal energy

The word **geothermal** comes from the Greek 'geo', meaning 'of the Earth' and 'therme', meaning 'heat'. In parts of New Zealand, energy transferred from hot rocks just below the ground is used to turn water into steam and drive turbines in geothermal power stations. Other countries that use geothermal power include the United States, Iceland and Japan.

Solar energy

Electricity can be generated by solar energy in two different ways. **Photovoltaic cells**, like those used to power the telephone box in the photograph below, are plates containing silicon or other metal-loids. When sunlight falls on the plates, electric charge moves inside them, creating an electric current. Solar thermal power stations can also use 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.



Solar-powered payphone

activities

REMEMBER

- 1 What is the Law of Conservation of Energy?
- 2 What damage can coal-fired power stations do to the environment, apart from chemical pollution?
- 3 State two reasons why it is worth considering alternatives to fossil fuels for the generation of electricity.

THINK

- 4 Which of the alternative methods of generating electricity:
 - (a) could be described as renewable energy sources?
 - (b) involve the use of energy from the sun? (*Hint: There is more than one answer.*)
 - (c) create thermal pollution?
- 5 Each of the alternative methods of generating electricity solves some of the problems caused by burning fossil fuels. However, each of them has disadvantages. What are these disadvantages?

CREATE

- 6 Create a flowchart 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.

INVESTIGATE

- 7 Research and report on one of the alternative ways of generating electricity. As well as using books, journals, magazines and newspapers, you can find information on the web site of the Sustainable Energy Authority, part of Sustainability Victoria, and other web sites that provide information about alternative sources of energy for the generation of electricity.

Thinking tools:

Cluster maps and flowcharts

1. Think of a topic and write it in the middle of a sheet of paper.
2. Around your topic, write down any ideas that link with it. Draw lines from the ideas to your topic.
3. Write down new ideas that are related to your first ideas, and link them with lines.

how to ...?

to stimulate the generation of new ideas

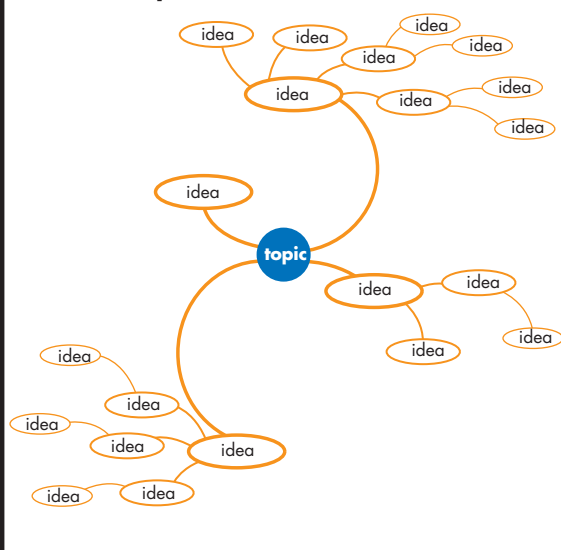
why use?

mumbles;
brainstorm
map; spider
diagram

also
called

example

cluster map



How can I develop the particular idea?

question

comparison

Similarity

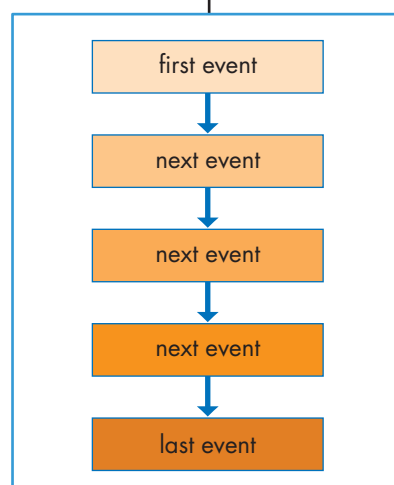
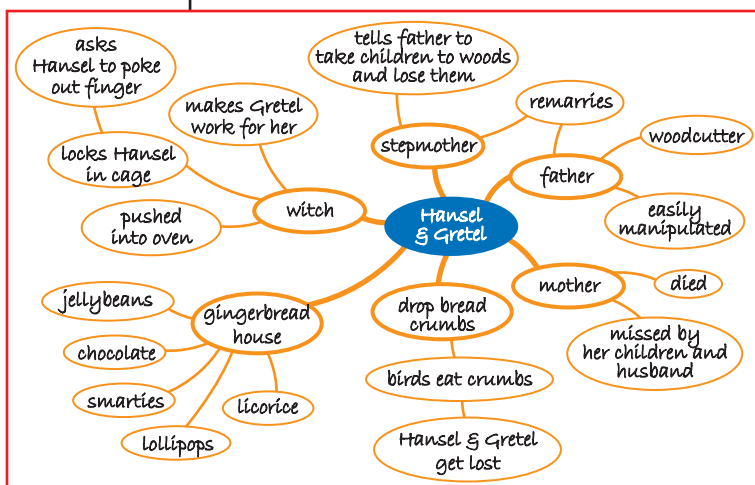
Both help you to think about the key ideas of the topics.

Difference

Flowcharts show you the sequence of events; cluster maps help you to group ideas.

flowchart

example

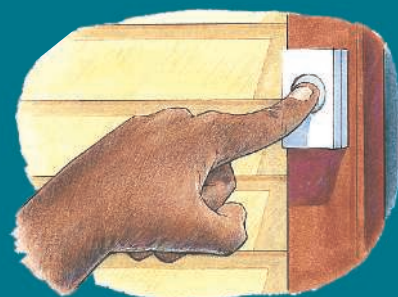
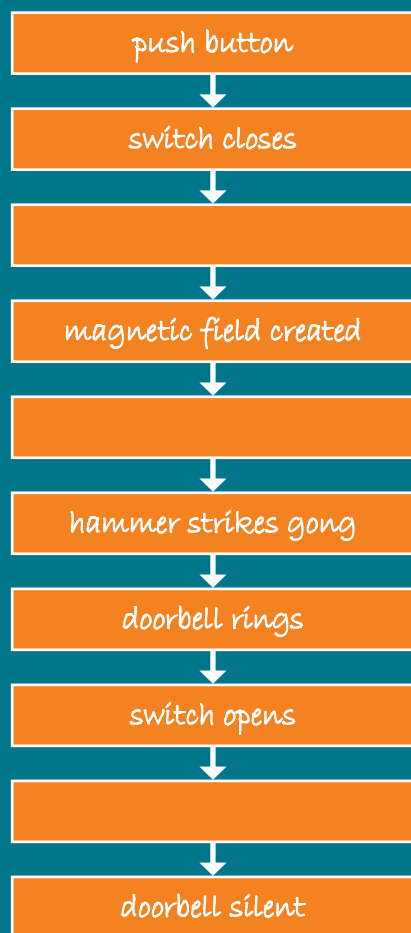
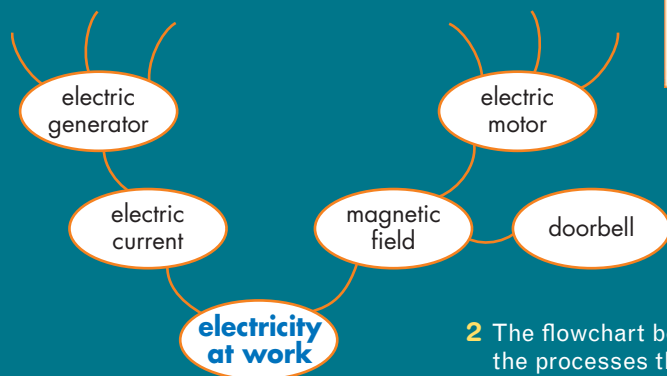


Adapted with permission from Hawker Brownlow Education © 2005 modellearning.com *Thinking Skills and EyeQ: Visual Tools for Raising Intelligence* by Ian Harris, Oliver Caviglioli and Bill Tindall

THINK AND CREATE

- 1 Use the ideas listed at right to create a cluster map on the topic of electricity and magnetism.

The diagram below can be used as a starting point. You may use some of the ideas in the list more than once if it is appropriate. Don't forget that you can make links between the different 'arms' of your cluster map.



- 2 The flowchart below left shows the processes that occur when a single gong doorbell button is pressed once.

(a) Copy the flowchart and fill in the missing steps in the sequence.

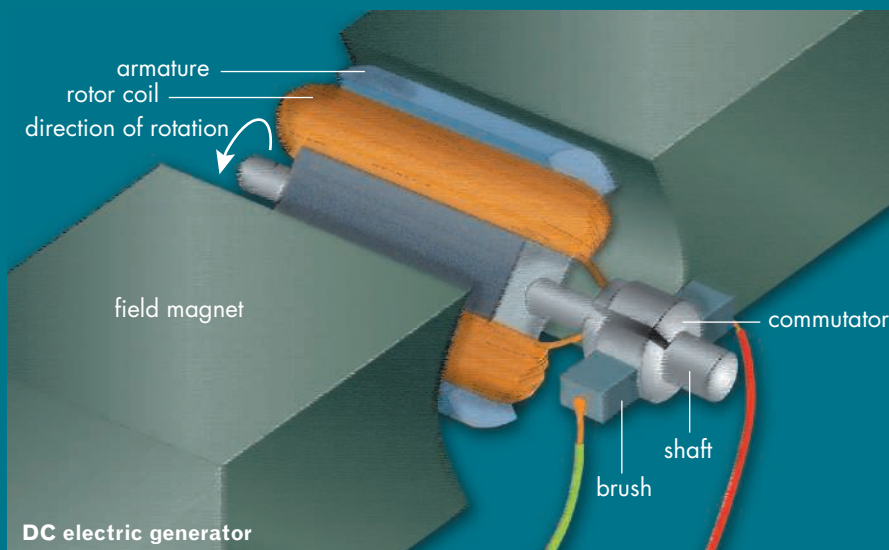
(b) Use another visual tool such as a cycle map or storyboard (see page 158) to illustrate the events that occur if the button is pressed and not released.

- 3 Construct a flowchart (or storyboard) to illustrate the sequence of events that takes place to make a DC electric motor work.

- 4 (a) Construct a flowchart (or storyboard) to illustrate the sequence of events that takes place to make a DC electric generator work.

(b) Describe the similarities of a DC electric motor and DC electric generator.

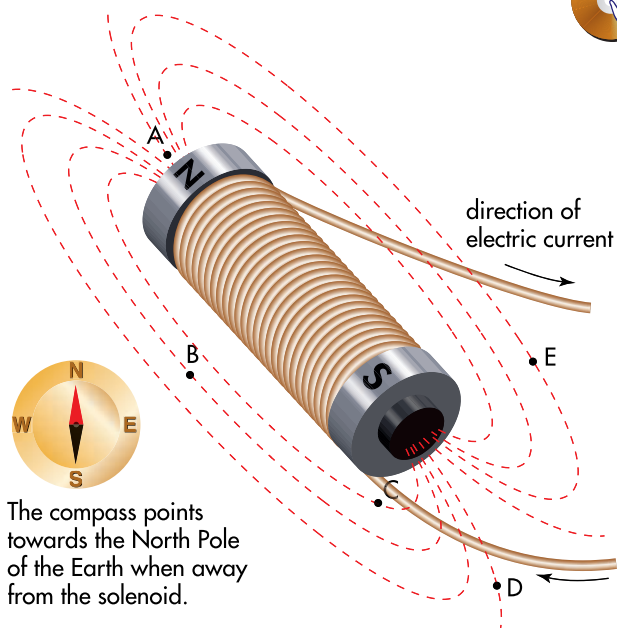
(c) Describe the differences between a DC electric motor and DC electric generator.



Looking back



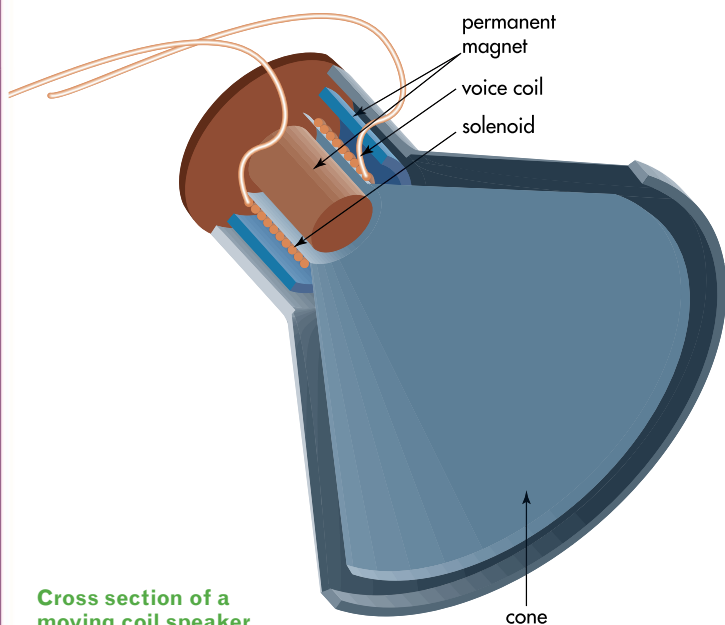
1. Make a copy of the diagram below.



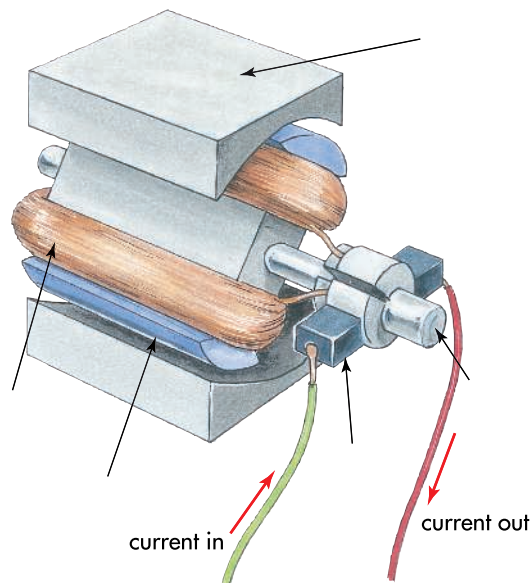
Draw arrows at each of the points A, B, C, D and E to show the direction that the compass needle would point if the compass was placed at each of the points when an electric current flows in the solenoid as shown.

At which of the points A, B, C, D or E is the magnetic field the strongest?

2. Use a flowchart to show how a moving coil speaker transforms electrical energy into the sound energy that you hear.



3. Make a copy of the diagram below.



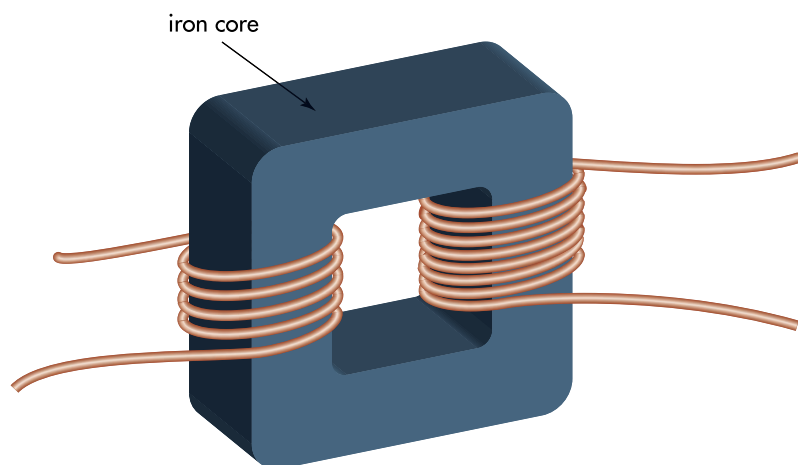
A simplified diagram of a DC electric motor

- (a) Complete the labelling of the diagram.
(b) Copy and complete the table below to indicate the role of each of the parts of the motor listed.

Part	Purpose
field magnets	
armature	
rotor coil	
shaft	
brushes	
commutator	

4. Many electrical devices contain electromagnets.
- Is an electromagnet a permanent or temporary magnet? Explain your answer.
 - Which part of an electromagnet is the solenoid?
 - What is the role of the iron core in an electromagnet?

5. Imagine that you were given a three-metre length of wire, an A4 sheet of thin card and a bar magnet.
 - (a) Explain how you could produce an electric current.
 - (b) What piece of equipment would you need to demonstrate that an electric current was produced?
6. List three changes that can be made to an electric generator to increase the size of the electric current it produces.
7. What do the letters AC and DC stand for? Explain the difference between AC and DC current.
8. Before electric power is transmitted, step-up transformers are used to increase the voltage. Before the electric power is distributed to individual homes, step-down transformers are used to decrease the voltage. What is the point of increasing the voltage at one end of the electric power system and then decreasing it again?
9. If the diagram below represents a simple step-down transformer:



- (a) Is the primary coil on the left or right?
- (b) How does the output voltage compare with the input voltage?
- (c) How does the output electric current compare with the input electric current?
- (d) If this was a 'perfect' transformer and no energy was lost by heating the iron core and surrounding air, how would the output energy compare with the input energy? Explain your answer.

10. (a) How is the effect in your home of a brownout different from the effect of a blackout?
(b) What causes a brownout?
11. What is the role of the turbines in a coal-fired power station?
12. Voltage is a physical quantity that measures how much energy is delivered to electric charge as it moves through an electric circuit. The unit of measurement of voltage is the volt. Which physical quantities are measured in units of:
 - (a) megawatts?
 - (b) joules?
 - (c) amperes?
13. How many watts are there in a megawatt?
14. Which of the methods of electricity generation in which fossil fuels are not used require turbines?
15. What are photovoltaic cells and how do they work?
16. The use of alternative methods of generating electricity provides one way of reducing our dependency on fossil fuels. Another way is by using less electricity. In a small group, make a list of ways in which you can decrease your use of electricity at home without making big changes to your lifestyle.
17. The table below lists some different methods of generating electricity in three columns. Write an appropriate heading for each of columns A, B and C.

Column A	Column B	Column C
hydro-electricity	coal	hydro-electricity
wind energy	natural gas	solar energy
wave energy	oil	wind energy
		biomass
		wave energy
		ocean thermal energy

18. Coal-fired power stations are known to produce many forms of pollution. Two of these forms are acid rain and thermal pollution. Describe each of these two forms of pollution and their effects on the environment.