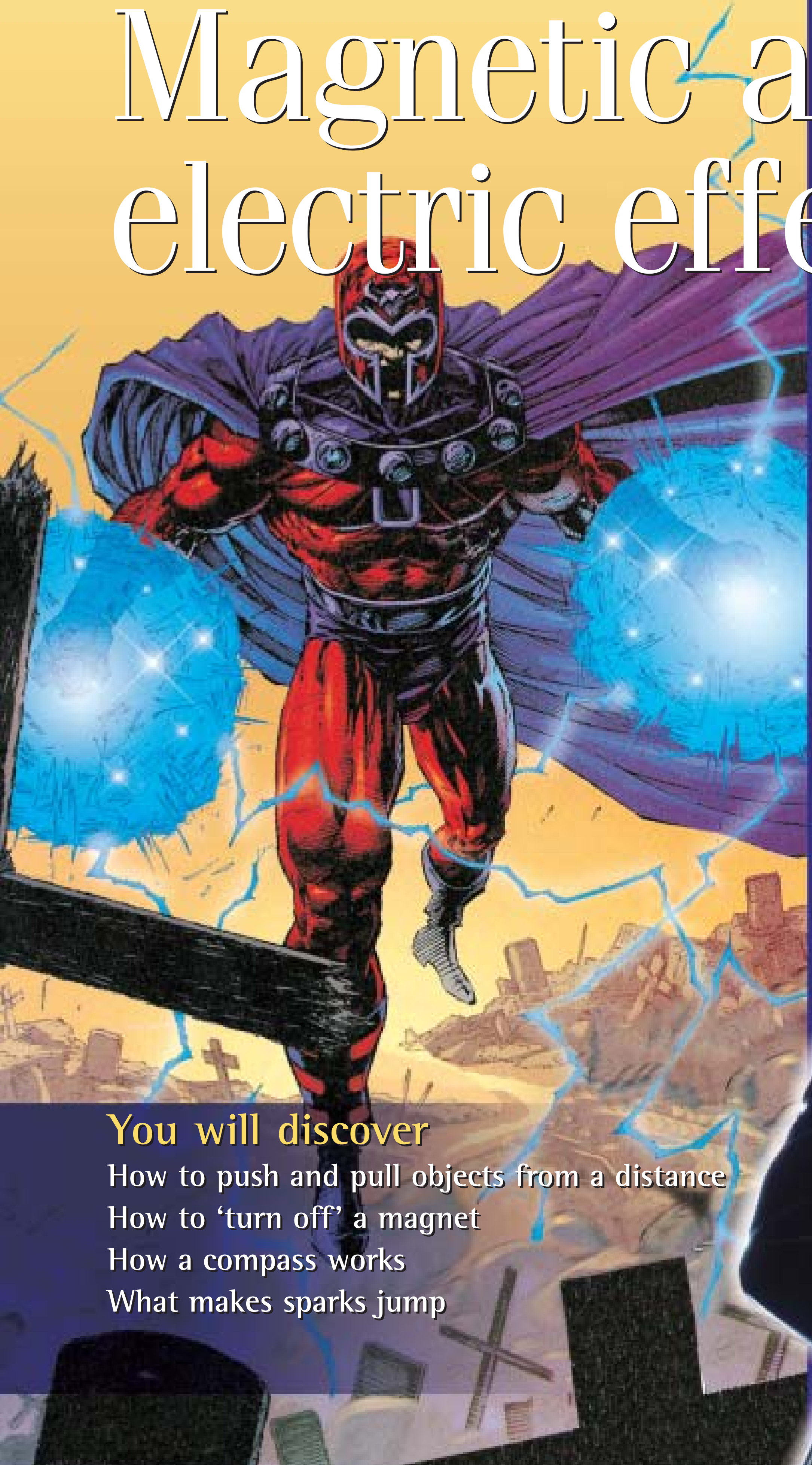
CHAPTER 6

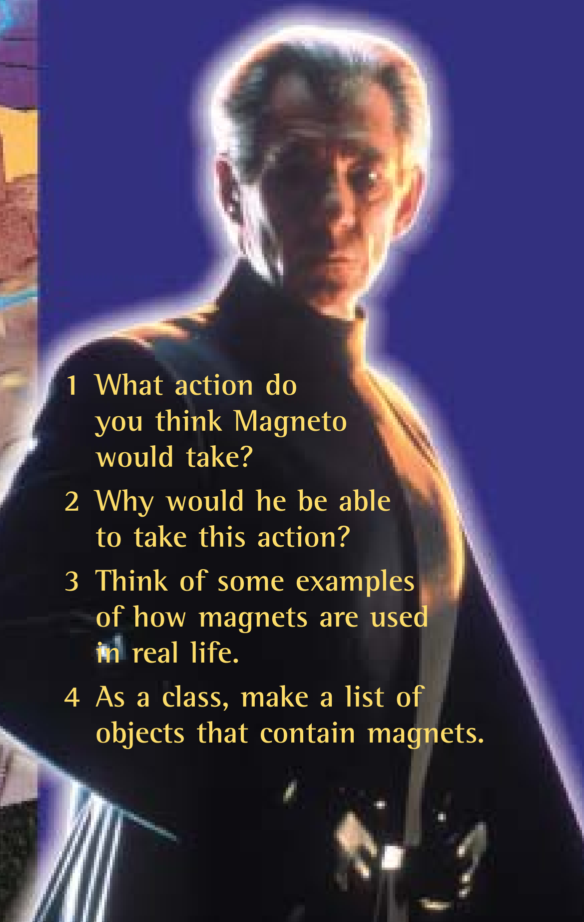
Magnetic and electric effects



Magneto – master of magnetism

Magneto is one of the main enemies of the Marvel Comic's heroes, the X-Men. Magneto has the ability to control anything that is magnetic; he can even control the flow of iron to the brain. In addition to magnetics, he can control other energy fields.

In a scene from the X-men movie, Magneto faces a blockade of police cars and hundreds of police with their guns aimed at him.



1 What action do you think Magneto would take?
2 Why would he be able to take this action?
3 Think of some examples of how magnets are used in real life.
4 As a class, make a list of objects that contain magnets.

You will discover

How to push and pull objects from a distance
How to 'turn off' a magnet
How a compass works
What makes sparks jump

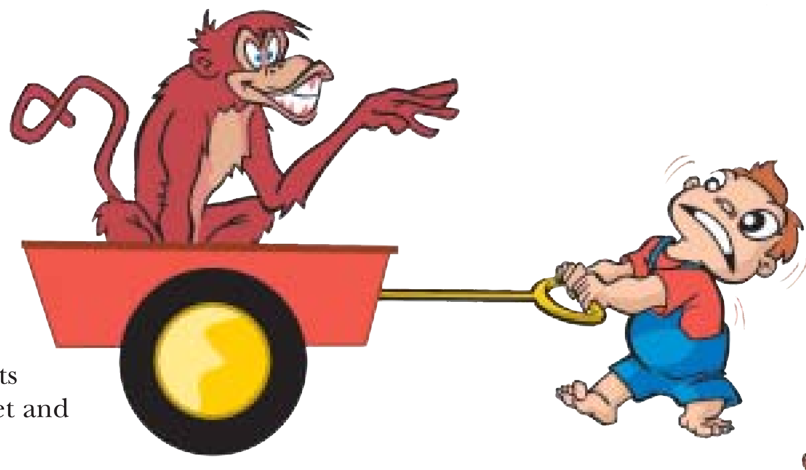
Attractive metals

Magnets come in many shapes and sizes, and **attract** some metal objects (like the fridge door). Magnets can even attract each other. The closer the magnet is to another magnet or metal object, the more strongly they pull together. The effect of a magnet can be a pull — but can it also be a push?

Out of touch

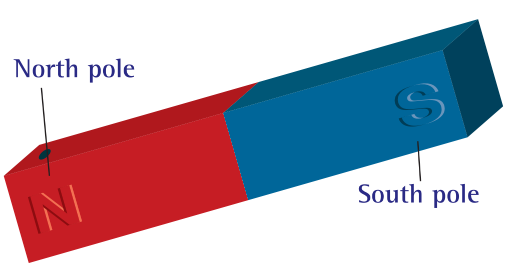
Almost every time you push or pull an object, you have to touch it. If you don't touch the object, you need something else to touch it — like a string. Magnets can pull objects without actually touching them. And the closer the magnet is to the object, the greater the size of the pull.

A push or pull is called a **force**. Magnets do not need to touch the objects they pull. So, the force between a magnet and an attracted object is called a **non-contact force**.



Poles

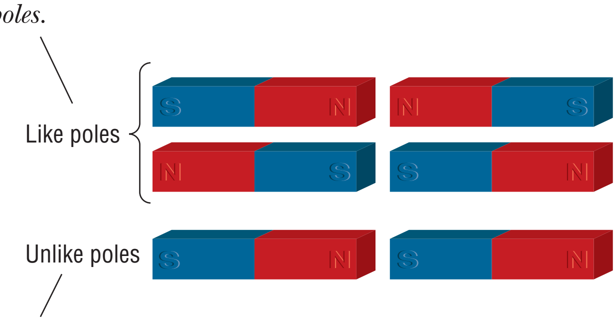
The pulling force of a magnet is strongest at its ends, or **poles**. All magnets have a north pole and a south pole. Even when a magnet is cut in half, each half will still have a north and a south pole. If you can keep cutting a magnet in half over and over again, each half will always have both north and south poles.



If you hang a magnet by its middle, it always lines up with the North and South poles of the Earth. The north pole of a magnet actually gets its name from the term 'north-seeking pole' because it lines up with or 'seeks' the North Pole of the Earth.

Opposites attract

*When the north poles of two magnets are brought close together, the magnets push away or repel each other. The same type of push (**repulsion**) is felt between two south poles.*



When the north pole of a magnet comes close to the south pole of another magnet, the opposite happens. They pull on each other, or attract.

Go to worksheet 26

Magical rocks

The ancient Greeks and Chinese are believed to be the first people to notice the power of magnets. They discovered a strange attraction between a certain stone and objects made from iron. Ancient storytellers told great tales of the 'magic' of magnets. They told of how magnets healed the sick, destroyed ships and frightened away evil spirits.

The stone that the ancient Greeks and Chinese noticed contained **magnetite**, a naturally occurring magnetic substance.

Can magnets push as well as pull?

You will need:
2 bar magnets
ruler.

- Hold two magnets about 10 cm apart, so that the north ends are facing each other. Slowly bring the magnets together.

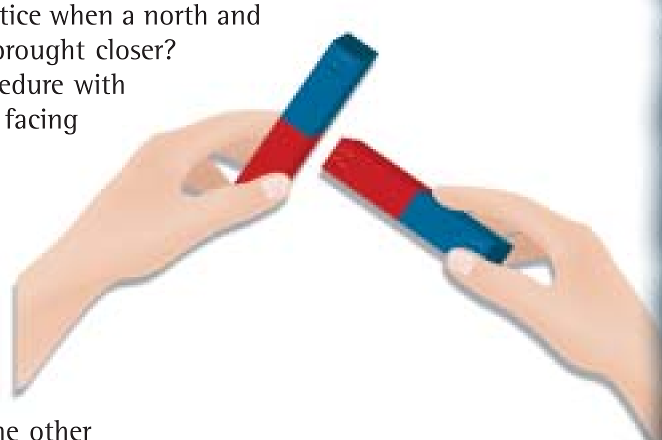
1. What do you feel when the north ends are brought closer?

- Hold the magnets 10 cm apart, so that this time a north and south end are facing each other. Bring them together slowly.

2. What do you notice when a north and south pole are brought closer?

- Repeat the procedure with two south ends facing each other.

3. Record your observations.



- Hold the magnets so that the north pole of one magnet meets the middle of the other magnet at right angles. Slowly move the magnets apart, then together.

4. Is the push or pull as strong at the middle as at the poles?

- Try this again with the south pole at right angles to the other magnet.

5. Complete these sentences:
   Like poles ____________.
   Unlike poles ____________.
6. Where is the pulling force of a magnet the greatest?

Activities

REMEMBER

1. What are the ends of a magnet called?
2. How should two bar magnets be placed so that they will attract each other?
3. State whether the following are true or false:
   (a) The pulling force of a magnet is strongest in the middle.
   (b) Magnets can only attract other magnets.
   (c) Magnets can push each other apart.
   (d) The closer two magnets are, the weaker the force between them.

THINK

4. How is a magnetic force different from most other pushes and pulls?
5. Suggest a reason why the north pole of a magnet would be attracted to the North Pole of the Earth.
6. What happens to the poles of a magnet when a magnet is cut in half?

IMAGINE

7. Imagine you were the one who first noticed the effect of stones containing magnetite. Write a story about how you discovered the stone. In your story, describe the effect and suggest whom you would tell about your discovery.

INVESTIGATE

8. Design and perform an investigation to find out which objects magnets are attracted to.

checklist

I can:
- ☐ label the poles of a magnet
- ☐ explain how magnets push and pull each other
- ☐ identify the parts of the magnet with the greatest pulling force.

Make it into a magnet

Once a **magnet**, always a magnet? Not necessarily. Some magnets keep their magnetic effect for years. Others lose their magnetic effect in just minutes. There are also magnets that can be turned on and off at the flick of a switch. No matter what type of magnet, the materials that form them have something in common.

Permanent and temporary magnets

A needle can be **magnetised** by stroking it with a bar magnet in the same direction many times. The domains in the needle are lined up only temporarily and quickly go back to their original directions. Objects that lose their magnetism after a short period of time are called **temporary magnets**.

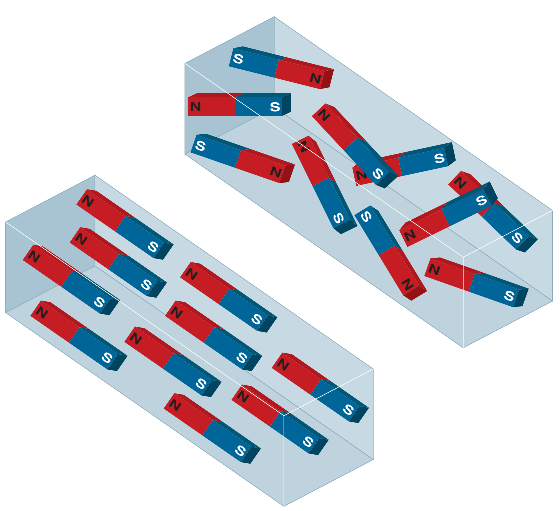
Permanent magnets keep their magnetism for long periods of time. Bar and horseshoe magnets are permanent magnets. They do not lose their magnetism easily, but can be damaged by being dropped or by being heated to very high temperatures.

Three special metals

Not all objects are attracted to magnets. Magnets affect only materials made with iron, nickel or cobalt. These three metals are made up of small parts that behave like mini-magnets. These small parts are called **domains**. Each of these domains or 'mini-magnets' has a north **pole** and a south pole.

As well as being affected by magnets, iron, nickel and cobalt can also be made into magnets. When the domains inside the metals face the same direction, the metal turns into a magnet.

If the domains inside magnetic materials are facing different directions, the pushes and pulls of the 'mini-magnets' have no effect. This material is not a magnet.

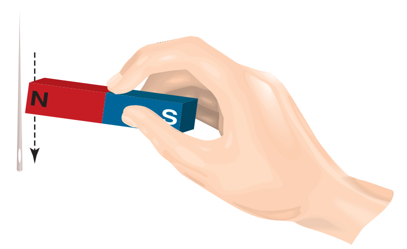


If the domains are lined up facing the same direction, the material has an overall north pole and an overall south pole. The material *does* have a magnetic effect. All magnets have domains that face the same direction.

How is a magnet made?

You will need:
steel needle
strong, permanent bar magnet
several pins.

- Use the north pole of a magnet to stroke the needle thirty to forty times. Stroke the needle in the same direction each time and lift the magnet well away from the needle between strokes.



1. Why do you need to stroke the needle in the same direction each time?

- Test your magnet by trying to pick up the pins.

2. How many pins does your magnet attract? Compare your results with those of your classmates.
3. Have you made a permanent or temporary magnet? How do you know?
4. How could you tell which is the north pole of your new magnet?
5. Draw a diagram of the needle. Use an arrow to show the direction that the needle was stroked in. Label the north and south poles of your new magnet.

Switched on or off?

A magnet's pulling **force** can be very useful. But sometimes it gets in the way.

An **electromagnet** is a magnet that can be turned on and off with the flick of a switch. It is made up of a coil of wire wrapped around a piece of iron. The piece of iron turns into a magnet when electricity passes through the coil. The iron stops being magnetic as soon as the electricity is turned off. Electromagnets are used in many machines and appliances.

Making electromagnets

You will need:

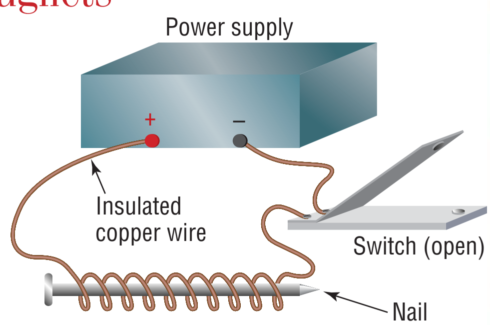
power supply

2 insulated wires, one short, the other 1.5 m long

large nail

switch

paperclips.



- Set up the circuit shown on the right.
- Wind the long wire neatly around the nail 15 times.
- Set the power supply to two volts and close the switch. Test the nail to see if it will pick up any paperclips.

1. Record your results in a table like the one below:

Voltage of power supply (V)	Number of turns of wire	Number of paperclips picked up
2	15	
2	20	
2	25	
2	30	
4	15	
4	20	
4	25	
4	30	

- Wind five more turns of wire onto the nail.

2. How many paperclips does the electromagnet pick up now?

- Keep winding the wire onto the nail. Record the number of paperclips picked up for 25 and 30 turns of wire.
- Raise the voltage to four volts. Repeat the steps above.

3. Record the number of paperclips picked up when the voltage is four volts.
4. What effect does increasing the number of turns of wire have?
5. What effect does raising the voltage have?

Activities

REMEMBER

1. What is the difference between a permanent and a temporary magnet?
2. How is an electromagnet different from a bar magnet?
3. What substance or substances does a needle contain if it can be magnetised?
4. What is the scientific name for the 'mini-magnets' that make up larger magnets?

THINK

5. Why doesn't iron always behave like a magnet with a north and south pole?
6. State two ways to increase the strength of an electromagnet.

CREATE

7. Design and build a device that uses an electromagnet to burst a balloon.

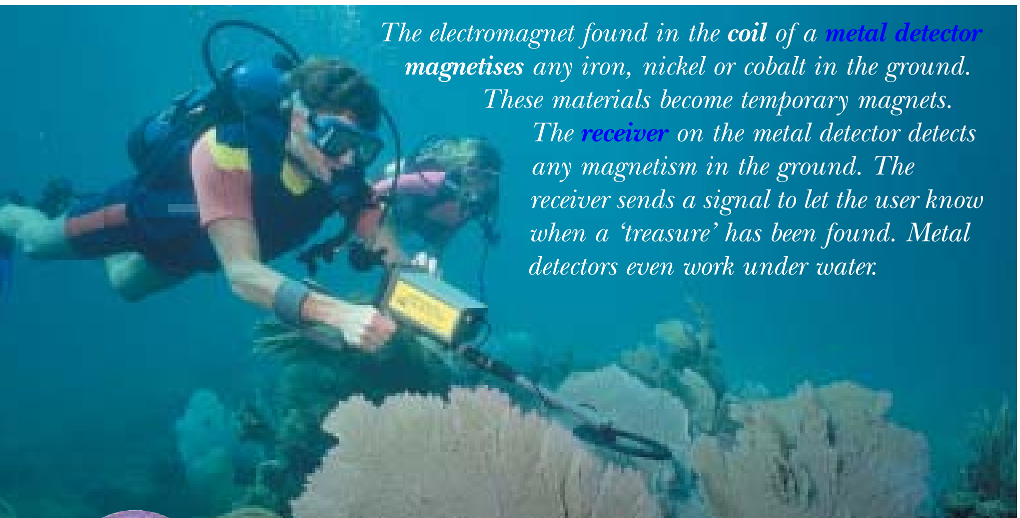
checklist

I can:

- ☐ explain magnetism in terms of domains in magnetic materials
- ☐ compare temporary and permanent magnets
- ☐ compare electromagnets with other magnets.

Using magnets

Permanent **magnets** and **electromagnets** are found in many places, including telephones, doorbells and liquid-crystal displays in calculators. They are even useful for finding treasure and creating pictures.

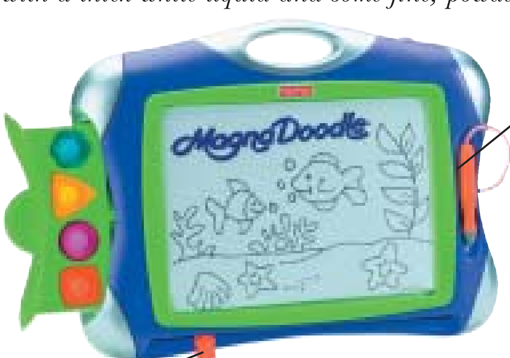


The electromagnet found in the ***coil*** *of a* ***metal detector magnetises*** *any iron, nickel or cobalt in the ground. These materials become temporary magnets. The* ***receiver*** *on the metal detector detects any magnetism in the ground. The receiver sends a signal to let the user know when a 'treasure' has been found. Metal detectors even work under water.*

Magnetic pictures

Magnets show up in the most amazing places! Four Japanese **engineers** invented the Magna Doodle in 1974. They were trying to make a blackboard that didn't create dust. The toy they came up with was the Magna Doodle. Since then, over 40 million of these toys have been sold around the world.

The Magna Doodle is made up of a thick plastic screen, a magnetic eraser and a magnetic pen. The screen is made up of small sections that look like the honeycomb found in some chocolate bars. Each of these sections is filled with a thick white liquid and some fine, powdered, black ***magnetite****.*



As the magnetic pen slides along the top of the plastic screen, the black magnetite is attracted towards it. The magnetite lies at the top of the thick liquid where it can be seen through the screen.

To remove the picture, the magnetic eraser slides over the back of the screen. The attraction to the eraser pulls all of the magnetite in the honeycomb sections to the back of the screen, leaving the front white.

Videotapes

Although magnetic videotape has the advantages of being cheap and easy to record and re-record on, it is easily damaged when stored near magnets. Magnets can change the pattern that has been stored on the tape.

The films that you see at the cinema are different from videotapes. Chemicals create the picture on the cinema film. The film used in cinemas, like that used in normal cameras, cannot be re-recorded on and is more expensive to make. Cinema films last much longer and produce higher quality pictures.

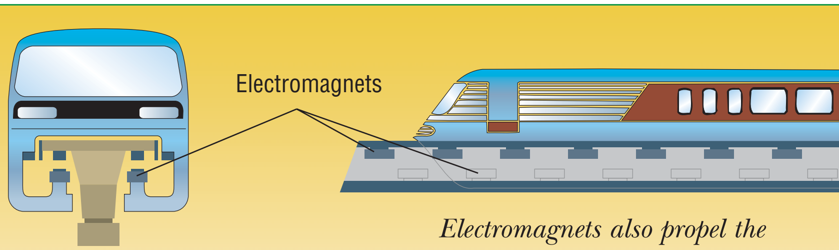
500 km/h magnets

The maglev train gets its name from MAGnetic LEVitation train. It reaches speeds of up to 500 km/h and doesn't even need a normal engine to run! Once the train is at full speed, passengers enjoy a fast, smooth and quiet ride.

The inside of a video recorder has two electromagnets, called heads. The recording head creates the magnetic pattern on the tape. The playback head reads the pattern and turns it into pictures and sound.

The plastic ribbon inside a videotape is coated with substances that contain 'mini-magnets' or **domains.**

When the ribbon passes through a magnetic field, the domains are forced into a pattern.



This train seems to float above the train tracks. It uses pushing ***forces*** *between electromagnets on the track and on the train to keep them apart. The train touches the track only while it is building up speed before lift-off.*

Electromagnets also propel the train forward. Magnets ahead of the train pull the train forward. Magnets behind the train push it forward.

Activities

REMEMBER

1. Why should magnets be kept away from videotapes?
2. How does a maglev train float above the track?
3. Which part of a metal detector is an electromagnet?
4. Why is magnetite used in a Magna Doodle?

THINK

5. Why is a maglev train able to travel so fast?
6. The coils in metal detectors need to be blocked off from the receiver. Why is this important?
7. Could you use a metal detector to find a pure-gold nugget? Explain your answer.

INVESTIGATE

8. Find out what combination of magnets are required for the maglev train to be pulled forward at the front and pushed forward from the back. You might find some clues by going to www.jaconline.com.au/science/weblinks and clicking on the Maglev Train link for this textbook.
9. Find out about the Magnetic Resonance Imaging (MRI) machine. What is it and how does it work?

checklist

I can:
- ☐ list and describe some of the uses of magnets
- ☐ explain how electromagnets are used in videotapes, maglev trains and metal detectors.

Making magnetic maps

A **magnetic field** is like a map of the pushes and pulls of a **magnet**. You can't actually see the magnetic pushes and pulls because the magnetic field is invisible. But there is a way to make it visible using iron filings. When the magnetic field is made visible you can see how big the pushes and pulls are. When a **compass** is placed in different positions around the magnet it reveals the direction of the pushes and pulls.

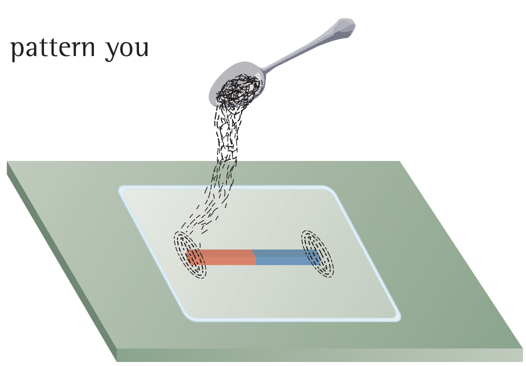
These iron filings show the magnetic field around a magnet. The iron filings are closer together where the pushes and pulls are strongest. Notice that the magnetic field is strongest near the ends (poles) of the magnet.

Making a magnetic map visible

You will need:
2 bar magnets
horseshoe magnet
small plastic bags
iron filings
large plastic lid (for example, ice-cream lid).

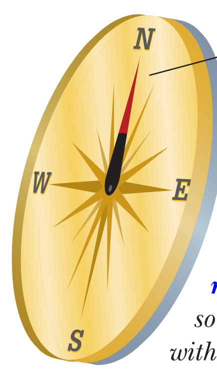
- Place one of the bar magnets in a plastic bag under the centre of the lid.
- Carefully sprinkle some of the iron filings over the lid. You may need to spread them a little by lightly tapping the lid.

1. Draw a diagram of the pattern you see in the iron filings.
2. What does this pattern represent?
3. Label the strongest parts of the magnet with an X.
4. Do the iron filings tell you which is the north pole of the magnet?



Which way is north?

A compass is a simple tool for letting us know where north is. The compass needle always points to the magnetic North Pole of the Earth. As long as you have a compass you'll always know which way is north. This is especially handy if you are lost!



*The compass needle moves freely around the centre point until it points north. It is pushed and pulled by **magnetic forces** so that it lines up with the Earth's magnetic field, just like a hanging magnet. In fact, a compass needle is a magnet. The part of the needle that points or 'seeks' north must be the north pole of the magnet.*

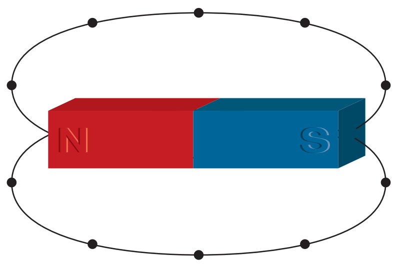
Finding the direction of a magnetic field

You will need:

bar magnet

compass.

- Place the compass at 10 different points around the magnet. Use this diagram as a guide:



- At each of the ten points, mark the direction that the compass needle points in. Use arrows to show the direction.

1. Describe the pattern of arrows noting that the arrows show the direction of the pushes and pulls around a magnet.

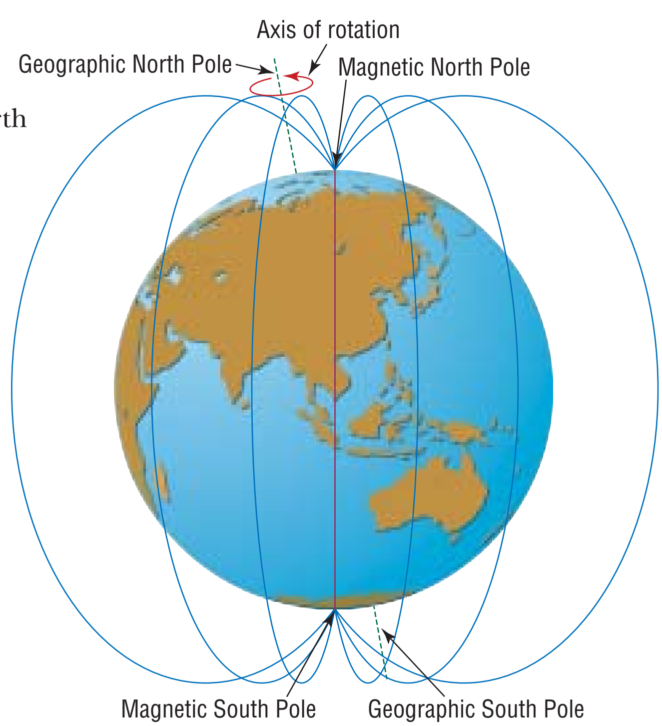
The Earth's magnetic field

The Earth is surrounded by a huge magnetic field. Scientists are still not sure what causes the Earth's magnetic field. Some believe that the large amounts of iron and nickel in the ground create the magnetic field. Others believe that, as the Earth spins, the liquid parts deep inside it move and create the Earth's magnetic field.

The magnetic forces around the Earth act on some objects in the same way that other magnets do. The force causes such objects to line up with the Earth's magnetic field. That is why a bar magnet hanging from its middle lines up with the North and South poles of the Earth.

Notice that there are two north poles and two south poles marked on the diagram at right.

The north poles of magnets do not point exactly to the North Pole, but actually line up with the magnetic North Pole of the Earth. The magnetic North Pole is nearly 2000 km from the geographic North Pole. The **magnetic South Pole** is found just over 2000 km from the geographic South Pole.



Activities

REMEMBER

1. How can you tell where the magnetic field is strongest around a magnet?
2. Why do hanging magnets line up with the North and South poles of the Earth?
3. A compass needle does not point exactly to the geographic North Pole. Where does it actually point?

THINK

4. Why is it important that the magnets used in compasses are small and light?
5. Why should magnets be kept away from compasses?
6. Draw a picture to represent the Earth with an imaginary magnet inside that helps us to think about the Earth's magnetic field. Label the north and south poles of the magnet and the North and South poles of the Earth.
7. The compass needle is missing in this diagram. Redraw the diagram showing the correct direction of the needle.

CREATE

8. Make a working model of a compass using a bar magnet as the compass needle.

checklist

I can:

- ☐ describe a magnetic field in terms of a map
- ☐ locate the strongest part of a magnetic field
- ☐ describe how a compass works.

The Sci-News Times

6 NOVEMBER 1997 WEATHER: EARTH — THE USUAL. SUN — HIGH SOLAR-FLARE ACTIVITY

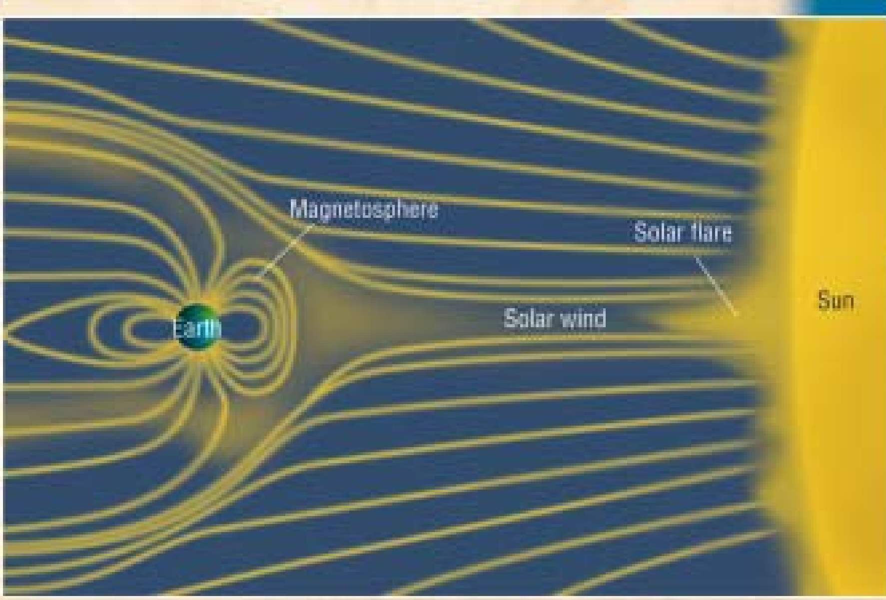
Homing pigeons grounded

All homing-pigeon races scheduled for the coming weekend have been cancelled due to **geomagnetic storms**. All owners of homing pigeons have been warned to avoid releasing them until the magnetic disturbance has passed. Two separate geomagnetic storms will strike the Earth within 48 hours on the weekend. They will distort the Earth's **magnetic field** and make it impossible for the homing pigeons to find their way home.

Why the pigeons get lost

Scientists have shown that homing pigeons use the magnetic field of the Earth to find their way over long distances. However, they still don't know exactly how the pigeons do this. An organ (like the eye or ear) that senses magnetism has not yet been discovered. It is possible that tiny crystals of **magnetite** found in the pigeons' brains act like mini-magnets. This could help pigeons to line up with the magnetic field — just like a **compass**. When the Earth's magnetic field is distorted by a geomagnetic storm, the pigeons don't know which way to fly.

Magnetically disturbed



Geomagnetic storms are caused by huge outbursts of energy on the Sun called **solar flares**. The flares release billions of tonnes of particles, which are carried away by the solar wind. The particles speed towards Earth at about three million kilometres per hour. When they arrive, they change the shape of the Earth's magnetic field.

It's not just pigeons!

Magnetite has been found in other animals, including some types of ant and bee. It is possible that they also lose their way in geomagnetic storms. Magnetite has also been found in the brains of dolphins. Even human brains contain small amounts of magnetite. Scientists are yet to find out how, or even if, we use it. There is still a lot to find out about animal magnetism.

Warning!

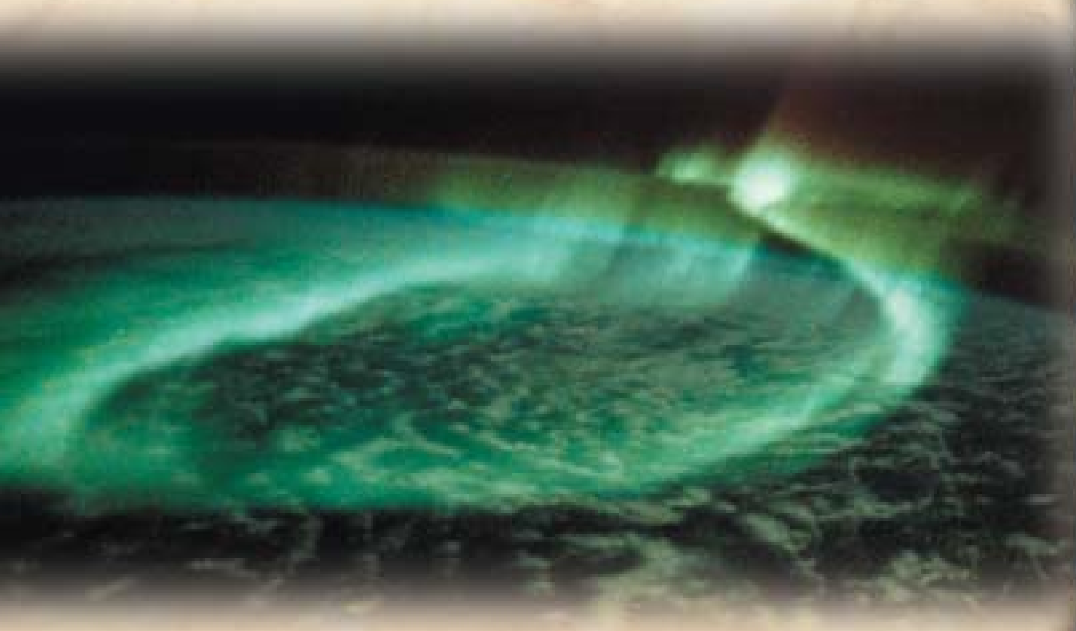
Some geomagnetic storms have caused millions of dollars of damage to business and industry. Emergency services are preparing for a busy weekend. The storms can affect:

- radio, television and telephone signals
- air and marine satellite-navigation instruments
- pipelines (corrosion).

The worst geomagnetic storms can even cut power supplies. In 1989, a geomagnetic storm knocked out the power supply to six million Canadians for nine hours. Experts predict that the two weekend storms will not be as serious as the 1989 storm. However, residents are advised not to panic if phones don't work or power is lost. Phone services and power will be restored within a few hours. Mobile-phone services are likely to be affected for the whole weekend.

The bright side of geomagnetic storms

Although geomagnetic storms can cause a lot of disruption, there is a bright side. The **aurora australis** (also called the southern lights) may be visible at night from parts of southern Australia. Usually this spectacular light show is visible only close to the South Pole. It is caused when the Earth's magnetic field captures particles caught in the solar wind. During a geomagnetic storm there are many more particles, so this natural light show is bigger and brighter. This photo (below) of the aurora australis was taken by a satellite camera.



Don't let a geomagnetic storm ruin your day . . . get Magnacoat

MAGNACOAT — THE ULTIMATE IN PROTECTION

A single coating protects against the most severe geomagnetic storms.

With magnacoat you can say goodbye to power blackouts, power surges, corrosion, radiation poisoning and electrical interference — guaranteed.

Magnacoat can be painted on anything — gas and oil pipelines, satellites, electrical cables, skin, pigeon feathers, and even your mobile phone.

Buy now and receive a free magnetometer.*

*While stocks last

Activities

REMEMBER

1. What causes geomagnetic storms?
2. How do geomagnetic storms affect the Earth's magnetic field?
3. Why do scientists believe that homing pigeons get lost during geomagnetic storms?
4. What causes the aurora australis?

THINK

5. The particles released by solar flares travel three million kilometres every hour towards Earth. If the Earth is 150 million kilometres from the Sun, how long does it take the particles to reach the Earth?

BRAINSTORM

6. During a geomagnetic storm, compass needles might not point towards the North Pole. Make a list of human activities that this might affect.

INVESTIGATE

7. Find out what the magnetosphere is.

IMAGINE

8. Imagine that there was such a thing as magnacoat:
   (a) What do you think it would be made from?
   (b) How do you think it might work?

checklist

I can:

- ☐ explain how geomagnetic storms on the Sun affect the Earth's magnetic field
- ☐ describe some of the hazards of geomagnetic storms.

Inside atoms

Imagine breaking up an object into smaller and smaller pieces. Eventually, the object cannot be broken up any further. It is a bit like breaking down a brick wall. In the end you just have a pile of bricks.

The small particles that are eventually formed by breaking up objects are called **atoms**. Atoms are the building blocks of all substances, just as bricks are the building blocks of walls.

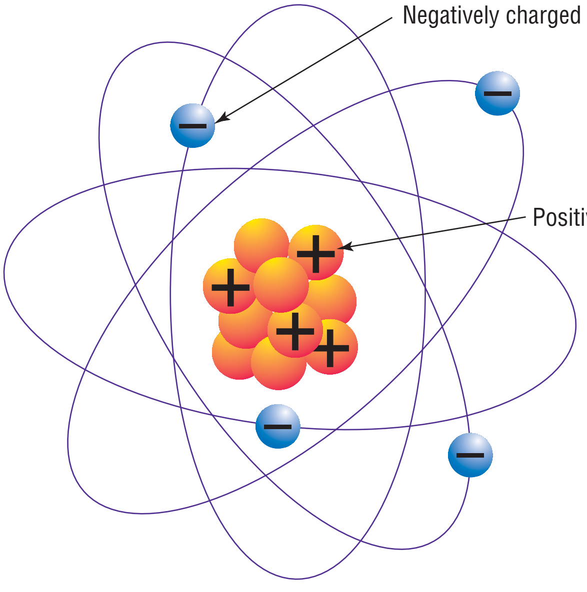
Atoms are very small particles. They are so small that they cannot be seen with a magnifying glass or a normal microscope. Scientists have studied these particles and found that they are made up of even smaller parts. Some of these smaller parts have an electric **charge**. There are two different types of electric charge: positive and negative.

HOW ABOUT THAT!

The central part of the atom is called the nucleus. The nucleus is very small compared with the overall size of the atom. To give you an idea of the size of the nucleus compared with the whole atom, imagine this: If the nucleus of an atom was the size of a marble, the overall size of the atom would be about as big as the MCG!

In and around atoms

Benjamin Franklin, an American scientist who lived in the 1700s, invented many scientific words that are still used when talking about electricity. He was the first person to use the word 'charge'. He also named the two charges found in atoms positive and negative. These charges are similar to the north and south **poles** of **magnets** because they are opposites of each other.



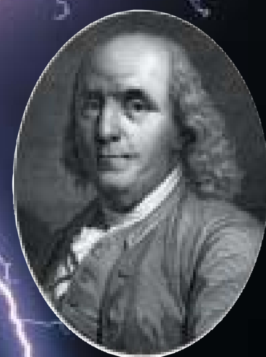
This is a simple model of an atom. The positive charge is in the centre of each atom and the negative charge is carried by very light particles that move around the outside of each atom.

THEN AND NOW

Democritus

Democritus was a famous philosopher (thinker) from ancient Greece. He was one of the first people to try to describe what all things were made up of. Democritus named the parts that make up all things '*atomon*', which means 'indivisible'. Unfortunately, his ideas about the atom faded away for almost 2000 years. It was not until the 1600s that serious thought went into investigating the atom again. Scientists are still discovering new things about atoms — how they behave and what's inside them.

Benjamin Franklin — ahead of his time



Apart from 'charge', Benjamin Franklin 'invented' the words battery, **conductor, discharge**, uncharged, electrician, and even electric shock. He used the term 'electric shock' after performing many experiments with electricity. One of Franklin's most well-known experiments involved flying a kite in a thunderstorm. A metal key was attached to the kite's string. During the storm, Franklin was able to make a spark jump from the key to his finger. This proved that the storm was electrical.

A balancing act

In most atoms, the amount of positive charge is the same as the amount of negative charge. Atoms are usually **neutral**. We could also say that atoms usually have *no overall charge*. When there is more positive charge than negative charge in an atom, the atom has an overall positive charge. If an atom has more negative charge than positive, it has an overall negative charge.

Tipping the scales of balance in a neutral atom is easy to do. Remember that the negative charges are on the outer of the atom. This part of the atom is the easiest part to change. Removing some of the outside negative charge tips the balance. The atom would then have more positive charge than negative charge.

How about making an atom negative overall? It is difficult to remove the positive charge from the centre of the atom. It is far easier to add more negative charge to the outside of the atom.

Go to worksheet 27

Activities

REMEMBER

1. Why can't atoms be seen with the naked eye?
2. How are atoms similar to magnets?
3. What is balanced in a neutral atom?

Go to worksheet 28

THINK

4. Negative charges are found around the outside of atoms. What keeps the negative charges around the positive charges in the centre of the atom?

INVESTIGATE

5. There have been many scientists who have made significant discoveries about the atom. Find out who they are and what their ideas were.

CONNECT

6. Benjamin Franklin began as a newspaper publisher, but at the age of 42 started his scientific adventures. During this time he discovered the lightning rod, lightning bells, bifocal lenses, the Franklin stove, the catheter and many other devices. Choose at least one of Franklin's discoveries and write about how he discovered it, what it does and how it works. To find out more, go to www.jaconline.com.au/science/weblinks and click on the Benjamin Franklin's Inventions link for this textbook.

checklist

I can:

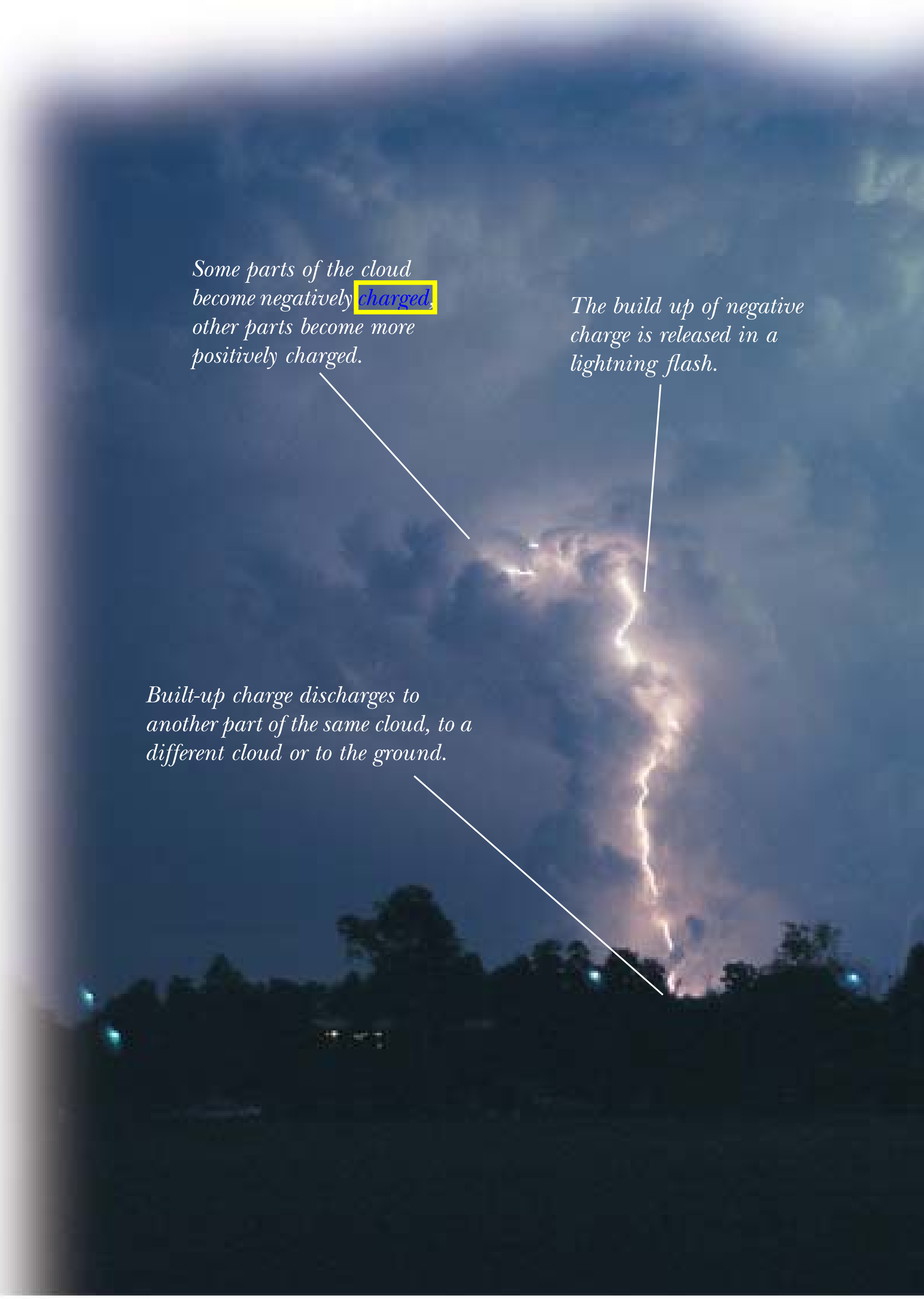
- ☐ list the types of charged particle found in an atom and describe where in the atom they are found
- ☐ describe the difference between positive, negative and neutral atoms.

Lightning strikes

Have you ever taken off your jumper and heard a crackling noise? Ever been 'zapped' by a door handle after walking on carpet? Has your hair ever stood on end after being combed? If so, you have felt the effects of **static electricity**.

Build-up

Static electricity is a build-up of **charge** on an object. The build-up is created by tipping the balance between the amount of positive and negative charge in the **atoms** of the object. When two objects are rubbed together, it is possible for some of the **negative charge** to shift from one object to the other. That leaves one object with an overall negative charge and the other with an overall **positive charge**. This movement of charge is slow and not noticeable.



When sparks fly

The 'zap' you feel when you reach for the door handle after rubbing the carpet comes from releasing built-up charge quickly. The build-up of negative charge jumps between your hand and the handle in the form of a spark. After the 'zap' you are ***neutral*** *again. The release of built-up charge is called* ***discharge****.*

Go to worksheet 29

Static electricity on a massive scale!

The particles of water and ice inside clouds are constantly moving against each other. Their movement causes charge to build up in the cloud. Some parts of the cloud become more negative, while other parts become more positive.

The charges keep building up. Eventually, there is so much negative charge built up in part of the cloud that it quickly discharges to another cloud or to the ground below. The result is the spectacular spark we call **lightning**.

The heat created during a lightning strike heats the nearby air to a very high temperature. The air suddenly expands and produces the crashing sound we know as thunder.

A bolt of lightning can measure 20 000 °C, which is much hotter than the surface of the Sun. If it strikes a building, it can cause a huge amount of damage. It is known that lightning takes the easiest path to the ground, so **lightning rods** are attached to the top of tall buildings. It is more likely that lightning will strike the rod, keeping the rest of the building safe.

Although lightning is spectacular to watch, it can also be very dangerous. Make sure you do not talk on the telephone during an electrical storm. Lightning can strike the phone line and travel to every phone on the line. Mobile or cordless phones are much safer. It is also unsafe to be outside during an electrical storm. Take shelter inside a building or in a car. Never take shelter under trees, as they are often struck by lightning.

Activities

REMEMBER

1. What is static electricity?
2. What is the release of built-up charge called?
3. What causes the spark you sometimes feel when you reach for a door handle after rubbing your feet on the carpet?
4. Why should you avoid standing under trees in a thunderstorm?

THINK

5. Explain why a crackling noise is sometimes heard when you take off a jumper.
6. It is possible for cars to build up an overall charge, particularly after a long drive. Suggest a reason for this.
7. Why is talking on a mobile phone safer than talking on a normal cord phone during a thunderstorm?

CONNECT

8. Search the Internet to find out how many people are struck by lightning each year in Australia.
9. During ancient times, there were many myths about lightning. Search the Internet to find out about these and other myths that people believe nowadays.

✓ checklist

I can:

- ☐ explain what static electricity is
- ☐ describe discharge in terms of the release of built-up charge
- ☐ list some safety measures to avoid injuries due to lightning.

The electric force

The spark between objects is not the only sign that **static electricity** is at work. The crackling of sparks is caused by the fast movement of negative **charges**. Sometimes charge between objects can move more slowly towards each other and not make a spark at all.

The charge moves because of an **electric force**. The electric force can pull on charges without touching them. The pull is greatest when such objects are close together.

Two ways to charge

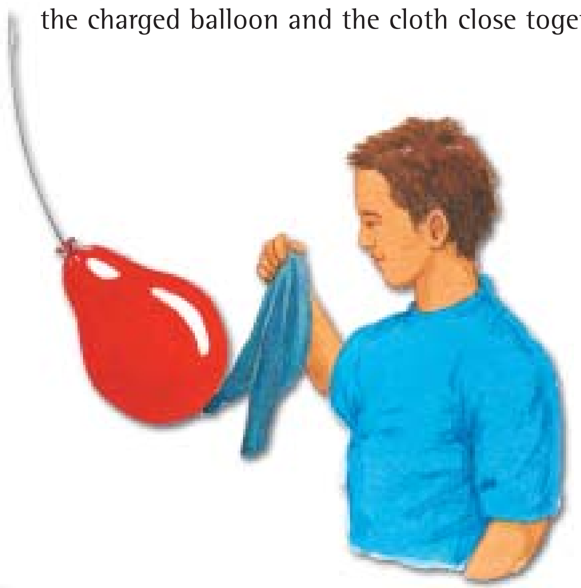
When two objects rub together, some of the negative charges from one object can move to the other. Both objects gain an overall charge.

Another way to transfer charges between objects is to allow them to touch. When a charged object touches a neutral one, negative charges can move between them. The neutral object now has an overall charge.

Can charges push as well as pull?

You will need:
2 inflated balloons
string
rod or stick (approximately half a metre in length)
piece of cloth (wool or silk).

- Tie the string to one of the balloons and hang it over the rod.
- Charge one of the balloons with the cloth. Hold the charged balloon and the cloth close together.

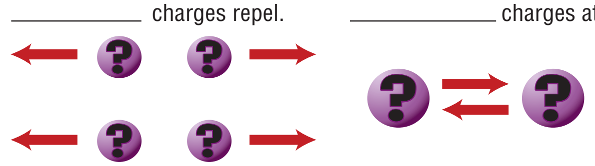


1. What happens to the balloon and the cloth when they are near each other?
2. Do the balloon and cloth have the same charge?

- Charge both balloons with the same cloth. Bring the two balloons close together.

3. Do the two balloons attract or repel this time?
4. (a) If the cloth is positively charged after rubbing, what is the charge on the balloons?
   (b) What if the cloth was negatively charged?
5. Why is it important to use the same cloth to rub both of the balloons?
6. Complete the sentences and label the charges as + or –.

__________ charges repel. __________ charges attract.



Can a charged object attract a neutral one?

You will need:
perspex rod
silk or wool cloth
thin stream of running water.

- Bring the uncharged rod close to the stream of water.

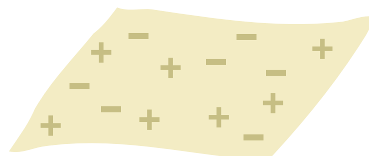
1. Describe what happens.

- Charge the rod with the cloth. Bring the charged rod near the water.

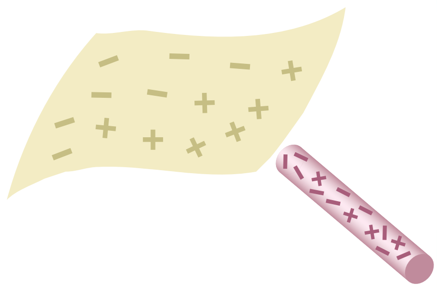
2. (a) Describe what happens to the water now.
   (b) Why does this happen?
3. Why is it important to try this experiment first with an uncharged rod?

Attracting neutral objects

Sometimes uncharged objects, like water and paper, are attracted to charged objects.



Neutral objects have equal amounts of negative and positive charge.



When a charged object comes close to the edge of a neutral object, the charges in the neutral object rearrange themselves. The charged object is attracted to the opposite charges in the neutral object. So, a ***negatively charged*** *object is attracted to the positive charges in a neutral object.*

Sticky clothes

Have you ever worn clothes straight from the clothes dryer and found that they stick to you? As clothes rub together in a clothes dryer, they can build up charge. If this happens, the charged clothes will be attracted to you when you wear them. If this is not the look you are going for, fabric softeners can help. Fabric softeners coat the fibres of clothes with substances that do not allow static build-up. They make the charge flow away so that it cannot build up.

Activities

REMEMBER

1. When a plastic rod is rubbed with a certain cloth, the rod becomes positively charged. What is the charge on the cloth?
2. Explain how charged objects can be attracted to uncharged objects.
3. State whether the following are true or false:
   (a) Objects with like charges attract.
   (b) Charged objects can attract uncharged objects.
   (c) Two neutral objects repel each other.
   (d) Neutral objects contain both negative and positive charges.
   (e) Objects with an overall negative charge still contain some positive charges.
   (f) If two objects repel, they must be **positively charged.**

THINK

4. How is an electric force like a magnetic force?
5. Describe two different ways to charge a plastic comb.

INVESTIGATE

6. Design an experiment to find out which materials are more likely to build up charge.

checklist

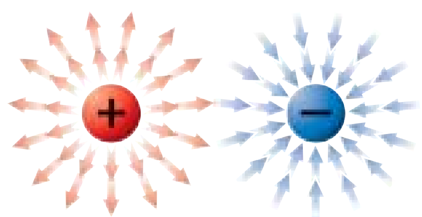
I can:
- ☐ describe how to charge up an object
- ☐ describe the forces between charged objects
- ☐ explain how neutral objects are attracted to charged objects.

Making electric maps

How much does a **charge** push or pull? And in what direction will charged objects move? Like **magnetic fields**, **electric fields** can provide information about the pushes and pulls near a charged object. Electric fields are invisible, but are revealed by other objects affected by charge.

Mapping charges

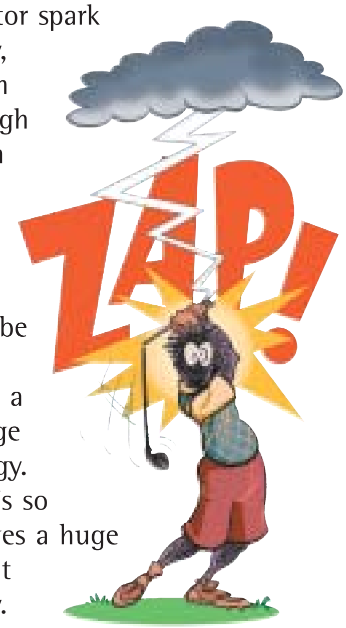
An electric field is like a map of the pushes and pulls caused by the electric charge of an object. Like a magnetic field, an electric field is invisible unless it is revealed by objects that are affected by the charge. When it is revealed, the electric field shows the direction of the pushes and pulls around a charge. It also shows how big the pushes and pulls are. The electric field lines are closest together near the charged object. This is where the **force** is strongest.



This diagram shows arrows pointing in the direction of the electric field around a positive and a negative charge. The electric field or 'map' shows the direction that a positive charge would be pushed or pulled by the **electric force**.

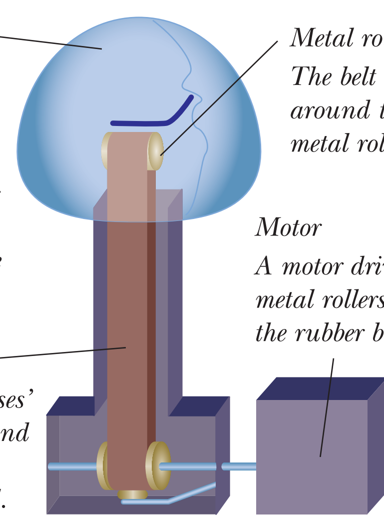
A deadly combination

The 240 V in your home can kill. However, a 100 000 V Van de Graaff generator spark is much safer. Even though each electric charge in a Van de Graaff generator spark carries a lot of energy, there is not very much charge jumping through the air. At home, each electric charge carries less energy, but there is a very large amount of charge moving through the wires. To be dangerous, the electricity has to have a large amount of charge carrying a lot of energy. That's why lightning is so dangerous. It discharges a huge amount of charge that carries a lot of energy.



The Van de Graaff generator

The Van de Graaff generator is a machine that makes **static electricity.** It has a large rubber belt held tightly between two metal rollers. When the motor is turned on, the belt begins to rotate. As it moves, the belt rubs against the metal rollers. Charges move between the belt and the metal rollers. The belt passes on the charge to the large metal dome. The dome becomes charged. Bringing a metal object near the dome will release the build-up of charge on the dome and produce a spark. So, the spark you see is the dome **discharging**.



Go to worksheet 30

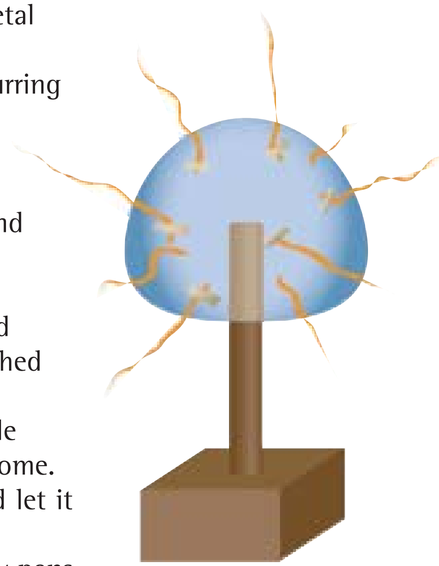
The electric field around a Van de Graaff generator

!CAUTION: Your teacher will carry out this activity. Do not touch the charged dome of a Van de Graaff generator. Always use an **earthed** testing rod to discharge. Carry out the demonstration while standing on a plastic tray.

You will need:
Van de Graaff generator
aluminium-foil patty pans
several strands of wool.

- Turn the Van de Graaff generator on and let it charge up. Bring the metal testing rod near it.

1. What do you observe occurring between the rod and the dome?
2. Explain your observation. Use words like charging and discharging in your explanation.



- Turn the generator off and discharge it using the earthed metal rod.
- Place the patty pans upside down on the top of the dome. Turn the generator on and let it charge up.

3. What happens to the patty pans once the generator charges up?
4. Discuss and then write down some possible reasons for your observations.

- Turn the generator off again and discharge it.
- Tape several strands of wool onto the dome. Make sure they are spread out over the surface of the dome. Turn the generator on and let it charge up once more.

5. What happens to the wool?
6. Explain why this happens in terms of the charges on the dome and the wool.
7. The wool forms a pattern around the dome. What do you think this pattern represents?

Conductors and insulators

The teacher needs to stand on a plastic tray in the experiment above because the tray is an **insulator**. Insulators do not allow charge to pass through them very easily. By standing on the tray, the charge from the Van de Graaff generator will pass through the metal rod, not the teacher.

The metal rod is a **conductor**. The built-up charge can flow easily through the metal rod, keeping the teacher safe from sparks.

Activities

REMEMBER

1. What two things does an electric field 'map' show?
2. How can you tell where an electric field is strongest?
3. How are insulators different from conductors?
4. Why is a spark from a Van de Graaff generator not as dangerous as lightning?
5. What charge — positive or negative — builds up on the dome of a Van de Graaff generator?
6. How do you discharge a Van de Graaff generator safely?

THINK

7. Water can be a good conductor of electricity. Why do you think it would be unsafe to operate a Van de Graaff generator while standing in a puddle of water?
8. Why do lightning rods need to be made out of materials that are conductors of electricity?

IMAGINE

9. Imagine you are a tiny particle with a small positive charge. Describe what will happen to you:
   (a) near a large positive charge
   (b) near a large negative charge
   (c) near a large neutral object.

checklist

I can:
- ☐ describe the electric field around a charge or charged object
- ☐ explain the behaviour of objects near a Van de Graaff generator
- ☐ explain what conductors and insulators are.

Static: good and bad

Static electricity can be a real nuisance sometimes, but it does have some benefits as well. Sparks caused by static electricity can trigger explosions, but without static-cling, printers and copiers would never work.

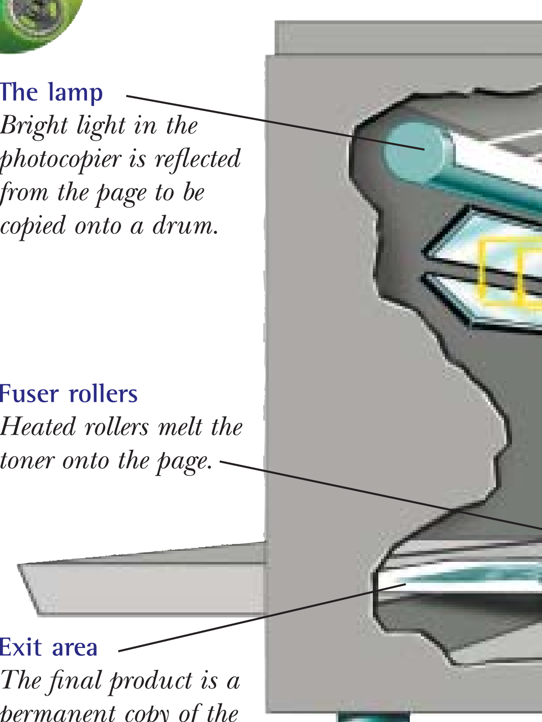
When getting out of a car is a hazard

A moving car is a great **charge** builder. As a car moves, its body 'rubs' against the air and its tyres 'rub' against the road. The rubbing can cause charge to build up on the car and its passengers. As you get out of the car and go to touch the metal body, a spark crosses the small gap between your hand and the metal just before you touch it. Zap!

Making an operation safer

Static electricity is a hazard in an operating theatre. Charge can build up on blankets and **discharge** quickly, causing a spark. Many of the instruments used in an operating theatre can also create sparks. This is very dangerous because gases that could easily explode are used in operating theatres. Doctors and nurses wear gowns made from natural fibres that do not build up electric charge easily. The patient and all of the equipment are **earthed**. An object is earthed when it is making contact with the ground. By earthing the patient and any equipment, charge flows to the ground before it can build up and cause a spark.

HOW IT WORKS



The lamp
Bright light in the photocopier is reflected from the page to be copied onto a drum.

Fuser rollers
Heated rollers melt the toner onto the page.

Exit area
The final product is a permanent copy of the original page.

When cleaning makes things dusty

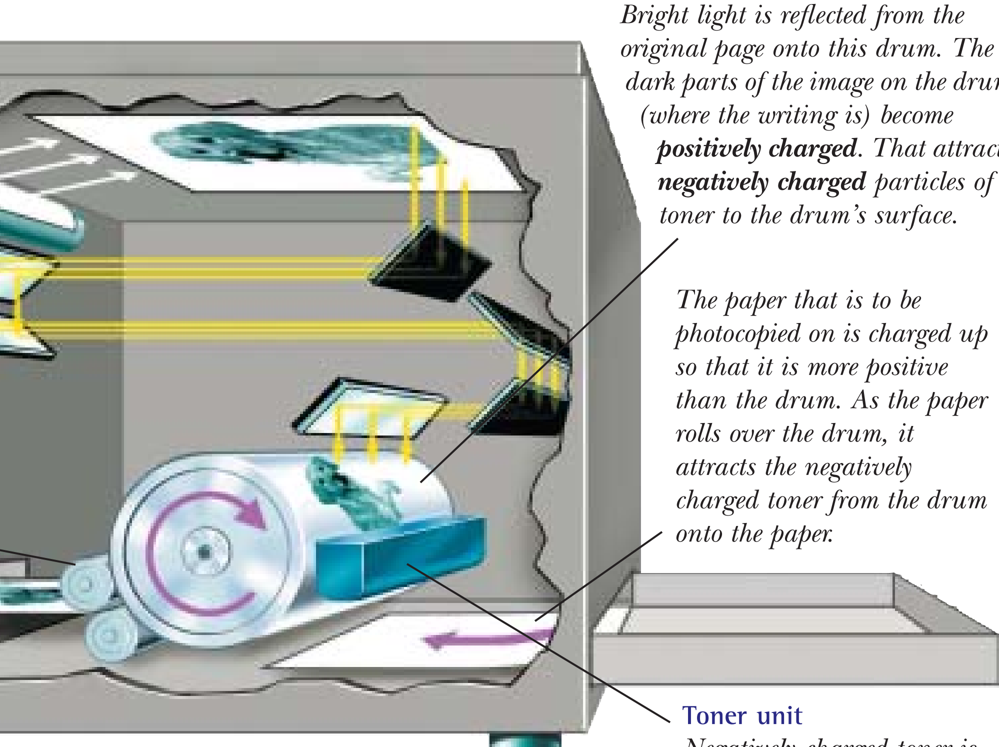
When you use a cloth to wipe over furniture it can sometimes make matters worse. Rubbing leaves the surface with an electric charge that can **attract** small dust particles in the air. The dust particles are **neutral** and will be attracted to either a positive or negative charge left on the furniture.

Using a furniture polish reduces the attraction between the furniture and dust particles by helping built-up charge leak into the air. Charge is less likely to build up and the dust won't come back so fast.

Have you ever noticed that your computer screen is dustier than the rest of the computer? Television and computer screens are excellent dust collectors. Charges build up on the screen, attracting dust particles.

Powder coating

Have you noticed the hard, painted finish on metal toys, bicycles, car-bumper bars and fridge doors? The paint is a long-lasting powder coating. Static charges are used to apply coloured powder to metal surfaces. As the powder shoots out of a nozzle, it is charged up and attracted to the metal's surface. Special ovens heat the powder and turn it into a smooth, tough surface. This method of painting gives an even coat of colour. One difficulty is that dust can also be attracted to the newly painted surface. Great care must be taken to keep dust away when the coating is applied.



Drum
Bright light is reflected from the original page onto this drum. The dark parts of the image on the drum (where the writing is) become ***positively charged****. That attracts* ***negatively charged*** *particles of toner to the drum's surface.*

The paper that is to be photocopied on is charged up so that it is more positive than the drum. As the paper rolls over the drum, it attracts the negatively charged toner from the drum onto the paper.

Toner unit
Negatively charged toner is stored here.

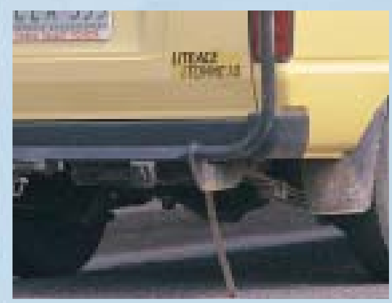
Activities

REMEMBER

1. Why are patients earthed during an operation?
2. How does charge build up in a car?
3. Why are heated rollers used in photocopiers?
4. Why can the screen of a television be dustier than the top of a television?

THINK

5. Why do some cars sometimes have strips attached to the bumper bar that touch the ground as the car moves?



6. Planes build up a lot of charge as they fly through the air. Explain why planes need to be earthed when they are re-fuelled.

INVESTIGATE

7. Plan and carry out an experiment that uses static electricity to separate salt and pepper. Find out why static electricity works for separating these mixtures and not others.
8. A static precipitator is used to remove soot particles from smoke. Find out how a static precipitator works. Draw a diagram to help with your explanation.

checklist

I can:

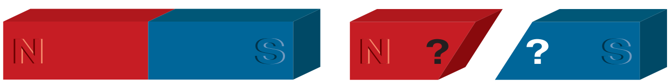
- ☐ list some of the dangers of static electricity
- ☐ list some practical uses of static electricity
- ☐ explain how and why objects are earthed.

Check and challenge

MAGNETIC AND ELECTRIC EFFECTS

Magnetic pieces

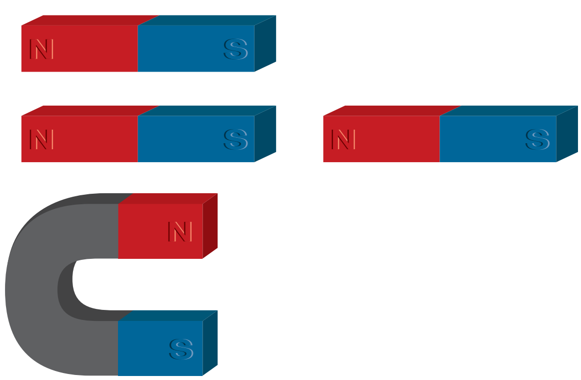
1. Label the poles formed when this magnet was cut in half.



2. What is a domain?
   A The space around a magnet or magnetic material
   B The end of a magnet
   C The edge of a magnet
   D A 'mini magnet' found in magnetic materials
   E A 'map' of the pushes and pulls around a magnet.

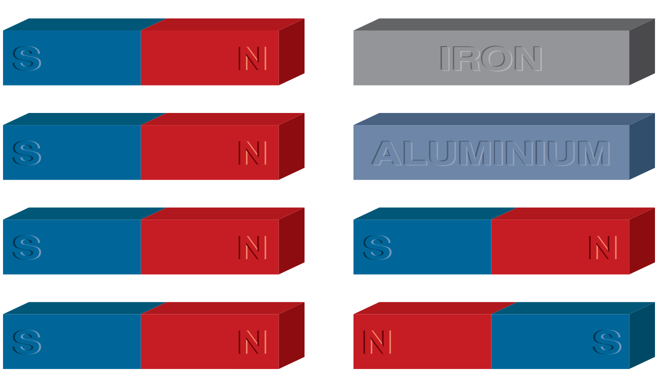
Magnetic field patterns

3. Copy these magnets and draw a map of the pushes and pulls around them.



Attraction and repulsion near magnets

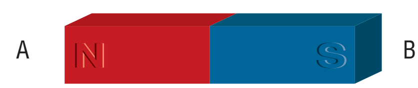
4. Which of the following objects will:
   (a) pull together?
   (b) push apart?
   (c) remain as they are?



5. Which part of a magnet has the greatest pulling effect?
   A The edges
   B The poles
   C The domains
   D The middle
6. By looking at a map of pushes and pulls around a magnet, how can you tell where the greatest pulling or pushing effect will occur?

The magnetic compass

7. Describe how a magnet could be used to find the magnetic North Pole of the Earth.
8. Re-draw this diagram. Show clearly the direction that a compass needle would point if it were placed in position A and position B.



9. Would a compass work if the needle were replaced with a piece of aluminium foil? Explain your answer.

Experimenting with magnets

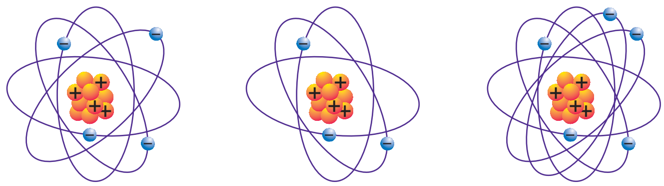
10. You can make your own compass by stroking a steel needle with a permanent magnet.
    Explain why you need to stroke the needle in one direction only. Use the word 'domains' in your explanation.
11. The following information refers to electromagnets made from wire coiled around an iron nail.
    List the electromagnets in order from strongest to weakest.

Electromagnet	Voltage (V)	Turns (coils) of wire
A	5	15
B	2	15
C	5	20

Atoms

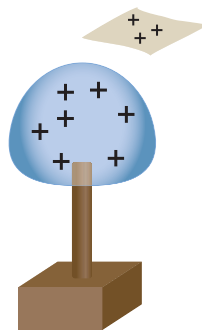
12. Why are the negative charges of an atom easier to remove than the positive charges?

13. Which of the following atoms is positively charged, which is negatively charged and which is neutral?



Attraction and repulsion in electric fields

14. This Van de Graaff generator has an overall positive charge.
    (a) In which direction would a positively charged piece of paper move if it was brought near the dome?
    (b) In what direction would a negatively charged piece of paper move?
    (c) Draw electric-field lines around the Van de Graaff generator.



15. Explain, with the aid of a diagram, how a neutral piece of paper is attracted to a charged plastic pen.

Static electricity

16. Imagine rubbing your shoes on the carpet, then reaching for the door. Why do you feel a spark if you reach for the metal door handle, but not if you reach for the wooden door?
17. Some objects produce a spark during static discharge and others don't. Which types of material tend to produce a spark?
18. Look up the word 'static' in the dictionary and then explain how static electricity gets its name.

Aeroplanes need to be earthed before they are refuelled because they build up large amounts of charge when they fly. If sparks were to jump between the plane and the fuel hose, a massive explosion could occur.

19. (a) Petrol tankers could build up charge travelling on the road. Describe how this could happen.
    (b) Describe how the tanker could safely release any built-up charge.

20. The spark between a cloud and the ground is caused by the release of built-up charge in the cloud.
    (a) What is the release of built-up charge called?
    (b) Where does the built-up charge in clouds come from?

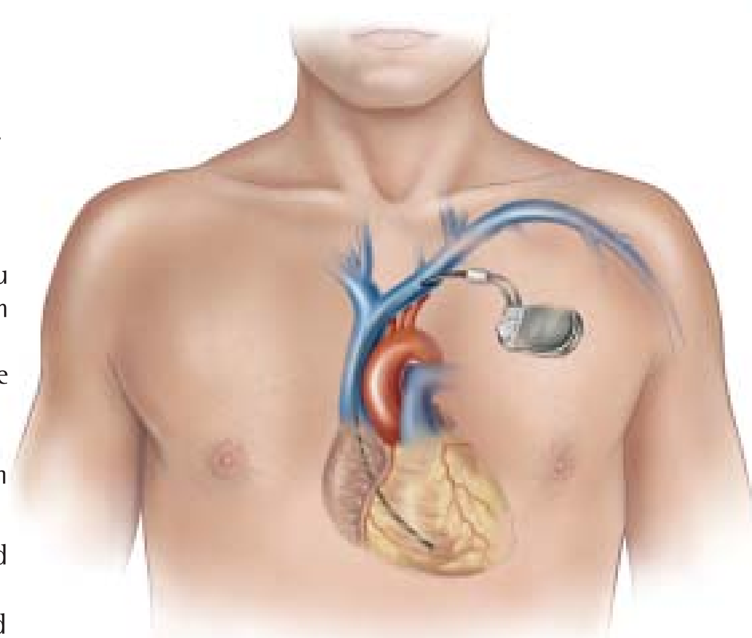
Challenge

Comparing magnetic and electric effects

1. Why do you think magnetic and electric forces are sometimes called 'non-contact forces'?
2. How are the poles of a magnet similar to the charges in an atom?
3. Make a list of the similarities and differences between magnetic and electric fields.

Medical magnets

4. A Magnetic Resonance Imaging (MRI) machine is a very strong magnet that is used to scan for diseases in the human body. Would the magnets used in this type of machine be permanent, temporary or electromagnetic? Give a reason for your answer.

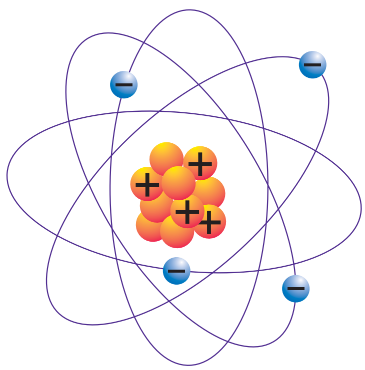


An artificial pacemaker is a device used by people with abnormal heartbeat patterns. The pacemaker works by giving the heart a small electric shock to 'remind' it to beat. Pacemakers are programmed like a computer. If the information programmed into the pacemaker needs to be changed, it can be wiped using a strong magnet.

5. Why do you think people with pacemakers should avoid touching a Van de Graaff generator?
6. Why must people with pacemakers avoid MRI machines?
7. Why is it important for doctors, patients and equipment to be earthed in an operating theatre?

SUMMARY OF KEY TERMS

atom: a very small particle that makes up all things. Atoms have the same properties as the objects they make up.



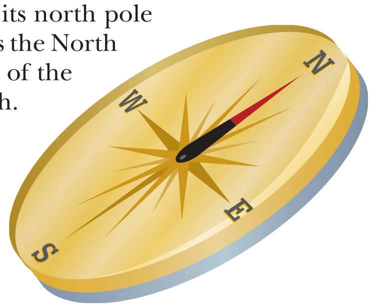
attract: a pull towards another object

aurora australis: a spectacular light show mainly visible from close to the South Pole. It is caused by solar particles interacting with the Earth's magnetic field. It is sometimes called the southern lights.

charge: (*noun*) a property of all objects. Charge can be positive or negative. There are some particles inside an atom that have no charge; (*verb*) to give an object an overall electric charge by adding or removing negative charges. Objects can be charged by rubbing.

charged: describes an object that has more of one type of charge than the other.

compass: a small magnet that is free to move in a circle. The magnet turns so that its north pole faces the North Pole of the Earth.



conductor: materials that allow charge to flow through them

discharge: to release built-up charge

domain: a 'mini-magnet' found in magnetic materials

earthed: to provide a path from an object to the ground for charge to flow through

electric field: lines that show the size and direction of an electric force. The size of the electric force is shown by how close the lines are together.

electric force: a push or pull towards or away from a charged object

electromagnet: a magnet formed by wrapping a coil of wire around an iron core. When electricity passes through the coil, the iron core becomes magnetic.

engineer: a person who uses scientific ideas to design and build new technology and make it work

force: a push, pull or twist

geomagnetic storm: an outburst of energy from the Sun that causes particles to speed towards Earth and interact with the Earth's magnetic field

insulator: material that does not allow charge to flow through it

lightning: the spark caused when built-up charges in a cloud discharge quickly to other clouds or the ground

lightning rod: conductive metal rod, often attached to the top of tall buildings. Lightning rods help to keep buildings safe from lightning strikes.

magnet: a piece of iron, cobalt or nickel (or combination of these) that pushes or pulls on other objects containing these same metals

magnetic field: lines that show the size and direction of a magnetic force. The size of the magnetic force is shown by how close the lines are together.

magnetic force: a push or pull between magnets and magnetic objects

magnetic North Pole: the place on Earth that the north pole of a magnet is attracted to

magnetic South Pole: the place on Earth that the south pole of a magnet is attracted to

magnetise: to make into a magnet

magnetite: a naturally-occurring magnetic rock

metal detector: a machine used to locate underground materials containing iron, nickel or cobalt

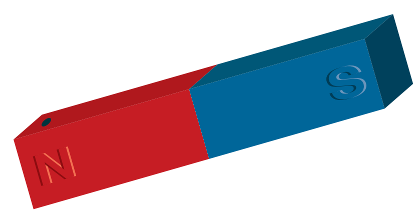
negatively charged: having more negative charges than positive charges

neutral: having the same amount of positive and negative charge

non-contact force: a push or pull felt between objects that are not touching each other

permanent magnet: a magnet that retains its magnetic effect for many years

pole: the ends of a magnet. One pole is the south pole, the other the north pole.



positively charged: having more positive charges than negative charges

receiver: a device that receives magnetic or other signals

repulsion: a push away from another object

solar flare: an outburst of energy from the Sun

static electricity: a build-up of charge

temporary magnet: a magnet that stays magnetic while it touches a permanent magnet, or one that is magnetic for a very short time